

Effects of social network factors on information acquisition and adoption of improved groundnut varieties: the case of Uganda and Kenya

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Abstract Social networks play a significant role in learning and thus in farmers' adoption of new agricultural technologies. This study examined the effects of social network factors on information acquisition and adoption of new seed varieties among groundnut farmers in Uganda and Kenya. The data were generated through face-to-face interviews from a random sample of 461 farmers, 232 in Uganda and 229 in Kenya. To assess these effects two alternative econometric models were used: a seemingly unrelated bivariate probit (SUBP) model and a recursive bivariate probit (RBP) model. The statistical evaluation of the SUBP shows that information acquisition and adoption decisions are interrelated while tests for the RBP do not support this latter model. Therefore, the analysis is based on the results obtained from the SUBP. These results reveal that social network factors, particularly weak ties with external support (e.g., researchers, extension agents, etc.), partially influence information acquisition, but do not influence adoption. In Uganda, external support, gender,

farm size, and geographic location have an impact on information acquisition. In Kenya, external support and geographic location also have an impact on information acquisition. With regard to adoption, gender, household size, and geographic location play the most important roles for Ugandan farmers, while in Kenya information from external sources, education, and farm size affect adoption choice. The study provides insight on the importance of external weak ties in groundnut farming, and a need to understand regional differences along gender lines while developing agricultural strategies. This study further illustrates the importance of farmer participation in applied technology research and the impact of social interactions among farmers and external agents.

Keywords Social networks · Strong and weak ties · Adoption · Information acquisition · Kenya · Uganda · Groundnuts

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Abbreviations

AT	Appropriate technology
FIML	Full information maximum likelihood
ML	Maximum likelihood
NRF	Non-research farmer
PCRSP	Peanut Collaborative Research Support Program
RBP	Recursive bivariate probit
RF	Research farmer
SUBP	Seemingly unrelated bivariate probit

Introduction

Groundnut (*Arachis hypogaea* L.) production is an enterprise of economic and nutritional value for farmers in Eastern Africa (Kidula et al. 2010; Okello et al. 2010). In this region, Uganda is a major groundnut producer where the crop is widely grown as a legume and as an oil crop, and is second only to the common bean as a source of protein (Kassie et al. 2011). Groundnut is a staple food, especially in Uganda, and has the highest return for labor input compared to other food crops. In Kenya, as well as Uganda, groundnut contributes to food security, income generation, and the overall economic growth for agriculture-based industries (Kassie et al. 2011).

Declining per capita production and low yields for groundnuts have created great concerns in Uganda and Kenya because of the important role that this crop can play in poverty reduction (Okoko et al. 1999, 2010). For example, in western Kenya, farmers achieve less than 30–50 % of the potential yield with an average output of 600–700 kilograms per hectare (kg/ha) (Kidula et al. 2010). In Uganda, the average national yield of 800 kg/ha of dry pods is in contrast with on-station trial records of roughly 3,000 kg/ha (Okello et al. 2010).

Challenges facing the agricultural sector have been addressed through technology development research and extension efforts to help farmers improve farm yields (Anderson and Feder 2004). However, the specific extension approaches used in the field have been a subject of debate regarding their effectiveness in addressing farmers' problems (Matuschke 2008). Several authors (e.g., Chambers 2009; Rivera 2011) highlight the need for greater farmer involvement and interaction with service providers in agricultural technology research to improve research-extension-farmer linkages.

An assumption often made in adoption of new or improved agricultural technologies is that information from early adopters is readily available to potential adopters; however, other intervening factors may have an impact on social learning and the adoption process (Katungi et al.

2006). Hounkonnou et al. (2012) pointed out that efforts to increase agricultural productivity place great emphasis on technology transfer yet fail to provide interlinked services, including extension services, credit access, production inputs, and market links. With the increasing need to enhance adoption of improved technologies, as illustrated by the declines in groundnut productivity in Uganda (Li et al. 2013) and Kenya (Kipkoech et al. 2007), Hartwich and Scheidegger (2010) among others argue that public funding of scientific projects and advisory services is not enough. The innovation process must include other players beyond government agencies, such as input sellers, product buyers, finance agencies, community groups, and farmer associations.

The challenges in groundnut production in Uganda and Kenya, specifically the lack of efficient seed production systems, provide a clear example of the need for multiple players to work together. As Ntare et al. (2008) noted, the private sector is not willing to fill this void due to low profit margins, the self-pollination nature of groundnuts and loss of seed viability, as well as the bulkiness and high transportation costs associated with groundnut seed production. A joint effort of all major players in groundnut production and marketing, including members of the public and private sectors, is needed to motivate farmers to innovate in ways that address these challenges (Hartwich and Scheidegger 2010).

In addressing challenges in groundnut production consideration should be given also to the different roles men and women can play in particular farming systems (Carr 2008). Some crops maybe labeled as “women’s crops” highlighting different vulnerabilities for men and women. The starting point for intervention is to understand who produces for the market and who produces for subsistence (in our case groundnut), evaluate challenges facing each group, and identify how social groups are linked in order to provide optimal support for adoption of agricultural technologies (Carr 2008).

Effective information sharing among farmers, researchers, and extension service providers is enhanced by interactions in social networks that occur freely through social ties rather than top-down bureaucratic models (Matuschke 2008). Valente (1996) defined social networks as a “pattern of friendship, advice, communication or support which exists among the members of a social system” (p. 70). Learning in social networks is influenced by tie strength, which is a reflection of the closeness and frequency of interactions among individuals (Granovetter 2005). As channels for learning, social ties determine the nature of information shared in the social system (Haythornthwaite 1996). Although literature exists on the role of social networks on adoption of agricultural technologies, a better understanding of how social, environmental, and

personal factors explain steps in the process—from information acquisition to adoption—can inform the development of more effective research, extension, and policy efforts.

