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Measuring the effectiveness of extension innovations for out-scaling agricultural technologies

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Low adoption levels of agricultural technologies undermine the impacts of national and international agricultural research. Using a combination of an ordered logit and Heckman selection models and a case study from an out-scaling program for a barley technology package in Ethiopia, this study provided evidence that a newly introduced farmer-to-farmer extension approach offers a viable option for tackling this development challenge. Model results showed that unlike the conventional approach, the new extension approach was effective in creating better access to seeds of the improved varieties and positively influencing farmers' perceptions, ultimately leading to favorable adoption decisions. Therefore, the new extension approach proved to be potent in strengthening the extension and seed distribution systems that are often weak links in the research-to-development continuum. The policy implications of these results are that developing world agricultural extension needs to be reoriented more towards enhancing farmer-to-farmer information and seed exchange. Moreover, building the capacity of forerunner farmers for acquiring and processing up-to-date information and knowledge about the improved technologies should be central in developing world extension strategy. By so doing, the desired outcomes in terms of wider adoption and diffusion of improved agricultural technologies could be achieved.

Key words: Scaling out, technology adoption, farmer-to-farmer extension, barley, Heckman.

INTRODUCTION

Experiences such as the Asian Green Revolution indicated that improved technology adoption for agricultural transformation and poverty reduction is critical in modern day agriculture (DeJanvry and Sadoulet, 2002; Evenson and Gollin, 2003). According to Anderson and Feder (2003), productivity improvements are only possible when there is a gap between actual and potential productivity. These productivity gaps arise mainly from technology and management differences. Hence, promotion of change through the generation of agricultural technologies by research and their dissemination to end users plays a critical role in boosting agricultural productivity in developing countries (Mapila, 2011). Agricultural extension can play a critical role in increasing production and improving rural livelihoods by enhancing the dissemination of information, transfer of skills, and up take of technologies (Birner et al., 2006).

Agricultural extension is in a great transition (Anderson et al., 2006). The agriculture knowledge infrastructure is evolving in a big way with the emergence of pluralistic extension approaches/models and innovations to cater for the needs of the farmer. Even though the farmer-to-farmer approach (FtF) has informally been used in different parts of the world since time immemorial, its formal recognition is a recent development in the history of agricultural extension in different countries (Saravanan, 2008). FtF has gained some prominence especially with the emergence of Farmer Field Schools (FFS). For example, in 2001, the Sustainable Soil Management Intervention (SSMP) in Nepal initiated FtF in 12 districts. The approach has drawn attention in the national agricultural extension system ever since. The Nepalese experience revealed that FtF is better in terms of client orientation, accountability, suitability, scaling-up or its ability to replicate and in affecting farm production compared to other models (Saravanan, 2008).

Experiences in Kenya also indicated that several attempts to introduce fodder legumes in highlands of central Kenya to reduce milk production costs by minimizing expenditure on concentrates have been unsuccessful (Franzel et al., 2000). However, dissemination of these technologies has become more effective by using informal methods especially the FtF (Wanyoike, 2003). As noted in Birner et al. (2006), factors influencing the effectiveness of agricultural service delivery are many, including the appropriateness of the advisory methods, the capacity and numbers of extension staff, and the management and governance structures of the organizations delivering the services and the degree of feedback from users.

As in many developing countries, the extension system in Ethiopia faces serious challenges due to limited financial and human resources in the face of huge demand for extension services (Sinja et al., 2004). This led to low transfer of knowledge from researchers to farmers calling for significant changes in the institutional systems and relationships. The conventional extension approach (CE) involved Participatory Demonstration and Training Extension System (PADETES) while the new extension approach under the out scaling program for a barley technology package adopted FtF. The main difference between the two extension approaches is that CE highly depends on the performance of extension agents to organize demonstration trials, assisting farmers in obtaining agricultural inputs and channeling farmers' problems to the relevant organizations. Hence, development agents (DAs) are under pressure to work with much more farmers than they can effectively help which negatively affects the efficacy of the approach and hence the rate of dissemination.

Under current conditions, one development agent in Ethiopia may be required to supervise the demonstration plots of up to 200 farmers (Befekadu and Berhanu, 2000). However, the new technology transfer approach is based on the premise that if innovations provided by agricultural research are tested, adapted and endorsed by selected forerunner farmers (called promoters or trainers), then the innovations have much higher chances of being easily passed on to other fellow farmers. This is because farmers have common interest and hence talk the same language and the level of trust between them is likely to be much higher than that of between farmers and DAs. One of the criteria that must be met before the development of a farmer to farmer information exchange system is that the innovators must be willing to become farmer promoters (extension workers and trainers) who share their knowledge and experience with other farmers at no cost (Wanyoike, 2003). Experts in the field of extension argue that FtF is very effective and can provide a solution to the longstanding problem.

