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Farmer field school and farmer knowledge acquisition in rice production: Experimental evaluation in China

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ABSTRACT

We collaborate with the Chinese Ministry of Agriculture (MOA) and conduct a randomized controlled trial (RCT) to examine the effects of farmer field schools (FFS) on the knowledge acquisition by farmers in rice production in Anhui, China. The intensification of China's agricultural production has raised widespread environmental concerns. Lack of advisory services to increase awareness and knowledge has been found to be the primary constraint to improving farming and environmental outcomes. However, training millions of small farmers is a significant challenge. To impart the knowledge of sustainable and low-carbon farm management, the MOA recently piloted a FFS program through its public extension system. A participatory approach to rural advisory services, FFS was initiated by the Food and Agriculture Organization during the late 1980s in Asia, and at present is being practiced in more than 90 developing countries. However, the effectiveness of the FFS program has not been conclusively demonstrated, and the results of previous impact evaluations have varied greatly according to evaluation methods. A major drawback of previous studies has been selective participation in the program, leading to biased estimates of program effects. We use an RCT to overcome these problems. The results are heterogeneous: FFS effectively improved farmers' knowledge of pest management and agro-environment; however, we find no effects on nutrient management and cultivation knowledge. Furthermore, the effects were smaller for female and old participants. Being a "best-design" approach of agricultural extension initiated by FAO, FFS faces challenges to be "best-fit" in China, where urbanization and agricultural transformation are emerging.

1. Introduction

The intensification of China's agricultural production has raised concerns about environmental stress. For example, previous studies have showed that Chinese farmers spray excessive amounts of pesticides, which is detrimental to their health (Pemsl et al., 2005). The high level of nitrogen fertilizer use has resulted in serious environmental stress by increasing greenhouse gas emissions and polluting ground and surface water through nitrogen leaching (Ju et al., 2009; Zhu and Chen, 2002). In 2010, nitrogen-fertilizer-related emissions constituted about seven percent of greenhouse gas (GHG) emissions from the entire Chinese economy and exceeded several-fold soil carbon gain resulting from N fertilizer use (Zhang et al., 2013). Recent studies reveal that groundwater abstraction also represents an important source of agricultural GHG emissions in China (Wang et al., 2012).

A lack of knowledge advisory services was found to be one of the primary reasons for unsustainable farming practices in China's agricultural production. Chinese farmers rely on their experience from the Green Revolution (1960–1980), which suggests that high volume use of agro-chemicals always leads to higher crop yields (Jia et al., 2013). Meanwhile, the accountability of delivering public extension services is low due to lack of funding since the late 1980s (Zhi et al., 2007). Many extension staff in county agricultural bureaus were taken off the government payroll and reassigned to township governments. Although Chinese government started a number of new initiatives in the mid-2000s to promote a demand-driven public agricultural extension system, the majority of extension staff are still overwhelmed by non-extension work (Hu et al., 2009).

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Agricultural extension programs in many developing countries are evolving and transforming towards participatory approaches that respond to farmers' heterogeneous and site-specific needs. Since the 1970s, the design of agricultural extension programs in developing countries has shifted from desk-bound bureaucracy to field-based agents who focused mainly on technology diffusion, such as Training and Visiting (T&V) (Picciotto and Anderson, 1997). T&V extension agents meet with a small group of contact farmers who are expected to disseminate information to the members of their communities and convey feedback to the agents, thus creating an interactive mechanism absent in the prior system (Birkhaeuser et al., 1991). However, given the prohibitive cost of establishing these programs and farmers' diversified needs, T&V was found unsuccessful after three decades of support from international donors such as the World Bank (Picciotto and Anderson, 1997).

Since the late 1980s, a number of development agencies such as Food and Agriculture Organizations (FAO) have promoted farmer field schools (FFS) as a more effective approach to transfer knowledge to farmers. FFS was first started in Indonesia in 1989 to disseminate Integrated Production and Pest Management (IPM) (Braun et al., 2006; CIP-UPWARD, 2003; Pontius et al., 2002). An FFS is a group of farmers (roughly 20–25) who meet periodically in a designated field throughout the major part of crop cycle. The farmers usually work in smaller subgroups and devote considerable time to agro-ecosystem analysis, in which they are encouraged to make observations of important processes and relationships. The FFS facilitator (typically an extension agent) encourages farmers to ask questions and seek to answers rather than lecturing or giving recommendations. Through group interactions, FFS participants sharpen their decision-making abilities and are empowered by learning leadership, communication, and management skills. By 2010, there were a multitude of FFS initiatives in more than 90 developing countries (Friis-Hansen and Duveskog, 2012).

