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The effects of a participatory approach on the adoption of agricultural technology: Focusing on the social network structure in rural Ethiopia

This study empirically examined the effects of the participatory approach on the adoption of new crop varieties and agricultural practices. Particularly, we focused on the social network structure and examined how the introduced technologies diffused through networks in rural Ethiopia. Our empirical results indicate that if farmers knew and trusted fellow participants, the probability of adopting a new maize variety increased by 25 percentage points. However, this network had no statistical impact on the diffusion of new agricultural practices. We conclude that the participatory approach has great potential in the adoption of new crop varieties through the social networks of farmers in Ethiopia.

Keywords: participatory research and extension, farmer research group, impact evaluation

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Introduction

In the past, mainstream rural development efforts have focused on technical innovations delivered by research through extension to farmers in a top-down model (Waters-Bayer *et al*., 2004). However, many studies have found that such interventions through formal research institutions generally do not necessarily provide farmers with more secure access to new technologies or improve their livelihoods (Van de Fliert and Braun, 2002; Waters-Bayer *et al*., 2004; Hoffmann *et al*., 2007). In particular, agricultural research in Africa has failed to provide useful outputs to poor small-scale producers (Mosley, 2002; Sumberg and Reece, 2004; Breisinger *et al*., 2011).

One possible reason for this failure of diffusion of technologies through formal institutions was that the technologies were not developed based on farmers' needs or constraints. Thus, most newly introduced technologies have been inappropriate for poor farmers in marginal, rain-fed areas (Hall and Nahdy, 1999, Waters-Bayer *et al*., 2004). More precisely, Collinson (2001) documented that, while formal researchers tend to prioritise physical productivity, improving labour and capital productivity are the primary goals from producers' point of view. To understand the problems farmers face and minimise the gap between researchers' priorities and farmers' needs, the idea that farmers should participate in the process of agricultural research, innovation and extension was first proposed in the 1970s (Johnson *et al*., 2003). Since then, this Participatory Research and Extension (PRE) approach has become a leading principle of sustainable rural development (Leeuwis, 2000; Mog, 2004).

Several theoretical studies have explored the advantages of the PRE approach (Leeuwis, 2000; Van de Fliert and Braun, 2002; Mog, 2004; Waters-Bayer *et al*., 2004). Hellin *et al*. (2008) suggested that the use of participatory approaches is one way to enhance rural innovation capacity, where such approaches may involve increased accessibility by farmers to externally developed technology, the joint development of relevant and appropriate technology by farmers and scientists, or the enhancement of local capacity to address problems and devise solutions. Hoffmann *et al*. (2007) argued that the PRE approach may yield many innovations and new kinds of knowledge because farmers have far more opportunities than researchers for experimentation under different cultural and environmental conditions.

In contrast, several studies have documented constraints and limitations of the PRE approach. Firstly, it is difficult to generalise a given PRE practice, as technologies innovated through the PRE are locally developed to fit particular biophysical and socio-economic settings and usually cannot be transferred in exactly the same forms to other settings, notably, to the highly varied environments in which many poor farmers live (Waters-Bayer *et al*., 2004). Secondly, there is a power difference between stakeholders; in particular, the gender issue is important. Akerkar (2001) observed that "gender was often hidden in participatory research in seemingly inclusive terms: the people, the community, the farmers" (p.4). Similarly, farmers' groups of PRE projects in Uganda and Latin America were found to be dominated by men (Hall and Nahdy, 1999; Humphries *et al*., 2000; Ashby *et al*., 2000). Thirdly, the professional identity of scientists can have an adverse effect. Hall and Nahdy (1999) documented that "the scientists felt their status would be in some way diminished by passively listening to what farmers had to say" (p.5). The loss of 'superiority' with respect to knowledge decreases scientists' motivation to be involved in PRE projects.

Another major problem of the PRE approach is that its impact has not been clarified because of the absence of impact evaluations based on statistical analysis. Although many studies have shown how PRE projects have influenced productivity and income in various regions, all these are qualitative case studies (Humphries *et al*., 2000; Classen *et al*., 2008; Kaaria *et al*., 2008; Humphries *et al*., 2012). One quantitative study by Sanginga *et al*. (2006) applied statistical techniques to data from a survey of 170 producers in Uganda. However, the objective of these authors was to identify the factors that motivate farmers to participate in PRE projects, not to evaluate the impact of the PRE. Because the effects of the PRE method have rarely been systematically analysed or reported (Johnson *et al*., 2003), there remains disagreement regarding the roles of formal and informal research and development (Hoffmann *et al*., 2007).