By employing a case study from Ethiopia, this paper attempts to find empirical evidence that supports this line of argument. Moreover, this study tests the hypothesis that extension efforts do not affect adoption decisions directly but, if at all, only indirectly through their influence on the perception of farmers. Given the huge interest of the Ministries of Agriculture (MoA) of Ethiopia and many other countries for effective scaling out strategies, the lessons drawn from this study will have huge significance. Analyzing factors that determine intensity of technology adoption has important implications as it provides essential information for improving the effectiveness of technology targeting and transfer methods including FtF, which is the focus of this paper.

MATERIALS AND METHODS

The Sirinka Agricultural Research Center (SARC) in the Amhara region of Ethiopia has since 2007 implemented a pilot program using the farmer-to-farmer extension approach to scale out improved agricultural technologies. Three improved barley varieties (Shedeho, Estayish, and Yedogit) along with their full production packages were demonstrated in Meket and Wadla districts in 2005 production season. After creating awareness and adequate demand for the varieties, in 2007, the center implemented a pilot program for scaling out the improved barley varieties in these districts. The program initially began with 72 hectares of land by involving 114 and 30 farmers in Meket and Wadla districts, respectively. Ensuring high degree of involvement of all stakeholders through a series of discussions was an important element of this project.

Farmers were selected and organized into manageable groups of 10 persons each and received training. Each group selected its chairperson and secretary and designed their own bylaws and evaluation mechanisms. They also designed a crop calendar; and each group implemented the crop calendar and recommended practices for the improved barley technology package. The participants agreed and signed the memorandum of understanding to give seed of new varieties to at least five other copy farmers through the FtF seed exchange system which took place through sale or grain exchange with other crops like wheat. Representatives from SARC, the district office of agriculture and other stakeholders participated from planning to implementation of the FtF approach. By employing FtF, the project was expected to succeed in increasing the adoption and diffusion of the improved varieties to wider areas (Assefa, 2009).

Study area and sampling procedure

The case study was conducted in Meket district of Northeastern Ethiopia. The elevation ranges from 1500 to 3300 m and 20% is classified as highland (locally called *dega*), 55% intermediate (*woyinadega*), and 25% lowland (*qola*). A two stage sampling technique was used to select five kebeles (Kebele is the smallest administrative unit in the country). Several kebeles form (a district from among) 31 major barley producing *kebeles* in the district. First, the only two *kebeles* namely Warkaye and Weketa in which the new FtF extension approach was implemented were purposively selected for inclusion in the sample. Then, three *kebeles* namely Agrit, Akat and Boya from the remaining 29 *kebeles* in which the new FtF extension approach that has not been implemented was selected randomly. Then, in the second stage, a sample of 176 farm households was selected randomly, which were divided between the five PAs using the probability proportionate to size (PPS) sampling technique (Table 1). Summaries of the socio-economic, institutional and psychological characteristics of the sampled respondents' are provided in Tables 2 and 3.

Methodology

New technologies are often recommended as packages with different components. However, for several reasons some farmers continue using their old technologies or tend to adopt only certain components of the new package, the combinations of which vary from one farmer to the other. Moreover, even among adopters of the same technologies, there is often variation in intensity or level of use of the technologies or practices. Understanding why some farmers are more open to try new technologies and why others resist the idea, why some farmers adopt one component of the package while rejecting the other as well as the underlying reasons for this variation among farmers is of a paramount importance.

Previous empirical studies on the adoption and diffusion of agricultural innovations found that farmers' adoption decisions are influenced by a wide variety of different factors (Feder and Zilberman, 1985; Foster and Rosenzweig, 1996; Kohli and Singh, 1998; Meinzen-Dick et al., 2004). Household head's sex (Overfield and Fleming, 2001; Adugna, 2002), literacy level and farming experience (Rahm and Huffman, 1984) are important determinants of adoption. Moreover, household size (Tadesse and Kassa, 2004; Smith, 1997), physical and financial capital including access to credit (Putler and Zilberman, 1988, Kansana et al.,1996), landholding size (Doss and Morris, 2001; Daku, 2002; Gabre-Madhin and Haggblade, 2001), farm income (Mwania et al., 1989; Abebaw, 1999; Degu, 2004) and availability and accessibility of the technologies such as seeds and distance to input sources (Doss, 2003; Nwosu, 1995) have significant influence on farmers' adoption decisions.