Results of previous impact evaluations have varied greatly. Some studies show that FFS participants attained higher knowledge scores and exhibited better adoption of sustainable farm practices relative to a group of nonparticipants (Bunyatta et al., 2006; Godtland et al., 2004; Lund et al., 2010; Siddiqui et al., 2012). Other studies find little evidence of impacts on these outcomes (Feder et al., 2004a,b; Tripp et al., 2005).

A major drawback of most previous studies is that they did not properly control for potential differences between FFS participants and farmers in the comparison group. The observed difference could arise from the nonrandom geographic placement of the program or from the voluntary nature of participants in FFS. For instance, FFS villages were often purposively selected for their relative advantages in road infrastructure or due to history of pest outbreaks or reported problems (Lund et al., 2010; Siddiqui et al., 2012). In some settings, partly because of limited budgets a concentrated mass of farmers were selectively assigned to FFS training for high visibility and performance achieved by administrative units (Witt et al., 2008).

In studies that suggest farmers acquire knowledge through FFS participation, evidence on the heterogeneity of effects is often lacking; we do not know which groups of participants—such as gender groups or farmers who have secondary employment—are more responsive to the participatory approaches of FFS. This is important and relevant to Chinese agriculture because of the emerging role of off-farm employment and other opportunities for rural labor. During the 1980s and 1990s, approximately 200 million people in the rural labor force found jobs off farm, with the annual increase amounting to more than six million farmers (NBS, 2010). Estimates of the rise in the share of the rural labor force employed in off-farm sectors range from 35 percent to 40 percent during that time. By the mid-2000s, of China's more than 500 million rural laborers, 265 million had off-farm employment (Zhang et al., 2008). China is meeting the "Lewis turning point" in the transformation of its labor force (Cai and Du, 2011; Knight et al., 2011). Since FFS is a participatory program whose benefits are fully realized only if farmers are involved in training throughout the season, off-farm employment could affect program effectiveness. Moreover, identifying the groups of farmers who are more responsive to FFS can support future program targeting and is crucial for China if it wants FFS be an effective tool for agricultural and ecosystem advisory services.

Earlier impact assessments of FFS on farmers' knowledge acquisition have focused on one or two pieces of technology employed in specific settings. For example, most impact studies have concentrated on measuring knowledge impact on pest management (Godtland et al., 2004; Lund et al., 2010; Yang et al., 2008) and soil nutrient management (Bunyatta et al., 2006; Siddiqui et al., 2012; Tripp et al., 2005). Some studies examined the impact of FFS on farmers' attitude towards agro-ecosystem (Moumeni-Helali and Ahmadpour, 2013; Witt et al., 2008) and awareness of health hazards that are related to inappropriate farm practices (Lund et al., 2010). However, yield-enhancing farm management includes sophisticated and integrated technologies, such as soil formation, nutrient management, pest management, and irrigation, which are complementary to each other. To be a sustainable and make agricultural production low-carbon, farmers should also understand the potential environmental pollution associated with inappropriate farm practices. Scientists and policy makers need to understand farmers' potentially heterogeneous response to different parts of an integrated package of sustainable farm management delivered by FFS. This will aid curricular prescriptions and revisions, which will help ensure future FSS effectively disseminate information.

To ensure food security and sustainable agricultural production, China's Ministry of Agriculture (MOA) has tried to improve its agricultural extension, including initiating a pilot FFS program between 2010 and 2012. China's public agricultural extension is a top-down system. This system played an important role in facilitating adoption of new technologies by farmers in the 1970s and 1980s (Huang et al., 2009). However, it also faced increasing difficulty in meeting farmers' demand for technology starting in the early 1990s when China moved to a more market oriented economy. In response to these challenges, several institutional and management reforms have been implemented since the late 1990s (Hu et al., 2012; Huang et al., 2009). One of these reforms has been aimed at providing better services to farmers and stimulating technology adoption by separating commercial activities from public extension services. This increased the incentives and responsibilities of the extension staff, shifted personnel management from the township level to the county level, and increased budgetary support (Huang and Rozelle, 2014). In addition to the above efforts, the pilot FFS program has been implemented in more than ten provinces since 2010.