In addition, the impact of the PRE approach on farmers not involved in the programme through technology diffusion from participant farmers has never been fully examined. Many studies have found that agricultural technology diffuses through social networks, especially in rural areas of less developed countries (Munshi, 2004; Todo *et al*., 2011). However, the spillover effects of PRE projects, such as whether new technologies introduced by the PRE approach diffuse to non-involved farmers through social networks, remain unclear.

Therefore, the objective of this study is to quantify the impact of the PRE approach on the diffusion of agricultural technologies, with a particular focus on whether and how new knowledge and agricultural practices introduced by a PRE project diffuse through social networks to community members who are not involved in the project.

Although there are many variants of the PRE approach – such as Participatory Technology Development (PTD) and Farmer Participatory Research (FPR) – in the present study, we focus on a PRE approach that particularly utilises Farmer Research Groups (FRGs) to involve farmers in the research process and strengthen the link between farmers' needs and research outcomes (Probst, 2000; Probst *et al*., 2003). Under the FRG approach, participating farmers identify their needs and test possible solutions by conducting on-farm trials. They are trained to collect the necessary data in a scientific way, which increases the credibility of their findings. In the present study, one FRG project conducted in Ethiopia is selected for detailed examination.

Data

Description of the FRG project

The FRG project (hereafter, "the project") selected for our case study was conducted in Ethiopia by the Japan International Cooperation Agency (JICA) and the Ethiopian Institute of Agricultural Research (EIAR). Like other sub-Saharan African countries, agriculture remains the main source of income for most rural households in Ethiopia. However, the agricultural productivity is fairly low due to low adoption of agricultural technologies (Todo and Takahashi, 2011).

To promote better understanding of agricultural knowledge among farmers, the project implemented the FRG in three zones in the Oromia region, namely East Shewa, Arsi, and West Arsi, from 2004 until 2009. During the implementation period, a total of 40 farmers' groups were established and a total 1,186 individuals participated in the project. While the gender issue has frequently been observed in FRG projects (Hall and Nahdy, 1999; Ashby *et al*., 2000; Humphries *et al*., 2000), in the present case the gender balance was successfully addressed: among the 1,186 participants, 633 (53.4 per cent) were women.

After the farmers' groups were established, each group chose its main focus from among 15 categories that covered a broad range of topics, namely agro-forestry, dairy products, pulses, maize, teff (a small grain cereal crop commonly produced in Ethiopia), vegetables, parthenium control, forage seeds, beehives, water harvesting, sweet potatoes, groundnuts, choppers, milk churners and market information. FRG participants then experimented with and evaluated new agricultural practices and improved technologies.

In the present study, we focused on two villages involved in the project: Awash Melkassa and Awash Bishola, located in southwest Ethiopia (approximately 100 km from the capital city of Addis Ababa). In the study area, the project established several farmers' groups that tested both new and conventional practices relating to teff, maize and vegetable (i.e. tomato, onion and pepper) production. More precisely, the project provided information on the new varieties of maize, soil compaction management technique for teff production, and row planting of vegetables. Therefore, for the impact evaluation, we examined the implementation by each group of three technologies: improved maize varieties, soil compaction for teff and row planting.

During the primary stage of the project, FRG participants evaluated the performance of two improved maize varieties, namely Melkassa-2 and Melkassa-3, by comparing them with a local variety, Awassa-511. The participants prepared trial plots and evaluated the productivity of each variety. According to the project report, the participants observed that Melkassa-2 yielded more maize grains than either Melkassa-3 or the local variety. More precisely, the average yield of Melkassa-2 was 36 qt/ha (ca. 34 l/ha), while Melkassa-3 and the local variety were 31 and 23 qt/ha (ca. 29 and 22 l/ha), respectively.

Soil compaction treatments were introduced potentially to impact germination and growth in teff production. Participants prepared trial plots (10 m by 10 m), employing different practices: no compaction, compaction before sowing, compaction after sowing, compaction before and after sowing, and traditional practices. To implement soil compaction treatments, roller-compactors were dragged by oxen or donkeys. The participants found that, while soil compaction increased plant numbers and germination rates, it did not affect productivity. Additionally, row planting and broadcasting were compared with respect to time spent, yield and germination. Until relatively recent years, direct broadcasting was common practice in rural areas of Ethiopia and diffusion rate of row planting was low. Therefore, the participants of the project first learned how to implement row planting and increased their awareness and knowledge of the technique. As a result, they learned that although row planting required more manual labour and labour hours, it increased productivity and reduced germination the day after planting. The project report shows one example of the haricot bean production; manual row planting requires 230.2 minutes/person and yields 99 kg/ha, while the time spent for preparation and average yield for broadcasting is 101.3 minutes/person and 93 kg/ha respectively.