Schultz (1995), Doss (2003), and Wale and Yallew (2007) hypothesized that the probability of adoption of a new technology will depend on the ability of farmers to perceive the advantages and compatibility with existing socioeconomic conditions. It is generally believed that farmers' level of knowledge on improved agricultural technologies influences their technology preference (Mwania et al., 1989). For example, a study by Abebaw (1999) and Doss (2003) reported that adopters were found to have better knowledge on fertilizer application than non-adopters did. Farmers' attitude towards risk, access to information on the productivity of the technology, and yield and price stability are all-important factors (Kaguongo et al., 1997; Feder et al., 1985; Kristjanson, 1987). Those technologies that involve lower risk have a greater appeal to smallholders who tend to be more risk-averse (Meinzen-Dick et al., 2004).

The effect of information provision on farmers' adoption decisions varies depending on the channel, source, content, motivation, and frequency of extension (Brown, 1991).When the innovation system promotes effective communication, problem identification, problem solving and personal interactions of a formal or informal nature, higher adoption of technology can be expected (Steffey, 1995). Empirically, the effects of extension participation and frequency of contacts on adoption have been reported as positive and significant (Kansana et al., 1996; Gebremariam, 2001). However, building on the line of argument by Schultz (1995), Doss (2003) and Wale and Yallew (2007) and Mwania et al. (1989), this paper argues that the effect of frequency of extension contacts on farmers' adoption decisions, if at all, would not be direct, but indirectly through its effect on the perception of farmers.

In the farmer-to-farmer extension approach, the frequency of extension contacts between farmers is believed to increase farmers' access to information on the biophysical and socio-economic traits of the technology and hence positively influence farmers' perceptions and reduce their skepticism towards the new technologies. Therefore, in order to measure the efficacy of the new extension approach under the scaling out intervention on farmers' perception and hence on adoption, a perception index (*PERIDX)* that captures the combined rating of farmers' perceptions on the different comparative advantages of the barley technology package is constructed (Equation 1):

$$PERIDX=HTECOMPT+HCOMPADV+HINPUTAVAIL-HPERISK-HINPUTPRC \quad (1)$$

Where: HTECOMPT = whether farmer perceives that the technology is highly compatible (1=Yes, 0=No), HCOMPADV=

whether farmer perceives that the technology has high comparative advantage (1=Yes, 0=No), HINPUTAVAIL= whether farmer perceives that the needed inputs (including seeds) for the technology are adequately (quality and quantity) and timely available (1=Yes, 0=No), HPERISK = whether farmer perceives that the technology involves high risk (1=Yes, 0=No) HINPUTPRC = whether farmer perceives that the prices of the inputs for the new technology are high (1=Yes, 0=No), PERIDX takes a maximum value of 3 and a minimum value of -2.

To establish the causality between farmer perceptions and the different extension approaches, the following regression equation was estimated (Equation 2). As the dependent variable PERIDX is an ordered variable, the ordered logit model was used to estimate Equation 2.

$$PERIDX = \alpha \boldsymbol{X}_i + \epsilon_i \qquad 2$$

Where, X_is are explanatory variables including the new and old extension approaches and other variables that are expected to influence farmers' perceptions and ϵ_i is the error term, which is assumed to be logistically distributed.

The main components of the technology package that are being promoted using the new scaling out approach are new barley varieties and inorganic fertilizers. To measure the efficacy of the new scaling out approach in enhancing the adoption of the new technology package, this paper follows Rogers (1983) to construct an adoption index (Y_i), which measures the extent to which the farmer has adopted from among the different components of the technology package as (Equation 3):

$$Y_i = \frac{\left(\frac{AV_i}{AT_i} + \frac{SRA_i}{SRR_i} + \frac{FRA_i}{FRR_i}\right)}{NP} \qquad 3$$

Where: $i=1, 2, 3\ldots n$, and n = total number of farmers in the sample; SRA_i and FRA_i, respectively are actual seeding and fertilizer rates used by the i^{th} farmer; SRR_i and FRR_i are recommended seeding and fertilizer rates respectively; AV_i Area under improved variety of barley for the i^{th} farmer; AT_i Total area under barley (improved variety + local, if any) for the i^{th} farmer; *NP,* Number of components from among the technology package that the farmer has adopted.

Adoption index (Y_i) is thus a continuous dependent variable, which takes values between 0 and 1.71. It cannot take a negative value and the clustering at zero is mainly because of selection bias. Moreover, the technologies were popularized through the FtF extension approach to achieve maximum exposure. Yet, due to differences in their access to information, not all farmers may have equal chance for exposure and therefore adoption. Farmers who are not aware about the existence and traits of a technology are not expected to adopt it. According to Greene (1998), this problem is similar to the "treatment effect" and the simplest method for consistently estimating such a model is to use one of the sample selection correction methods.