Groundnut farmers' willingness to use new technologies is related to their ability to acquire information from relevant sources (Rogers 2003). According to Rogers (2003), adoption is an individual's decision to make full use of a technology. Ties in social networks are meaningful to the actors; thus, understanding how these relationships impact learning and adoption is critical to researchers as well as policy makers. Our study provides insights on how social ties shape learning and decisions in the adoption process for groundnut farmers in Uganda and Kenya. Specifically, this study examines the effect of social networks, particularly social ties, on two decision variables—information acquisition and adoption of new groundnut varieties—paying special attention to the possible statistical interdependence between the two variables.

In this article, first we present a theoretical overview of learning in social networks. Next we discuss the methodology, data, and econometric model specification. We then present the results and a discussion of the findings. Finally, we provide conclusions and recommendations for future research.

Learning in social networks

Studies on the adoption of new farming practices are often based on the assumption that farm characteristics (e.g., size), individual farmer characteristics (e.g., age, education), farmers' economic status (e.g., credit access), and geographic location (e.g., semi-arid region) determine farmers' adoption behavior (Feder et al. 1985; Genius et al. 2006). Additional evidence (e.g., Conley and Udry 2005; Hoang et al. 2006; Monge et al. 2008; Munshi 2004) indicates that adoption behavior is also influenced by farmers' interactions within their social networks. Studies following this line of research suggest that a complex set of social network factors may mediate adoption decisions (Conley and Udry 2005).

Researchers have used social learning theory (Bandura 1977) to test the effects of social relationships on farmers' decisions to adopt new technologies (Bandiera and Rasul 2005; Conley and Udry 2005; Foster and Rosenzweig 1995). Munshi (2004) described social learning as a process whereby individuals learn from their neighbors' decisions and experiences about a new technology. The shift to social approaches in understanding adoption of new technologies is driven by the recognition that interactions within social networks influence individuals' attitudes and behaviors, which in turn affect adoption choices (Matuschke 2008). As noted by Pretty (2003), social bonds play a

critical role in communities, citing connectedness (i.e., bridging and bonding) as a critical feature in resource use among network and group members. Pretty noted that links created within and beyond community boundaries describe the ability of groups and individuals to engage external agencies to acquire useful resources.

Social interactions and ties in networks support learning by enabling individuals to acquire new information, share their knowledge with others, and evaluate the effects and usefulness of their actions (Bandiera and Rasul 2005). The nature of social ties (i.e., strong or weak ties) affects the quality and the process of information flow within social networks (Granovetter 2005). Strong ties are described as relationships among individuals in a social network that are emotionally connected (e.g., family, friends, and neighbors). In contrast, weak ties are acquaintance relationships that act as bridges, connecting social groups in a social system to the broader society (Granovetter 2005). The connections farmers have with researchers, extension service providers, financial agents, and seed and input providers are examples of weak ties.

Interactions among actors in a social network can enhance learning when people utilize their strong ties to affirm what they already know with people whom they know and their weak ties to acquire new information from others (Ruef 2002). Individuals with few weak ties will be deprived of information originating from other parts of the social system and will be confined to the views of those trafficking information they already know (Granovetter 1983). In contrast, strong ties are helpful sources of information once a technology has been adopted (Ruef 2002). A comprehensive study by Monge et al. (2008) on how interactions in social networks affect adoption of new technologies among farmers in Bolivia highlighted that the denser the interactions between farmers and agents with whom they have weak ties, the higher the expected adoption intensity. However, once a technology was adopted in a given community its diffusion rate was influenced by strong ties.

Flow of information among farmers and similarity in farmer characteristics also play a role in learning in social networks. A study by Munshi (2004) of farmers involved with high yielding wheat and rice varieties in India found that information flow was disjointed and learning within networks was impeded among rice farmers where there was much heterogeneity in growing conditions and population characteristics. In contrast, among wheat farmers who shared similar farming characteristics, both the flow of information and social learning were robust. To compensate for lack of social information, the rice farmers, who lacked the extended networks enjoyed by wheat farmers, tended to experiment on their own farms more than wheat farmers.

In their study of fertilizer technology adoption by pineapple farmers in Ghana, Conley and Udry (2005) also found that information flow and learning in social networks was strong among farmers with similar characteristics. Additionally, they found that other factors were related to technology adoption including credit access, growing conditions, clan membership, and religion. Accounting for these other factors, Conley and Udry (2005) concluded that farmers were influenced most by information from their experienced neighbors to make adoption choices. This study from Ghana demonstrates that learning is enhanced when information is available in a social system, but adoption decisions may also be affected by other location-specific factors.

Social network factors and tie strength as well as individual characteristics can influence farmers' learning and adoption behaviors in different ways and at different times in the adoption process. For example, Foster and Rosenzweig (1995) examined how learning by doing and learning from others influenced adoption of high yielding varieties of wheat and rice at the onset of the Green Revolution in India. They found that the impact of learning from others with more experience was prominent early in the transition to new technologies. Over time, however, farmers' own experiences evolved to have more influence on their decisions. Similar to Monge et al. (2008), Foster and Rosenzweig concluded that social relationships connecting farmers to their peers helped to promote information sharing and decision-making regarding adoption of new technologies. However, decisions to adopt were also influenced by farmers' own individual characteristics.