Household survey

To collect socioeconomic information on both FRG participants and non-participants, we conducted a household survey from January to February 2012. Firstly we collected a complete list of the farming households in both villages. In total, 213 names were listed for Awash Melkassa and 208 for Awash Bishola.

In Awash Melkassa, we investigated all farmers on the list. However, owing to missing variables, seven farmers were omitted; hence the number of observations in Awash Melkassa used in the analysis was 206. In the case of Awash Bishola, we randomly selected 150 people for the household survey from the list of 208 individuals. Unfortunately, because some data for 16 individuals were missing, data for only 134 people were available for the analysis. Hence, the total number of observations in our study was 340. Among these 340 interviewed households, 42 individuals participated in the FRG.

Table 1 presents basic information on FRG participants and non-participants. Although there were no significant differences between the two groups with respect to any variables, the proportion of female household heads among FRG participants was relatively high compared to that of non-participants.

Table 1: Summary statistics for Farmer Research Group project participants and non-participants.

Variable	Participants	Non-participants	Total
Number of observations	42	298	340
Age of the household head	45.62	45.18	45.23
	(13.43)	(16.40)	(16.05)
Female household head (%)	40.5	28.9	30.3
Educational years of the household head	3.69	3.12	3.19
	(3.64)	(3.54)	(3.55)
Number of household members	6.05	5.82	5.85
	(2.35)	(2.53)	(2.50)
Total area of agricultural land (ha)	1.60	1.33	1.36
	(1.33)	(1.11)	(1.14)
Proportion of maize plot	0.11	0.12	0.12
	(0.13)	(0.19)	(0.18)

Note: standard deviations are in parentheses

Network variables

To identify the social network within each village, we asked each household to list up to five trustworthy persons in the same village and the names of each of these individual's household heads. By comparing the names of each person and each person's household head, we determined whether the listed people participated in the FRG. We found that 46 non-participating respondents mentioned at least one FRG participant as a trustworthy person. In addition to these 46 individuals, 14 FRG participants mentioned at least one FRG participant's name too. We define this social network of respondents and FRG participants as a FRG network.

In addition to the FRG network, we investigated the network of respondents and agricultural extension agents, locally known as 'development agents' (hereafter, 'extension agents'). In Ethiopia, extension agents promote new agricultural technologies developed by researchers to farmers in rural villages. Each village has between one and three extension agents, and there are about 50,000 agents in Ethiopia as a whole, forming a widespread extension system. The extension agents have completed three years of college and are trained as agricultural specialists. Extension agents are assigned to villages and regularly visit farmers to provide training at extension centres in their regions. Therefore, extension agents are officially designated as one of the major channels of dissemination of new agricultural technologies in Ethiopia.

In this study, we employed two types of indicators of networks with extension agents. The first is by simply knowing any extension agent. Here, knowing an agent is defined as a mutual relationship. In other words, if the respondent knows an extension agent, then that agent should also know the respondent. The second indicator relates to knowing and trusting any extension agent. Following the study by Todo *et al*. (2013), we employed two dummy variables to identify the level of trust: being able to borrow ETB 200 (approximately USD 10) from the extension agent and being able to lend the extension agent ETB 200. If the respondent could borrow and lend ETB 200, we presumed that there was a trust network between the respondent and the extension agent. To avoid confusion, we define the first indicator as 'knowing any extension agent' and the second indicator as 'trusting any extension agent'.

Empirical framework

We used a probit model to evaluate the impact of the FRG network on the adoption of improved maize varieties and agricultural practices, such as soil compaction and row planting.

To identify the determinants of improved maize variety adoption, we estimated two non-linear probability models: one that employs the variable 'knowing any extension agent' and one that employs the variable 'trusting any extension agent'. As the dependent variable, we used a dummy variable that took a value of one if the respondent adopted improved maize varieties during the last cropping season and zero otherwise.

In addition, as an independent variable, we employed a dummy variable that takes a value of one if the respondent is part of the FRG network and zero otherwise, enabling us to capture quantitatively the impact of the FRG networks. To control the effects of participating in the project, we used a participation dummy variable that takes a value of one if the respondent participated in the FRG project (defined as the FRG dummy). Additionally, we included the following as independent variables: the age of the household head, a female household head dummy, the educational years of the household head, the number of household members, the total area of agricultural land, and the area of the maize plot as a proportion of the total area of agricultural land.