Therefore, given its potency in terms of reducingself selectionbias, the two-step Heckman model, also called Heckit (Heckman, 1979) is used here to study the determinants of adoption of the new barley technology package.The Heckit model has emerged as the de facto default alternative to Tobit when values are clustered at zero due to selection bias rather than censoring (Sigelman and Zeng, 1999; Maddala, 1992).

In the first step, the selection equation was estimated as a probit function. The dependent variable is the adoption dummy for the improved barley technology package, which is regressed on a number of exogenous variables. To handle the issue of non-exposure bias, knowledge of the technology package and the dummy variable for identifying participation of villages in the scaling out program are included in the selection equation as proxy variables to indicate whether the household has the minimum amount of information necessary for making adoption decisions.

The selection equation takes the form (Equation 4):

$$Z^*_i = W_i \alpha + \varepsilon_i \qquad 4$$

$$Z_i = \begin{cases} 1, if Z_i^* > 0 \\ 0, if Z_i^* \leq 0 \end{cases}$$

Where:
Z_i = the observed behaviour of a household with respect to technology adoption; it takes the value of 1 if adoption is observed and 0 otherwise. In this step, the probability of (propensity to) adopt is estimated.
W_i = vector of covariates including perception index (*PERIDX*) for observation *i*(list, description and summary statistics of the explanatory variables included in the selection model are presented in Tables 2 and 3), α= vector of coefficients to be estimated and ε_i = random disturbances.

In the second step, the outcome equation is estimated where the adoption index for the improved barley technology package is regressed on most of the explanatory variables included in the selection equation (including perception index ($PERIDX$)) and the Inverse Mills ratio (IMR) from the first step estimation. The outcome equation takes the form:

$$Y_i = \begin{cases} X_i \beta + u_i, \text{if} \quad Z_i^* > 0 \\ 0 \qquad\qquad , \text{if} \quad Z_i^* \leq 0 \end{cases} \qquad 5$$

Where: Y_i= The dependent variable of the outcome equation (the adoption index); X_i = Vector of covariates (some of the covariates from the first step estimation and others which are believed to also affect the outcome variable directly, Tables 2 and 3 shows the list, description and summary statistics on the variables used in this study) and the IMR derived from the first-stage equation which corrects for selectivity bias and endogeneity (Greene, 1998) ; β = vector of coefficients; U_i = Random disturbances assumed identically and independently distributed normal with mean zero and a constant variance.

For the variables, which appear only in the outcome equation the coefficients can be interpreted as the marginal effects while for the coefficients that appear in both the selection and outcome equations, the following formula due to Sigelman and Zeng (1999) is used.

$$\frac{\partial E[y_i / z_i^* > 0]}{\partial x_{ik}} = \gamma\beta_k - \gamma_k \rho\sigma_\epsilon \delta(-w\alpha)$$

Where:

Yi is the dependent variable, Z_i is a latent variable denoting selection, β_k and Υ_k are the estimated coefficients for X_k in the outcome and selection equations, ρ is the correlation coefficient between the error terms of the selection and outcome equations, σ_ϵ is the root mean squared error of theoutcome equation, and δ(-wα) is a function of the IMR, obtained from the linear predictions (-wα) of the selection Equation 5. The Stata 12 software (Stata Corp, 2011) was used for the estimation of both the Ordered Logit and Heckman selection models.

RESULTS

In this study, adoption is defined as the use of the whole or part of the technology package for at least two years. Accordingly, adoption index for sampled households was calculated using Equation 3. Then, the values on the adoption index variable were used to classify respondent farmers in to four categories {farmers with adoption index values of 0 are classified as non-adopters while those with 0.01-0.61 are classified as low-level adopters (low), those with adoption index values of 0.62-0.83, and 0.84-1.71 are classified as medium-level (medium) and high-level (high) adoption categories. Note that the adoption index variable is censored from below) as non-adopters and low, medium, and high adopters. About 51% of the respondents had adoption index score of zero that indicates their overall non-adoption of the package while the remaining proportion had adoption index scores ranging between 0.01 and 1.71 indicating different levels of intensity of adoptions. Results from one-way analysis of variance showed that the mean adoption index was significantly different (at 10% level) across the four adoption categories (Table 4). Moreover, the rate of adoption of improved barley technology package was higher (79.41 and 43.33%) for the two *kebeles* in which the new approach was implemented compared to 36, 27 and 21% in the 3 *kebeles* where the conventional approach was used (Table 1).