In sum, farmers' learning in social networks is influenced by a confluence of factors. It is a continuous process involving farmers' processing information from a variety of sources (Diouf et al. 2000) including (a) their own experiences, (b) the experiences of other farmers, and (c) the nature of their ties (strong or weak) with other farmers and network members. Numerous researchers (e.g., Doss 2006; Hoang et al. 2006; Manski 1993; Matuschke 2008) have identified a gap in understanding the role these various social network factors have in acquiring information and adopting a new technology. Our study was designed to address this gap. It highlights the role of social network factors in information acquisition and adoption of improved groundnut varieties. In the following section we provide a detailed discussion of our methodology.

Methods and procedures

Farmers' technology adoption decisions are preceded by a period of information acquisition about technology

characteristics (Dimara and Skuras 2003). Farmers who are aware of a certain technology form expectations of its benefits based on information circulating in their networks. If the expected net benefits are positive, farmers expend extra effort to gather more information, often focusing on the economic aspects of the technology before making their choice.

Theoretical models

Using econometric modeling strategies, the choice to acquire information or not, and the choice to adopt a new technology or not can be modeled as binary choices. The binary options for information acquisition can be represented as not acquiring information ($y_1 = 0$) or acquiring information ($y_1 = 1$). Similarly, for a new technology, not adopting or adopting can be represented by $y_2 = 0$ or $y_2 = 1$, respectively. Following Greene (2007), and Chang and Mishra (2008), we first estimate a seemingly unrelated bivariate probit (SUBP) to empirically explore relationships between two farmer decisions: information acquisition and adoption of improved seed varieties. The SUBP model is used to assess if these two decisions are correlated with unobserved characteristics among farmers (e.g., beliefs, risk aversion). Then, we use a recursive bivariate probit (RBP) model to further examine if acquiring information is endogenous in the adoption model, which would indicate that both decisions are jointly determined (Chang and Mishra 2008; Amare et al. 2012). Endogeneity implies that information acquisition as an explanatory variable in the adoption equation is correlated with unobservable factors captured by the error term. This is an econometric problem that if present would lead to biased estimates for all parameters included in the adoption equation (Greene 2007).

Before proceeding with the formal statement of the model it is useful to state that we find support for the SUBP model but not for the RBP. In other words, the evidence suggests that the error terms across the adoption and information acquisition equations are indeed correlated but there is no evidence of endogeneity.

We start by describing the SUBP model as

$$y_1^* = \beta X' + \varepsilon, \quad \text{where } y_1 = 1 \text{ if } y_1^* > 0, \text{ otherwise } y_1 = 0$$

$$y_2^* = \delta Z' + \mu, \quad \text{where } y_2 = 1 \text{ if } y_2^* > 0, \text{ otherwise } y_2 = 0$$

where y_1^* and y_2^* are unobserved latent variables that represent the propensity to acquire new information and the choice to adopt, respectively. The variables y_1 and y_2 denote the observable responses (0 or 1), X and Z are vectors of covariates, and β and δ are vectors of unknown parameters to be estimated. The terms ε and μ are the respective errors which are assumed to be jointly normally

distributed, with mean zero, a variance of 1, and a correlation coefficient equal to ρ (Cameron and Trivedi 2009). The coefficient ρ , which captures the possible effect of unobserved characteristics on information acquisition and on adoption, can be positive, negative, or null. The SUBP model is estimated using the maximum likelihood (ML) method.

Second, we represent the RPB model as follows:

$$y_1^* = \beta X' + \varepsilon, \quad \text{where } y_1 = 1 \text{ if } y_1^* > 0, \text{ otherwise } y_1 = 0$$

$$y_2^* = \alpha y_1^* + \delta Z' + \mu, \quad \text{where } y_2 = 1 \text{ if } y_2^* > 0, \text{ otherwise } y_2 = 0$$

where y_1^* and y_2^* are as defined in the SUBP model and y_1^* is considered to be endogenous in the y_2^* equation. The coefficient ρ denotes the correlation between the unobservable explanatory variables of the two equations. Full information maximum likelihood (FIML) is employed as the estimation method consistent with Amare et al. (2012).

In both the SUBP and RBP models, we have four possible outcomes (Chang and Mishra 2008):

- a farmer acquires information and adopts an improved variety ($y_1 = 1, y_2 = 1$);
- a farmer acquires information but does not adopt an improved variety ($y_1 = 1, y_2 = 0$);
- a farmer does not acquire information but adopts an improved variety ($y_1 = 0, y_2 = 1$); and
- a farmer does not acquire information nor adopts an improved variety ($y_1 = 0, y_2 = 0$).

Following Monfardini and Radice (2008), and Castello (2010), the Wald test is used for both models to evaluate the hypothesis $H_0: \rho = 0$. In the SUBP model, the results of the Wald test would indicate that acquiring information and adoption are correlated if we fail to accept the null hypothesis (i.e., $\rho \neq 0$) (Monfardini and Radice 2008). Failure to account for this correlation may lead to inefficient (imprecise) estimates (Wooldridge 2001). In the RBP model, a non-significant result for the Wald test (i.e., $\rho = 0$) would mean that information acquisition in the adoption model is exogenous and thus these decisions are not jointly made requiring no further considerations in the estimation.

Independent variables

A major limitation of past research on adoption of new technologies is that typically data on farmers' social relationships have not been included in the analysis. We try to overcome this limitation by explicitly accounting for social network factors in our models. The choice of variables to explain farmers' acquisition of information and adoption of new varieties was based on the literature described earlier while making an effort to ensure that the included variables

can be considered exogenous. When variables can be safely considered exogenous to the information acquisition and adoption decisions, the resulting parameters can be expected to be unbiased (Wooldridge 2001). Socioeconomic and social network variables as well as geographical location were key factors in model estimation. We also included factors such as farm size, age of household head, education level, labor availability and gender because these variables have been found to play a significant role in information acquisition and adoption (e.g., Feder et al. 1985; Genius et al. 2006). In addition, in order to account for contextual differences the models discussed above are estimated separately for Uganda and Kenya.