In the cases of the two agricultural practices (soil compaction and row planting), we estimated two probit equations: one to investigate the determinants of knowledge of how to implement a technology (knowing the technology) and one to investigate the determinants of adoption of a technology (using the technology), where the latter is conditional on knowing the technology. We tested both equations, which are similar to the equations used to examine the adoption of improved maize varieties, by changing the extension-agent-network variables. As independent variables, we used the same variables as those used in the maize variety equations, except the area of the maize plot as a proportion of the total area of agricultural land.

Results

The adoption of improved maize varieties

The estimation results for the probit model of the adoption of improved maize varieties are presented in Table 2. Columns 1 and 2 present results obtained under inclusion of the 'knowing any extension agent' variable and the 'trusting any extension agent' variable, respectively.

The results obtained when the 'knowing any extension agent' variable was included, in column 1, indicated that the FRG network had a significant and positive effect on adoption of improved maize varieties. This result indicates that involvement in the FRG network increases the probability of adopting improved maize varieties. This positive effect was also observed consistently in results obtained when the 'trusting any extension agent' variable was included. These results suggest that the reputation of the improved maize varieties may diffuse through the FRG network. Hence, farmers within the FRG networks may decide to use new maize varieties even if they do not participate in the project. In fact, more than 70 per cent of the respondents involved in the FRG network reported that they had discussed the new agricultural technologies with their close friends and mentioned that 'friends' is one of the major information source of new crop varieties. In contrast, we found no significant effect from the FRG dummy. However, the insignificant result implied that the knowledge of new varieties was fully diffused from FRG participant to farmers involved in the network, and thus there is no difference between the participants and involved farmers on the adoption rate, resulting the insignificance of the FRG dummy.

In addition, we found that 'knowing any extension agent' did not affect the adoption behaviour of respondents, whereas 'trusting any extension agent' had a significantly positive effect. These results indicate that trust increases the likelihood of adoption.

Furthermore, we did not find any significant effects of the other variables, including the female household head dummy variable. The insignificant effect of the female household head dummy indicates that female heads do not face disadvantages regarding technology adoption, although such disadvantages been observed in other areas (Hall and Nahdy, 1999; Ashby *et al*., 2000; Humphries *et al*., 2000).

Next, to quantify the impact of the FRG network, we used the results of the probit estimation to calculate marginal effects; these calculations are shown in columns 3 and 4. The marginal effects obtained for the second equation in column 4 indicate that the magnitude of the FRG network was 0.250, which implies that being part of the FRG network increased the probability of adoption by 25.0 percentage points compared with farmers outside the FRG network. In the case of the network with the extension agent, the marginal effect of trusting any extension agent was 0.218. In other words, trust in the extension agent increased the probability of adopting improved maize varieties by 21.8 percentage points.

Table 2: Determinants of adoption of improved maize varieties by farmers.

Variable	Equation 1	Equation 2	Marginal effects for (1)	Marginal effects for (2)
	(1)	(2)	(3)	(4)
Age of the household head	-0.007 (0.009)	-0.003 (0.009)	-0.003 (0.003)	-0.001 (0.003)
Female household head dummy (1=Yes)	0.408 (0.299)	0.356 (0.301)	0.148 (0.102)	0.129 (0.104)
Educational years of the household head	-0.021 (0.036)	-0.017 (0.036)	-0.008 (0.013)	-0.006 (0.013)
Number of household members	0.013 (0.052)	0.015 (0.053)	0.005 (0.020)	0.006 (0.020)
Total area of agricultural land (ha)	-0.077 (0.118)	-0.051 (0.118)	-0.029 (0.045)	-0.019 (0.045)
Proportion of maize plot	-0.886 (0.617)	-0.531 (0.629)	-0.335 (0.233)	-0.200 (0.237)
FRG dummy (1=Participate)	0.168 (0.336)	0.019 (0.349)	0.062 (0.121)	0.007 (0.131)
FRG network	0.646*** (0.310)	0.738** (0.315)	0.224** (0.095)	0.250*** (0.091)
Knowing any extension agent	0.325 (0.521)		0.127 (0.207)	
Trusting any extension agent		0.581** (0.258)		0.218** (0.095)
Constant	0.387 (0.745)	0.050 (0.630)		
Observations	136	136	136	136
Log likelihood	-83.66	-81.28		

Note: Standard errors are in parentheses; **, and *** indicate statistical significance at the 5 and 1% levels respectively.