Among landraces, long maturing varieties locally called *Ehilzer, Tikurgebse* and *Ginbote* were found to be the dominant varieties used by non-adopters. Seeding rate is an important component of barley technology package. The mean seeding rate for barley was found to vary significantly among adoption categories at 0.01% level. Only 41, 64 and 82% of low, medium and high adoption categories respectively used the recommended seed rate (Table 5). Another component of the barley technology package is fertilizer application where the recommended rates are 100 kg/ha and 50 kg/ha for DAP and Urea, respectively. Only 23, 32 and 41% of the low, medium and high adoption categories respectively used the recommended amounts of chemical fertilizers (DAP plus Urea).

Out of the five stages of the innovation and decision process, persuasion occurs when an individual forms a favorable or unfavorable attitude towards the innovation (Rogers, 1983). In this paper, it is hypothesized that persuasion (that is, decision) to adopt a given technology occurs when an intervention succeeds to influence the perceptions of the subjects of interest. In this paper, perception is proxied by PERIDX - a composite index of perceptions on various attributes of the technology package. The results of the ordered logit model show that the newly introduced FtF extension approach indeed was effective in positively influencing farmers' perceptions about the new technologies (Table 6). Moreover, education and access to seed were found to positively and significantly (at 10% level) influence perception. Whereas, the traditional extension approach which involves frequent visits by Development Agents (DAs) with farmers was found to have no significant effect on farmers' perceptions. The positive and significant coefficient estimate on the SOU variable shows that farmers that are in the villages where the new FtF extension approach is implemented have better perceptions about the technologies than those living in the villages where the conventional extension approach is used. This suggests that the FtF is more effective in favorably influencing farmers' perceptions about the new technologies than the conventional extension approach.

The coefficient estimates of the first and second stages of the Heckman selection model are presented in Table 7. With positive and highly significant coefficient on the perception index variables, the results of the first stage estimation of the Heckman selection model confirm that farmers' perceptions about the new technologies indeed area among the most important factors that determine their adoption decision. After controlling for the effect of farmer perceptions, both the new FtF and the

Table 1. Distribution of Sample Households across sample *kebeles.*

Name of PAs	New scaling out/up intervention implemented	Total number of Barley growers	Number of barley growers included in the sample	Percentage of farmers in the sample who adopted the improved barley varieties
Warkaye	Yes	1346	34	79.41
Weketa	Yes	1171	30	43.33
Agrit	No	1788	45	26.67
Akat	No	998	25	36
Boya	No	1674	42	21.43
Total		6977	176	39.77

Source: Authors own calculations from survey data.

Table 2. Descriptive statistics for continuous variables.

Variable	Description	Unit	Mean (SD)	Is this variable included in the model?		
				Logit model	Heckman model	
					selection	Outcome
AGE	Age of respondents	Years	48.64 (10.78)	Yes	Yes	Yes
DACONT	Number of contacts with EAs	Number	1.64 (0.57)	Yes	Yes	No
FARTOFAR	Farmer's access to extension	Number	2.48 (1.49)	Yes	Yes	No
FARMSIZE	Farm size	Ha	1.06 (0.55)	No	Yes	Yes
HHSIZE	Household size	Number	4.91 (1.45)	No	Yes	Yes
LITLEVEL	Literacy level	Years	2.489 (2.28)	Yes	No	No
EXTDIST	Distance to extension center	Km	6.434 (4.27)	Yes	Yes	Yes
FARMEXP	Farming Experience	Years	30.41 (11.89)	Yes	Yes	Yes
ASSETOWN	Value of asset owns (in '000s)	Eth. Birr	1.59 (0.61)	Yes	Yes	Yes
PERIDX	Combined perception on the technology		1.42 (1.95)	No	Yes	No

Source: Authors own calculations from survey data.

conventional extension systems as well as all other variables that were also included in the ordered logit model such as sex of the household head, distance to extension office, access to seed, and farmer experience were found to have no significant effect on adoption decision. These results confirm the hypothesis that extension interventions as well as farmer characteristics do not directly influence adoption but only through their effect on perception that ultimately influences the adoption decisions. Household size and access to credit are found to have positive and significant (at 10% level) influence on farmers' adoption decisions (Table 6).

In the second stage, estimation of the Heckman selection model, the coefficient on IMR is found to be negative and significant. This suggests that unobservable factors that increase the likelihood of a favorable adoption decision of the improved barley technology decrease the intensity of adoption.

The number of years since the farmer first started using the technology, which is a proxy for the extent of knowledge and experience with the new technology is found to have a positive and significant effect on intensity of adoption. Experience in using the improved barley technology package accounted for 10.8% of total variability in the intensity of adoption.