The coefficients from the SUBP and RBP models are difficult to interpret directly; thus, to make inferences that have economic relevance the marginal effects of the covariates on the probability of observing the various possible outcomes are calculated (Greene 2007). In general, a marginal effect represents the change in a dependent variable that would be produced by a one unit change in an explanatory variable (Greene 2007). In the analysis below, we only report the marginal effects for farmers' acquiring information and adopting new seed varieties (i.e., $y_1 = 1, y_2 = 1$).

In sum, the theoretical econometric models enable us to determine whether the two decisions under analysis for groundnut farmers—to acquire information and to adopt new varieties—are correlated or made jointly, and to examine how social network, demographic, and environmental factors relate to groundnut production processes in Uganda and Kenya.

Data collection procedures

Data for this study were collected as part of the Peanut Collaborative Research Support Program by a team including researchers from institutions in the USA, Kenya, and Uganda. Enumerators collected data in each country between April and August 2010 in groundnut-producing areas.

Survey sites covered regions that had received groundnut research interventions, mainly Eastern and Northern Uganda, and in Kenya the area under the KARI-Kisii mandate. For example, from 2002 to 2005, the Crop Protection Program (Appropriate Technology [AT] Uganda) together with other partners implemented a farmer-led seed multiplication program in Eastern Uganda to enable access of newly released disease-resistant groundnut varieties by poor households, especially women farmers (Research Into Use [RIU] 2011; Sustainet 2011). Farmers in Northern Uganda participated in a similar program for 18 months.¹

¹ Personal communication with Okello on October 24, 2011.

Under the AT program, 72 farmers were involved in the seed multiplication programs in three districts, and a total of more than 17,000 farmers received improved seed in the first phase (RIU 2011). A similar program was implemented in Kenya through the Catholic Diocese of Homa Bay Environment Program in collaboration with researchers and extension staff. However, unlike Uganda, only two farmers participated in the seed multiplication program per year (Sustainet 2011). Farmers received improved seeds through purchases from beneficiaries, collaborating institutions, seed fairs, gifts, and payment in kind (RIU 2011; Sustainet 2011).

Data from Kenya were collected from Ndhiwa district (i.e., Ndhiwa, Nyarongi, and Kobama divisions). In Uganda, the data came from nine districts located in three regions (Teso, Busoga, and the Northern Region) (see Table 1). Potential participants who planted groundnuts in either/or both cropped seasons in 2009 were first identified as either research farmers (RF), defined as those who received direct intervention from researchers and/or extension service providers concerning groundnut farming, or non-research farmers (NRF) who had no such direct contacts. Farm-level data were then obtained via face-to-face interviews from a random sample within each group for a total sample of 491 farmers (RF = 243, NRF = 248) in both countries. Sample size was determined based on the resources available to undertake the fieldwork.

Data on social network factors were collected with a focus on: (a) farmers' membership in associations; (b) people with whom farmers were most likely to discuss important groundnut matters; (c) who and/or what had the greatest influence on farmers' choice of groundnut seed in the 2009 cropping seasons; and (d) who and/or what provided the greatest support towards success or better

productivity in groundnut farming. From the total sample of 491, 461 households provided complete data for the analysis reported below. Summary statistics for specific variables are reported in the following section followed by the econometric results and discussion.

Results and discussion

Descriptive analysis

Definitions of the variables and descriptive statistics are presented in Table 2. As outlined in the table, the number of farmers who adopted and planted an improved variety in 2009 was very high in both countries, with 88 % in Uganda and 90 % in Kenya.

The demographic characteristics of farmers in both countries were similar. The distribution of gender among household heads was 52 % male in Uganda and 58 % in Kenya. The average age of household heads was in the mid-forties, with an average of seven years of schooling. The average number of people in the household was between seven and eight. Land was a scarce resource for farmers in each country with roughly one to two hectares. Most of the farmers had prior experience with at least one improved variety (85 % in Uganda and 97 % in Kenya).

On variables reflecting institutional support, similarities existed between farmers in each country for distance to market and membership in associations. Distance to the nearest main market was 7–8 km and approximately three quarters of the farmers were members of one or more local groups or associations engaged in crop production and marketing. The largest difference between farmers in the two countries was in credit access; 20 % of farmers reported having access to credit in Uganda compared to 10 % in Kenya.

With respect to social network variables, there was a notable similarity for both countries in terms of the percentage of farmers (13 % in Uganda and 16 % in Kenya) who ranked information from weak ties as most important towards their farming success. A greater percentage of farmers in Kenya (49 %) identified strong ties as most important, compared to 29 % of farmers in Uganda. In relation to sources of seed, farmers in both countries obtained seed from internal local sources (86 % in Uganda and 83 % in Kenya) more frequently than from external sources (14 % in Uganda and 17 % in Kenya). The acquisition of seeds was also very similar in both countries: 10 % of farmers in Uganda and 16 % in Kenya planted purchased seeds. About three quarters of the farmers used their own seed stock, while others received seed as gifts or payment in kind (see Table 3).