The adoption of agricultural practices

Table 3 presents the estimation results for the adoption of soil compaction. The determinants of knowing the practice of soil compaction are presented in columns 1 and 2, and those of using soil compaction are presented in columns 3 and 4. We found that the FRG dummy had a slight positive impact on knowing and using soil compaction. However, the

Table 3: Determinants of diffusion of soil compaction.

Variable	Knowing soil compaction		Using soil compaction	
	(1)	(2)	(3)	(4)
Age of the household head	0.006 (0.005)	0.007 (0.005)	0.012** (0.006)	0.012** (0.006)
Female household head dummy (1=Yes)	-0.149 (0.169)	-0.195 (0.172)	0.013 (0.183)	-0.021 (0.186)
Educational years of the household head	0.083*** (0.023)	0.070*** (0.023)	0.104*** (0.025)	0.093*** (0.025)
Number of household members	-0.037 (0.031)	-0.036 (0.031)	-0.016 (0.033)	-0.017 (0.034)
Total area of agricultural land (ha)	-0.031 (0.067)	-0.028 (0.071)	-0.015 (0.071)	-0.007 (0.075)
FRG dummy (1=Participate)	0.352* (0.214)	0.282* (0.220)	0.425* (0.219)	0.344 (0.226)
FRG network	0.061 (0.190)	0.042 (0.193)	0.092 (0.199)	0.073 (0.202)
Knowing any extension agent	0.668** (0.315)		0.685* (0.363)	
Trusting any extension agent		0.677*** (0.148)		0.687*** (0.160)
Constant	-1.309*** (0.445)	-0.942*** (0.331)	-2.187*** (0.515)	-1.845*** (0.371)
Observations	340	340	340	340
Log likelihood	-209.3	-201.2	-176.0	-168.6

Note: Standard errors are in parentheses; *, **, and *** indicate statistical significance at the 10, 5 and 1% levels respectively.

involvement in the FRG network did not significantly impact either knowing or using soil compaction.

These results indicate that the probability of adopting soil compaction increases by participating in the FRG, whereas involvement in the FRG network does not significantly influence the adoption behaviour. We assume that the reason for not having the spillover effect relates to lack of actual experience. One important component of the FRG method is that participants conduct on-farm trials and experience new agricultural technologies first-hand. Because of this field experience, participants can evaluate the final outcomes of technologies and decide whether to adopt them. However, such experience cannot be shared with others by verbal communication and thus the new practices did not disseminate through the FRG network.

In contrast, the effects of both extension agent network variables on knowing and using soil compaction were significantly positive. Additionally, we found that the number of years of education of the household head had a significant positive effect on the diffusion of soil compaction information and adoption. This finding implies that highly educated farmers are more likely than less-educated farmers to be familiar with and adopt soil compaction technology. One possible reason for the positive correlation between the educational level of the household head and adoption of soil compaction may be the complexity of the technology. Indeed, implementing soil compaction is more complicated than using improved varieties, as farmers must know when and how to draft the compactor. As farmers are required to understand the components of the relevant technology before they can implement it, educational level plausibly strongly influences adoption of this technique.

With respect to the diffusion of row planting, we found no significant effects from the FRG dummy, as well as the FRG network dummy (Table 4). In contrast, the extension agent network variables were found to affect positively adoption of row planting techniques. The insignificant effects from the FRG variables and positive correlation between the extension agent network variables and adoption of row planting are reasonable. While row planting is common agricultural practice in many areas and countries, many farmers in rural Ethiopia continuously preferred to use the low labour input method, such as direct broadcasting, during the project implementation period. Although the FRG participants observed the increase in the productivity by adopting row planting, they also faced the requirement of more manual labour and labour hours. Such additional inputs may diminish farmers' interest in row planting, which explains the insignificance of the FRG variables. However, recently, the Ethiopian government started rolling out row planting technique by utilising extension agents (Vandercasteelen *et al*., 2013). In fact, we observed many agricultural workshops held by extension agents to encourage the use of row planting technique to community members. We assumed that such political decision advocating row planting enhanced the diffusion effect of the extension agent, resulting in the positive effect from the agent network dummy.

Table 4: Determinants of diffusion of row planting.