Table 3. Descriptive statistics for discrete variables.

Variable	Description	Units		Frequency	%	Is this variable included in the model?		
						Logit model	Heckman model selection	Heckman model Outcome
SEXHH	Sex of household head	Dichotomous: male= 1; female= 0	Male	14	7.95	Yes		
			Female	162	92.05		Yes	Yes
CREDACESS	Farmer's access to credit	Dichotomous: yes = 1; no= 0	Yes	80	45.45	Yes	Yes	Yes
			No	98	54.55			
KNOWLEDGE	Having knowledge about improved barley varieties	Dichotomous: yes = 1; no= 0	Yes	104	59.09	No	No	Yes
			No	72	40.91			
SEEDACCESS	Farmer's access to improved barley seed	Dichotomous: yes = 1; no= 0	Yes	78	44.32	Yes	Yes	Yes
			No	98	55.68			
SOU	Farmer is in the *kebeles* where the new FtF is introduced	Dichotomous: yes = 1; no= 0	Yes	113	64.20	Yes	Yes	Yes
			No	63	35.80			
HTECOMPT	whether farmer perceives the technology as highly compatible (1=Yes, 0=No)	Dichotomous: yes = 1; no= 0	Yes	39	22.16	No	No	No
			No	61	78.84			
HCOMPADV	wither farmer perceives that the technology has high comparative advantage (1=Yes, 0=No)	Dichotomous: yes = 1; no= 0	Yes	29	16.45	No	No	No
			No	71	83.55			
HINPUTAVAIL	whether farmer perceives that the needed inputs (including seeds) for the technology are adequately (quality and quantity) and timely available (1=Yes, 0=No)	Dichotomous: yes = 1; no= 0	Yes	64	36.36	No	No	No
			No	36	63.64			
HPERISK	whether farmer perceives that the technology involves high risk (1=Yes, 0=No)	Dichotomous: yes = 1; no= 0	Yes	38	21.59	No	No	No
			No	63	78.41			
HINPUTPRC	wheatear farmer perceives that the prices of the inputs for the new technology are high (1=Yes, 0=No)	Dichotomous: yes = 1; no= 0	Yes	47	26.70	No	No	No
			No	53	73.30			

Source: Authors own calculations from survey data.

Table 4. Distribution of sample respondents by intensity of adoption of improved barley technology.

Program area	Adoption category	Adoption index N	Adoption index Mean(SD)	Max	Min	F value
No	Non adopter	72	0.00(0.00)	0.00	0.00	1266.68***
	Low adopter	10	0.54(0.04)	0.60	0.47	
	Medium adopter	9	0.73(0.06	0.83	0.63	
	High adopter	22	1.07(0.17)	1.33	0.90	
	Total	113	0.32(0.45)	1.33	0.00	
Yes	Non adopters	16	0.00(0.00)	0.00	0.00	211.32***
	Low adopters	10	0.54(0.07)	0.60	0.39	
	Medium adopters	10	0.72(0.09)	0.83	0.54	
	High adopters	27	1.15(0.21)	1.71	0.87	
	Total	63	0.69(0.49)	1.71	0.00	

Source: Authors own calculations from survey data; *** indicates significance at 99% confidence level.

Table 5. Mean values of seed and fertilizer rates by adoption category.

Technology components		Adoption categories Non-adopters	Low	Medium	High	Total	F-value
Seed rate(kg/ha)		145[a]	92.4	96.7	117.8	112.98	84.26***
Fertilizer rate	DAP(kg/ha)	31.16	33.74	41.53	71.58	44.50	6.58***
	Urea(kg/ha)	18.79	20.33	22.12	30.48	22.93	7.48***

Source: Authors own calculations from survey data; *** indicate significance at 99% confidence level. Note: [a] refers to seed rate applied to landraces (local varieties).

Table 6. Parameter estimates of the Ordered Logit Model for perception.

PERIDX	Coef. (Robust std.err.)
SEXHH	1.17(0.84)
DACONT	-0.28(0.27)
CRDTUSE	0.39(0.30)
FARTOFAR	0.58***(0.11)
LITLEVEL	0.17**(0.07)
EXTDIST	-0.01(0.03)
SEEDACCESS	0.75**(0.29)
SOU	1.03**(0.42)
AGE	0.01(0.02)
ASSETOWN	0.00(0.00)
Farming experience	0.01(0.02)
Number of obs	168
Wald chi^2 (11)	109.28***
Log pseudo likelihood	-263.83846

Note: *** and ** represent significance at 99 and 95% confidence levels.

Table 7. First Stage (Probit) and Second stage (OLS) estimates of the decision and intensity of improved barley technology adoption.