Table 1 Sample distribution by country and by division/district (N = 461)

Country	Surveyed division/district	Research farmers	Non-research farmers	Total
Kenya	Ndhiwa	65	71	136
	Nyarongi	23	40	63
	Kobama	19	11	30
	Total	107	122	229
Uganda	Amuria, Budaka, Kumi, Pallisa, and Soroti (Teso)	64	68	139
	Jinja and Kamuli (Busoga)	20	17	39
	Lira and Pader (Northern Region)	41	22	64
	Total	125	107	232

Table 2 Variable definitions and descriptive statistics

Variables	Definition	Uganda				Kenya			
		Freq	%			Freq	%		
Dependent									
Acquire information	Number of farmers who acquired information from external sources, i.e. weak ties (researchers, extension, NGOs, media, etc.)	118	50.9			91	39.7		
Adoption	Number of farmers who planted improved groundnut varieties in 2009	209	90.1			202	88.2		
Continuous		Mean	SD	Min	Max	Mean	SD	Min	Max
Age	Age of head of household (years)	47.83	12.75	14	87	44.90	13.89	18	87
Land	Average operated land (ha)	19.2	1.33	0.40	8.09	1.03	0.83	0.10	5.06
Household size	Number of people in household	8.57	3.30	2	20	7.30	3.34	1	18
Education	Years of education for household head	7.13	4.06	0	18	7.26	3.25	0	16
Distance	Distance to the nearest main market (km)	8.02	11.18	0.05	100	7.09	4.78	0.10	22
Binary		Freq	%			Freq	%		
Gender	If head of household is male (1 = yes, 0 = otherwise)	121	52.2			133	58.1		
Credit	If farmer requested credit (1 = yes, 0 = otherwise)	47	20.3			22	9.6		
Farmer type	If farmers belongs to researcher group (1 = yes, 0 = otherwise)	130	56.03			107	46.7		
Own experience	If farmer previously tried at least one improved variety (1 = yes, 0 = otherwise)	197	84.9			223	97.4		
Association	If farmer is a member of an association (1 = yes, 0 = otherwise)	173	74.6			183	79.9		
Internal support	If farmer ranked first strong ties as influential towards their success in groundnut farming (1 = yes, 0 = otherwise)	57	28.8			111	49.1		
External support	If farmer ranked first weak ties as influential towards their success in groundnut farming (1 = yes, 0 = otherwise)	25	12.6			36	15.9		
Teso	1 if Teso, 0 if otherwise	132	56.9						
Busoga	1 if Busoga, 0 if otherwise	37	15.9						
N. Uganda	1 if N. Uganda, 0 if otherwise	63	27.2						
Ndhiwa	1 if Ndhiwa, 0 if otherwise					136	59.4		
Nyarongi	1 if Nyarongi, 0 if otherwise					63	27.5		
Kobama	1 if Kobama, 0 if otherwise					30	13.1		

N = 232 for Uganda, and N = 229 for Kenya

Table 3 Percentage distributions for sources of seed and means of acquiring seed

	Sources of seed			Means of acquiring seed		
	External	Internal	Gift	Cash	Own stock	Other
Uganda	13.6	86.4	10.2	14.0	73.7	2.1
Kenya	17.0	83.0	4.6	16.3	77.8	1.3

External sources include extension, research, non-government organizations, exhibitions, field days, and seed stockists. Internal sources include friends, neighbors, relatives, and own stock

Econometric results

This study examined how social network factors relate to the decision to seek information and adopt improved varieties among groundnut farmers in Uganda and Kenya. Specifically, our study examined the extent to which linkages with external and internal sources of information influenced farmers’ behavior, while accounting for various other factors that impact the adoption process. It is important to point out that both the SUBP and RBP models include variables that

can be safely considered to be exogenous to the information acquisition and adoption decisions. The exception is acquired information in the RBP models, a matter that is subjected to econometric testing.

Results for the SUBP model on *information acquisition* (y_1) and *adoption of improved groundnut varieties* (y_2) for each country and the corresponding marginal effects are given in Table 4 for Uganda and Kenya. The first step was to use Wald test to evaluate the null hypothesis that $\rho = 0$ for the SUBP models. The value of $\rho = 0.33$ for Uganda

was significant at the 5 % level (Chi square = 4.42, $df = 1$, p value = 0.035). In the case of Kenya, the parameter $\rho = -0.28$ was also statistically significant at the 5 % level (Chi square = 3.97, $df = 1$, p value = 0.046). Thus, we failed to accept the null hypothesis that $\rho = 0$ for both countries, indicating that the probability that a farmer acquired information was indeed related to the probability of adopting improved varieties through unobserved effects captured in the models' error terms. That is, unobserved effects not captured by the data, such as in-kind benefits

Table 4 SUBP estimates for the information acquisition and adoption models for Uganda and Kenya

Variable	Uganda			Kenya		
	Information acquisition	Adoption	Marginal effects	Information acquisition	Adoption	Marginal effects
Constant	-0.917** (0.431)	0.837** (0.756)		-0.210 (0.609)	3.060*** (0.769)	
Age	0.007 (0.007)	0.002 (0.009)	0.003 (0.003)	-0.001 (0.006)	-0.003 (0.008)	-0.001 (0.002)
Gender	0.504*** (0.184)	0.361 (0.243)	0.202 (0.068)	-0.246 (0.190)	0.153 (0.240)	-0.070 (0.065)
Education	0.002 (0.021)	-0.006 (0.029)	0.001 (0.008)	0.044 (0.029)	-0.093*** (0.038)	0.006 (0.010)
Household size		0.076** (0.036)	0.003 (0.002)		0.005 (0.033)	0.001 (0.003)
Land	-0.113* (0.064)	0.187 (0.138)	-0.035 (0.024)	0.130 (0.131)	-0.171 (0.153)	0.029 (0.045)
Distance	0.003 (0.007)	-0.010 (0.008)	0.001 (0.003)	0.005 (0.024)	0.002 (0.031)	0.002 (0.008)
Internal support	0.306 (0.197)		0.114 (0.072)	0.098 (0.194)		0.034 (0.066)
External support	0.735*** (0.251)		0.257 (0.078)	1.067*** (0.277)		0.369 (0.086)
Teso	0.436* (0.243)	-0.416 (0.455)	0.146 (0.094)			
N. Uganda	0.249 (0.269)	-1.033** (0.463)	0.013 (0.109)			
Ndhiwa				-0.549* (0.336)	-1.033** (0.513)	-0.278 (0.115)
Nyarongi				-0.870** (0.366)	-1.056** (0.543)	-0.345 (0.083)
Rho	0.326** (0.144)			-0.279** (0.132)		
Log-likelihood	-210.55, $p = 0.000$			-213.82, $p = 0.000$		
Wald chi-sq ($df = 17$)	47.43			44.94		
Wald test of $\rho = 0$ ($df = 1$)	4.42, $p = 0.035$			3.974, $p = 0.046$		
Sample size	232			229		