Variable	Knowing row planting		Using row planting	
	(1)	(2)	(3)	(4)
Age of the household head	0.001 (0.005)	-0.001 (0.005)	0.005 (0.005)	0.004 (0.005)
Female household head dummy (1=Yes)	0.152 (0.197)	0.121 (0.199)	0.215 (0.161)	0.191 (0.162)
Educational years of the household head	0.061** (0.028)	0.039 (0.027)	0.045** (0.022)	0.036 (0.022)
Number of household members	-0.042 (0.035)	-0.028 (0.034)	0.015 (0.029)	0.020 (0.029)
Total area of agricultural land (ha)	0.216** (0.105)	0.228** (0.104)	-0.021 (0.064)	-0.014 (0.064)
FRG dummy (1=Participate)	-0.185 (0.258)	-0.141 (0.270)	0.126 (0.213)	0.099 (0.217)
FRG network	0.204 (0.237)	0.161 (0.236)	0.148 (0.185)	0.135 (0.185)
Knowing any extension agent	1.079*** (0.276)		0.580** (0.279)	
Trusting any extension agent		0.705*** (0.184)		0.396*** (0.142)
Constant	-0.373 (0.451)	0.431 (0.373)	-1.171*** (0.411)	-0.781** (0.318)
Observations	340	340	340	340
Log likelihood	-147.9	-147.8	-228.9	-227.3

Note: Standard errors are in parentheses; **, and *** indicate statistical significance at the 5 and 1% levels, respectively.

Furthermore, in the case of the number of years of education of the household head, we observed trends similar to that observed with respect to soil compaction. The educational years were found to influence positively adoption of row planting, although this correlation was not as strong as that observed in the case of soil compaction. In addition, we found that the total area of agricultural land managed was positively associated with knowledge of row planting techniques, although this association was insignificant in the adoption. We assume that because adoption of row planting requires increased labour inputs, farmers who own large amounts of agricultural land are unlikely to adopt row planting, even if they know how to implement it.

Discussion and conclusion

In this study, we have empirically examined the effects of a Farmer Research Groups (FRG) project using a Participatory Research and Extension (PRE) approach on the adoption of such agricultural technologies as improved maize varieties, soil compaction and row planting, focusing on the social network structure in rural Ethiopia.

In the case of improved maize varieties, we found an indirect impact of the FRG project. Our empirical results indicate that knowledge of and trust in fellow FRG participants positively affected variety adoption. More precisely, involvement in a FRG network increased the probability of adopting improved maize varieties by 25.0 percentage points. Although the trust network with extension agents also had a positive effect, the magnitude of the FRG network's impact was greater than that of the trust network with extension agents. These results suggest that new varieties diffuse through the reputations of farmers and that FRG networks can play an important role in farmers' adoption behaviour.

However, we found that the FRG network had no statistical impact on the diffusion of selected agricultural practices, such as soil compaction. We assume that the reason for this insignificant result relates to lack of actual experience. Even if participants observed a positive outcome of a new agricultural practice, such knowledge from experience is difficult to share with others through verbal communication, limiting the effects of the FRG network on the diffusion of such practices. With respect to row planting, there were no statistically significant differences in both FRG dummy and FRG network variables, although row planting is a simple technology. One possible reason of the insignificance is because of the additional inputs, such as increased manual labour and labour hours. During the project implementation period, since many farmers in rural Ethiopia prefer to use less labour intensive technologies, row planting provided by the present FRG approach may not meet the needs of farmers.

In contrast, the social network with extension agents had a significantly positive impact on the adoption of new agricultural practices. Because extension agents regularly visit farmers to provide training, farmers involved in social networks that include extension agents may have more opportunities than those not involved in such networks to learn about new agricultural practices in their fields. These results suggest that extension agents contribute to the dissemination of new agricultural practices, especially practices requiring experience before they can be adopted. With respect to row planting, we found a strong correlation between the farmers' adoption choice and extension agent network variables. This strong correlation is most likely due to political decisions. In recent years, the Ethiopian government decided to advocate row planting through the extension agent, and thus we may observe such diffusion efforts by the extension agents in our estimation results.

Overall, our empirical results suggest that the FRG approach affects differently the technology diffusion depending on the characteristics of technologies. The FRG approach has great potential in the diffusion of simple agricultural technologies, such use of new varieties, via the social networks of farmers. However, the estimation results of adopting row planting suggest that if introduced technologies require additional inputs, the FRG approach may not affect the adoption behaviour of farmers, even if technologies are simple. Furthermore, the spillover effects of the FRG would be limited if technologies are complex and require experience to properly employ, as suggested by the results of the adoption of soil compaction. Enhancing dissemination to non-participant community members represents additional challenge of the present FRG approach.

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