Outcome equation (adoption index)		Selection equation (Adoption dummy)	
ADOINDEX	Coef. (Robust Std. Err.)	BADOP	Coef. (Robust Std. Err.)
SEXHH	0.30***(0.05)	SEXHH	-1.07**(0.46)
AGE	-0.01**(0.00)	AGE	0.01(0.02)
KNOWTECH	0.06(0.04)	DACONT	0.06(0.21)
FARSIZE	0.05**(0.02)	FARTOFAR	0.11(0.09)
HHSIZE	-0.05***(0.01)	FARSIZE	-0.09(0.23)
EXTDIS	0.00(0.00)	HHSIZE	0.19*(0.10)
CRDUSE	-0.07**(0.03)	EXTDIS	-0.01(0.03)
SEEDACCESS	0.03(0.03)	CRDUSE	0.47*(0.26)
SOU	0.10**(0.04)	SEEDACCESS	-0.02(0.26)
FAREXP	0.01**(0.00)	SOU	0.17(0.29)
ASSETOWN	0.00(0.00)	FAREXP	-0.00(0.01)
YRSTARTED	0.11***(0.02)	ASSETOWN	0.00(0.00)
IMR	-0.44***(0.06)	PERIDX	0.43***(0.08)
_cons	0.65***(0.14)	_cons	-1.13(0.90)
Number of obs	166	Wald chi^2	71.14***
F	101.87***	Log pseudolikelihood	-70.009117

Source: Authors own calculations from survey data; ***, **and * indicate significance at 99, 95 and 90% confidence levels

conventional extension systems as well as all other variables that were also included in the ordered logit model such as sex of the household head, distance to extension office, access to seed, and farmer experience were found to have no significant effect on adoption decision. These results confirm the hypothesis that extension interventions as well as farmer characteristics do not directly influence adoption but only through their effect on perception that ultimately influences the adoption decisions. Household size and access to credit are found to have positive and significant (at 10% level) influence on farmers' adoption decisions (Table 6).

In the second stage, estimation of the Heckman selection model, the coefficient on IMR is found to be negative and significant. This suggests that unobservable factors that increase the likelihood of a favorable adoption decision of the improved barley technology decrease the intensity of adoption.

The number of years since the farmer first started using the technology, which is a proxy for the extent of knowledge and experience with the new technology is found to have a positive and significant effect on intensity of adoption. Experience in using the improved barley technology package accounted for 10.8% of total variability in the intensity of adoption.

DISCUSSION

Among the most important results from this study is that the traditional extension approach, which is based on the provision of information through visits of Development Agents (DAs) with farmers, was found to have no significant effect on farmers' perceptions. Sanginga et al. (1999) also argue that contact with extension services in the South Western Savannah region of Nigeria did not have much impact on farmers' adoption and the intensity of use of improved soybean varieties while the farmer-to-farmer horizontal dissemination of information played a more important role in the dynamics of technology diffusion. Moreover, using a nationally representative data from Ethiopia, Yigezu et al. (2014), also found that the number of contacts with extension agents does not have significant effect on the decision and intensity of adoption of improved barley and potato varieties. The possible explanations for this result are that 1) extension agents' time might be too thinly spread among many farmers, which reduce their efficacy; 2) development agents are extremely busy as they are responsible for many other tasks including ensuring repayment of agricultural loans and also serve as important channels for pushing the government's agenda, which again might undermine their efficacy in promoting new agricultural technologies.

Another interesting result in this study is that, after controlling for the number of FtF contacts, farmers in the villages where new FtF is introduced had more favorable perceptions about the improved barley technologies than those in the villages where the conventional DA based extension approach was used. The possible explanation for this result is that success stories about the innovators in the villages where the FtF is implemented are likely to be more common and the performance of their crops clearly visible to all residents in the former villages leading to better perceptions among farmers including those who did not have direct contacts with the forerunner farmers as they would be informed by others who did.

Access to seed of the improved barley varieties was also found to be among the most important factors that influence farmers' perceptions and attitudes about the new technology package. This is consistent with the theoretical expectation in that varieties for which no adequate (quantitative and qualitative) and timely availability of seed is guaranteed are likely to not be attractive to farmers. The education level of the household heads had also a positive and significant effect on their perceptions indicating that farmers that are more educated are more likely to accept new technologies. Access to credit also has significant (at 10% level) influence on adoption which is consistent with the findings of Putler and Zilberman (1988) and Kansana et al. (1996). On the other hand, sex, age and farming experience of household head, their net worth, their access to credit and distance of their residence from the DA office were all found to have no significant effects on farmers' perceptions about the new technologies.