Values in parentheses are robust standard errors. The reference variables for regions are Busoga for Uganda and Kobama for Kenya. The reference variable for internal and external support is individual effort. $E[y_1|y_2 = 1, x] = 0.494$ (Uganda) and 0.333 (Kenya) computed at the mean of the Xs. The dy/dx is for a discrete change of a dummy variable from 0 to 1

*** Significant at 1 %, ** Significant at 5 %, * Significant at 10 %

(exchange of labor, gifts in the form of seeds and fertilizer, informal credit systems, managerial ability, etc.) and product market opportunities associated with individual social networks, may have an indirect influence on a farmers' decisions to seek information and to plant improved groundnut varieties.

Similar to observations by Huth and Allee (2002) and Moreno and Sunding (2003), the positive value for ρ in the SUBP model for Uganda suggests that information acquisition and the adoption of improved groundnut varieties are complementary decision variables. By contrast, as Huth and Allee (2002) indicate, the negative sign for ρ in the Kenya model indicates that the two decision variables move in the opposite direction. For example, for Kenyan farmers the decision to acquire information was related to the decision not to adopt new varieties.

A way to think about these results is that information acquisition and the use of improved seeds worked together as a strategy for improved productivity in Uganda, whereas in Kenya after acquiring information farmers may find that investing in improved groundnut varieties may not be profitable. These results also reflect the level of importance of the groundnut crop to the farmers in both countries. Okello et al. (2010) noted that groundnut serves as a staple food and a source of income for farmers in Uganda. Increasing groundnut production is a national priority as a means to improve food security, which is demonstrated by the emphasis given to involving farmers in groundnut seed production. In Kenya, Kidula et al. (2011) noted that groundnut is grown mainly as an oil crop, inferring that farmers grow the crop for the market as a source of income. If other options provide higher profits for Kenyan farmers then groundnut production and adoption of new varieties maybe a lower priority.

In the RBP model, the non-statistically significant results of a Wald test for $\rho = 0$ for both Uganda and Kenya (see the Table 5 in the Appendix) indicate that the null hypothesis that information acquisition is exogenous cannot be rejected, suggesting that the decision to acquire information and to plant improved varieties was not jointly determined. Therefore, the SUBP model outperforms the RBP model and the remaining analysis is focused on the results of the SUBP model.

Results for Uganda

As shown in Table 4, consistent results across the two models (information acquisition and adoption) are obtained for the parameters associated with gender and age in Uganda, whereas in the case of Kenya, the estimates for the variables age, distance to the market, and geographic location had consistent parameter signs. In addition, the results indicate that weak ties through external sources, gender, and geographic location for Teso have a positive

and significant effect on acquiring information in Uganda, while farm size has a significant negative effect. Concerning adoption, the results show a positive and statistically significant parameter for household size and a negative one for Northern Uganda (N. Uganda).

The findings on information acquisition highlight the role of weak ties in supporting Ugandan farmers' learning about new technologies. The coefficient for external support, in which farmers identified external sources as most influential in farming success, was positive and statistically significant at the 1 % level. The marginal effects associated with external support indicate that the probability of acquiring information is roughly 26 % higher for farmers with access to external support compared to those who do not have such support. Farmer involvement in seed multiplication programs in Uganda likely provided opportunities for contact with external agents thereby establishing weak-tie interactions. The willingness by Ugandan farmers to invest in these linkages exemplifies the importance of weak-tie links in groundnut farming. These findings are consistent with work by Granovetter (1983) and Ruef (2002) indicating that weak ties act as bridges that enable access to new information across social boundaries. This effect is not confirmed for internal support (strong ties), though the coefficient was positive.

Results further reveal that in Uganda the parameter for farm size is negative and statistically significant at the 10 % level, implying that farmers with small land holdings are more likely to acquire information about new varieties. These results contrasts the assessment made by Scandizzo and Savastano (2010) who argued that households with larger farms are more likely to acquire information and adopt. When food security is an issue, as it is for many groundnut-farming communities in Uganda, a negative relationship can occur as smallholders seek information to increase productivity. The findings for Uganda could also indicate that when a crop is grown as a staple food and a source of income, then smallholder farmers, especially those with large households, are likely to invest more in information acquisition.

The findings also reveal that gender is an important factor in information acquisition for farmers in Uganda. The parameter for gender is positive and statistically significant at the 1 % level. The probability that a farmer would acquire information and subsequently plant an improved variety is roughly 20 % higher for male farmers compared to women. The findings indicate that male-headed households with small land holdings are more likely to acquire information from external sources. Similar to Conley and Udry (2005), we find that male-headed households are better placed to utilize their weak ties to gain knowledge about groundnut farming. The findings are in line with work by Carr (2008) in Ghana who argued that some crops and related agricultural strategies could be

gender sensitive, impacting the behavior and decisions of men and women farmers in different ways. Our results also support work by Leckie (1996) who noted that information on farming was socially gendered such that formal and informal information sources are not accessible to female farmers. Hence, female farmers are forced to use alternative strategies to acquire information through their social networks. The findings on group membership support these results as roughly three quarters of the participants were associated with one or more groups especially those focused on crop production and marketing.

In the literature, household size is often used as a proxy for labor availability. In the Uganda model, the parameter for household size is statistically significant at the 5 % level indicating that larger households are more likely to use improved groundnut varieties. Similar to Abdulai et al. (2008), we argue that groundnut farming is a labor-intensive enterprise especially with improved varieties; so labor constraints may be a limiting factor for adoption among smaller households.

Geographic location may be another factor that influences Ugandan farmers' decision to seek information and to adopt. The parameter for the Teso region is positive and statistically significant at the 10 % level for information acquisition, but the parameter for Northern Uganda is negative and statistically significant at the 10 % level for adoption. These results indicate that farmers in the Teso region are more likely to acquire information from external sources as compared to those in Busoga (the reference region). Consequently, farmers in Northern Uganda are less likely to plant improved groundnut varieties as compared to farmers in Busoga. These findings suggest that location-specific factors may have an effect on the decision to acquire information and to adopt improved groundnut varieties. In this particular case, the results are consistent with the fact that Teso and Busoga are located in areas where farmer participation with researchers and other agencies has been more intense as compared to Northern Uganda.

Results for Kenya

For farmers in Kenya, weak ties contributed significantly to the acquisition of information. The coefficient for external support is positive and significant at the 1 % level. The marginal effects indicate that farmers with access to external supports have a probability of acquiring information that is roughly 37 % higher compared to those who do not have such supports. Farmers who worked with researchers established weak ties that enabled their learning about new seed varieties. These findings are similar to observations by Granovetter (1983) on the benefits of weak ties and by Sanginga et al. (2006) on participation in farmer research groups, providing support for the importance of weak-tie relations within social networks on information

acquisition. These results underscore the benefits of farmer involvement in technology research and exemplify the role of external agents in enhancing learning in social networks. The observed difference between Kenya and Uganda could be explained by the fact that in Uganda farmers are more involved in seed multiplication and distribution programs. Hence, information regarding groundnut farming is more accessible among social networks in Uganda compared to Kenya. This finding is consistent with Munshi (2004) who reported that lack of information in a social system, as in the case of Kenya, could slow the learning process in a social network and hence hamper adoption. Although the parameter for internal support was not significant for the Kenya model, we cannot ignore the fact that roughly 49 % of those interviewed considered their strong ties as important in their success as groundnut producers.

In Kenya, findings on adoption of improved varieties indicates that farmers' level of education plays a significant role in adoption decisions. Specifically, farmers with more years of education are less likely to adopt. The parameter is negative and statistically significant at the 1 % level. This finding is consistent with work by Bandiera and Rasul (2005) who suggested that more educated farmers with access to information are less sensitive to choices made by network members. Educated farmers have the ability to critically acquire and evaluate information related to technology performance, which may promote or deter adoption. The findings may imply that compared to Uganda, farmers in Kenya may be producing groundnuts primarily for the market. Hence, as educated farmers evaluate information on enterprise profitability, they may find other options more desirable compared to groundnut production. The finding provides evidence that less educated farmers may be the main groundnut producers regardless of gender. External actors in the groundnut sector should seek to understand how marginalized groups use their networks and how public services could be used to provide support.

In the adoption process, farmers must weigh the pros and cons of using the new technologies, which in our study was improved groundnut seeds. In Kenya, the local setting in which farmers operated is a key component in the adoption of improved groundnut varieties. The coefficients for geographic location are negative and significant at the 5 % level for Nyarongi, and at the 10 % level for Ndhiwa divisions. According to Okoko et al. (2011), Nyarongi and Ndhiwa produce the highest amount of groundnut in Homa Bay County; therefore, research activities and extension efforts are likely to be more concentrated in those divisions. This could also imply that farmers are more homogenous and share similar farming characteristics while having easier access to information regarding groundnut production and marketing within the community. By contrast, information regarding groundnut farming may be more difficult to obtain inside the

social system in Kobama division. These findings are consistent with the notion that farmers located in Nyarongi and Ndhiwa divisions understand the major challenges related with groundnut farming as an income generating option. Hence, given other alternatives they may be less likely to acquire information and adopt improved groundnut varieties compared to farmers located in Kobama division. These findings are similar to what Conley and Udry (2005) reported for Ghana where information flows and learning in social networks is strong among farmers with similar characteristics; however, the decision to adopt may be linked with other location-specific factors or individual characteristics (e.g., education level). As suggested by Genius et al. (2006), the local setting can have an important role in determining farmers' opportunities and incentives, and their responses. The negative marginal effect associated with geographic location on information acquisition and adoption is substantial. At the margin, farmers located in Kobama are more likely to jointly acquire information raising the probability of adoption by roughly 28 and 35 % compared to Ndhiwa and Nyarongi, respectively.