Households with larger family sizes were found to adopt the technologies on relatively smaller area than those with smaller families, which seems to be counter intuitive. Tadesse and Kassa (2004) also found similar results. A possible explanation for this result is that the traditional varieties might have low tolerance to weeds but on the other hand may have desirable consumption qualities that fetch higher prices, which despite their low yields, might still make them profitable. Therefore, families, which have larger labor supply, might be inclined into the cultivation of the local varieties more than the improved varieties.

Once they decide to adopt the new technologies, male-headed households were found to use the improved technology package at a higher intensity than female-headed households, which have also decided to adopt the new technologies. This suggests that male-headed households have better opportunity cultivate the improved barley technologies on relatively larger areas. These results are consistent with the findings of Mekuria (1994). A possible explanation is that male-headed households often cultivate larger crop areas and hence once they make up their minds, they are likely to cultivate the new technologies on larger areas. The positive and significant coefficient on farmer experience shows that more experienced farmers are likely to adopt the new technologies at larger scale. This result is intuitive because, by trying the technology on a small scale and gradually increasing the area size over a number of years, the farmers may clear all possible skepticism and prove to themselves that the technology indeed is good for them thereby leading to larger scale adoption. As a result, experience with the new technologies will improve farmers' acquaintance and confidence with the new technologies leading to lower level of uncertainty on the performance of the technologies.

FtF enhances farmers' understanding and perception on the compatibility, comparative and risk reducing advantages of improved technologies, which ultimately influences their attitudes toward the technologies. At the same time, our results show that once farmer perceptions are controlled for, neither the new FtF nor the frequency of contacts between development agents and farmers under the conventional extension approaches have significant effect on farmers' adoption decision. This shows that the efficacy of any extension approach in enhancing adoption of improved technologies depends on the efficacy of the approach in influencing farmer perceptions and confidence on the socio-economic and biophysical benefits of the technology. Doss (2003) and Wale and Yallew (2007) reported that the probability of adoption of a new technology depends on the ability of farmers to perceive the advantages and compatibility of technologies with existing socioeconomic conditions.

Conclusions

Low adoption levels of agricultural technologies undermine the impacts of national and international agricultural research. Some technologies with proven biophysical and socio-economic advantages often remain on the shelf or are confined to few users and/or small localities adding to the frustration of technology developers, development workers and donors. One of the underlying reasons is that farmers in many parts of the world are often sceptical about the adoption of new agricultural technologies and innovations possibly due to lack of awareness or empirical evidence of the benefits over conventional practices.

Conceptually, this paper hypothesized that any of the agricultural extension approaches do not have direct effect on farmers' adoption decisions but, if any, indirectly through their effect on farmers' perception on the new technologies. To this effect, an ordinal variable PERIDX that is a composite measure of farmers' perception on the different attributes of the technology package is constructed. Then, an ordered logit model, which regress the different extension approaches and other variables, which are believed to influence farmers' perceptions on PERIDX, is estimated first. By so doing, the paper attempted to establish causality between different extension approaches and farmer perceptions. Then, the two-stage Heckman selection model, which corrects for self-selection bias is estimated where the decision on the intensity of adoption is conditional on the decision whether to adopt the improved barley technology package or not.

Results from the ordered logit model confirmed that the new (to Ethiopia) farmer to farmer extension approach (FtF) is effective in favourably influencing farmers' perceptions about the intrinsic characteristics of the new technology package. While the conventional extension package which is based mainly on development agents' efforts to convince farmers is found to be ineffective in influencing farmers' perceptions and attitudes toward the new technologies as well as in improving farmers' access to seed. FtF is, therefore, plays an important role in strengthening the often-weak links of extension and seed system in the research-to-development continuum.

Estimates from the two-stage Heckman selection model provided evidence that farmers' perception about the biophysical and socio-economic traits of the technology package- proxied by the perception index (PERIDX) is an important explanatory variable for farmers' adoption decision. One of the interesting results in this paper is that after controlling for farmers' perceptions, neither the conventional DA based extension nor the new FtF extension approaches have significant effect on farmers' adoption decision.

The policy implications of these results are that there is a need for: 1) the governments of the developing world to develop mechanisms and reorient their extension strategies more towards enhancing farmer-to-farmer information exchange. 2) Increasing investment on building the capacity of forerunner farmers in each locality for acquiring and processing adequate information and knowledge about the intrinsic and extrinsic features of the technologies; and 3) Further research to evaluate different extension models that support the FtF approaches so as to ensure the development of self-sustaining community managed extension models that lead to sustainable technology development and faster diffusion.

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