Conclusions

The increasing need for development agencies to improve livelihoods in farming communities has led to a growing focus on the use of social networks as an entry point to engage farmers in poverty reduction and food security strategies. This is imperative because formal systems often lack the capacity to provide external linkages to useful resources. The analyses reported in this paper showed that factors that influence farmers' decisions to acquire information and to adopt new technologies for a given crop can vary across regions. To determine the most helpful strategy, actors need to be mindful of the structure of social networks (i.e., formal and informal) in groundnut production. Key differences in factors that impact the adoption process, particularly gender, land and household size in Uganda, and education level in Kenya, further demonstrate that a one-size-fits-all strategy may not be appropriate.

In this study, we analyzed the effect of social network factors on information acquisition and the adoption of improved groundnut varieties for samples of farmers in Uganda and Kenya. We first employed a SUBP model to test if information acquisition and adoption were correlated, which was found to be the case. A RBP model was then used to examine if acquiring information was endogenous in the adoption model, which would indicate that both decisions are jointly determined. Endogeneity was rejected and thus the analysis centered on the SUBP model.

Findings from this study reveal that weak ties have a significant impact on how farmers acquire information about new varieties in both countries. This is in line with our expectations

noting that the seed production system for improved groundnut varieties is a major challenge in both Kenya and Uganda. Farmers utilized weak ties (i.e., researchers, extension agents, input sellers, and buyers) to acquire information related to groundnut farming. For example, in Kenya, where farmer-led seed multiplication programs are lacking, farmers with external connections used these links to acquire information. In both countries, farmers identified external links as very important to their groundnut productivity. The findings underscore the need for policy makers, researchers, and agencies involved in groundnut production to understand the nature of social networks that support groundnut seed production and distribution.

It is evident that information acquired through individuals' social networks is critical in the adoption of improved groundnut varieties, but other factors also play a role. In Uganda, for example, programs promoting groundnut seed production ensure that farmers readily acquire information from the social system. However, information is just one component in the groundnut production process. Non-social network factors further influenced information acquisition for farmers in both countries, with gender, household size, and geographic location impacting Ugandan farmers, and education and geographic location influencing Kenyan farmers. The findings support work by Hartwich and Scheidegger (2010) and Hounkonnou et al. (2012) indicating that advisory services are not enough in increasing technology adoption and agricultural productivity. Such services must be interlinked with other services, and demographic and social networks should be accounted for.

Gender is a major factor affecting the decision to acquire information and to plant improved groundnut varieties, especially in Uganda. Education and extension services should address core issues that marginalize women in farming, especially biases in land tenure systems, access to credit, and the availability of technology. Specifically, better understanding is needed of the distinct nature of women's workloads, responsibilities, and challenges and how women farmers utilize their social networks to access production resources. Understanding these factors will enable policy makers and advisory service providers to make sense of how women farmers could be empowered to fully utilize available services to improve livelihoods in farming communities.

In addition, results are consistent with those of prior researchers showing that weak ties could provide useful links as channels for social learning. Findings also suggest that although social networks are necessary in facilitating learning, other factors that are outside the farmers' domain may be driving forces in adoption. This is particularly true for geographic location, which determines opportunities and resources available to facilitate technology use. The underlying goal is to understand how social structures impact information flows within networks and how these

links can be used to promote dissemination of improved technologies in ways that enhance the viability of groundnut farmers in Eastern Africa and the communities in which they live.

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Appendix 1

See Table 5.

Table 5 RBP estimates for the information acquisition and adoption models for Kenya and Uganda

Variable	Kenya			Uganda		
	Information acquisition	Adoption	Marginal effects	Information acquisition	Adoption	Marginal effects
Constant	−0.133 (0.598)	1.667** (0.684)		−0.910** (0.428)	0.912 (0.697)	
Acquired information		1.262*** (0.158)	0.305		−0.468 (0.778)	−0.013
Age	−0.001 (0.007)	−0.002 (0.006)	−0.001	0.007 (0.006)	0.003 (0.009)	0.003
Gender	−0.220 (0.192)	0.220 (0.185)	−0.024	0.502*** (0.182)	0.441* (0.235)	0.200
Education	0.037 (0.030)	−0.083*** (0.031)	−0.008	0.002 (0.020)	−0.007 (0.027)	0.001
Household size		0.018 (0.016)	0.000		0.007** (0.033)	0.002
Land	0.121 (0.122)	−0.222* (0.120)	−0.014	−0.111* (0.064)	0.154 (0.151)	−0.038
Distance	0.004 (0.023)	−0.005 (0.023)	0.005	0.003 (0.007)	−0.008 (0.008)	0.001
Internal support	0.066 (0.109)		0.026	0.276 (0.214)		0.104
External support	0.989*** (0.260)		0.378	0.734*** (0.245)		0.257
Teso				0.431* (0.241)	−0.368 (0.457)	0.153
N. Uganda				0.255 (0.270)	−0.942* (0.503)	0.038
Ndhiwa	−0.540* (0.331)	−0.745 (0.504)	−0.399			
Nyarongi	−0.809** (0.381)	−0.501 (0.538)	−0.330			
Rho	−1 (0.000)				0.578 (0.396)	
Log-likelihood	−210.80, $p = 0.000$			−210.43, $p = 0.000$		
Wald chi-sq ($df = 18$)	116.31			56.78		
Wald test of $\rho = 0$ ($df = 1$)	0.385, $p = 0.535$			1.226, $p = 0.268$		
Sample size	229			232		

Values in parentheses are robust standard errors. The reference variables for regions are Busoga for Uganda and Kobama for Kenya. The reference variable for internal and external support is individual effort. $E[y_1|y_2 = 1, x] = 0.206$ (Kenya) and $= 0.503$ (Uganda) computed at the mean of the Xs. The dy/dx is for a discrete change of a dummy variable from 0 to 1

*** Significant at 1 %, ** Significant at 5 %, * Significant at 10 %

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