Recognizing the advantages of a rigorous evaluation that an RCT allows, we were invited by MOA to evaluate an FFS pilot program in rice in Anhui province in 2011. This provides a unique opportunity to study the effects of China's FFS program. Working with the MOA, we randomly assigned villages to FFS treatment and control groups and, within treatment villages, randomly assigned individual farmers to participate to mitigate potential selection biases that have affected nearly all the FFS evaluations to date.

The objective of this study is to examine the effects of FFS on farmers' knowledge acquisition in China's rice production. Specifically, we aim to answer two questions. First, does FFS successfully affect Chinese farmers' knowledge acquisition and identify the type of farmer who is more responsive to the training?

Second, given the complexities involved in providing training on integrated low-carbon farm management that is still yield enhancing, which aspects of the training are most effectively delivered through FFS?

This paper focuses on immediate changes in farmers' knowledge acquisition after accessing to FFS training. It is not our objective to examine the impacts on behavior given the short term – the evaluation survey was made immediately after the FFS treatment. Multiple studies have shown that changes in farmers' behavior and technology transfer (such as diffusion) took place after farmers obtained updated knowledge (Godtland et al., 2004; Tripp et al., 2005). Educational researchers and practitioners are increasingly aware that for technical knowledge that involves complexity and uncertainty farmers' decision making is complicated and the cognitive formation is dynamic (Pontius et al., 2002; Verduin et al., 1977). As a method of adult learning, FFS seeks to foster human awareness and empowerment related to agricultural production and ecosystems. While many studies assess the impact of technology adoption, there is little knowledge on the internal mechanisms of acquisitive learning, especially the formation of knowledge for different components of the integrated technology package. Consequently, we focus here on intermediate knowledge outcomes, saving FFS impacts on agricultural practices for later work.

The rest of this paper is organized as follows. In Section 2, we introduce our research design and data collection methods. In Section 3, we examine farmer's knowledge score and other characteristics. We conduct a multivariate analysis in Section 3.2. We discuss the implications of our results and conclude in Section 4.

2. Methods and materials

2.1. Randomized controlled trial (RCT) evaluation design

Impact assessment of social programs is often subject to estimation bias due to selection effects, and an RCT potentially mitigates this bias, allowing for more accurate casual inference. When farmer opt-in to a treatment or selected based on observed characteristics, it is difficult to disentangle treatment effects from farmer characteristics. In the case of FFS, farmers that opt-in might systematically vary in their learning ability or farm practices, making comparisons with non-participating farmer problematic. The RCT approach ensure farmer participation is, on average, unrelated to farmer characteristics.

In this study, we applied a clustered randomized control trial (RCT) in two countries (Chaohu and Tianchang) where rice is the major agricultural product. Because the FFS program was delivered at the village level, we designed and implemented a clustered RCT, using detailed power calculations to determine on the number of villages and farmers per village. Power calculations were based on expected changes in fertilizer use by researchers in Hubei, and we believe the study had sufficient power for us to look at other outcomes, including farmer knowledge. The sample size for each control and treatment group was set using a standard alpha of 0.05 and 80 percent power to detect a 15 percent pre and post change.

Based on these power calculations we surveyed 56 treatment and control villages in Anhui with 15 farmers in each village, allowing us to detect the minimum desired effect of FFS. We increased this sample size to 18 to account for attrition. In addition, because we are also interested in studying diffusion effects of FFS training, we surveyed an additional 10 farmers in each village who were categorized as "exposed" farmers; that is, they were not issued an invitation letter to attend FFS training, but were surveyed at the baseline and post-treatment stage. Finally, in accordance with the Ministry's recommendation of a minimum of 25 participants in each FFS, we issued 7 additional invitation letters in each treatment village to reach this target; these 7 households were not surveyed.

Townships and villages were randomly selected based on the study design and FFS implementation plans. In Anhui, we chose four townships and randomly selected 14 villages from each township for a total of 56 villages. Each of the townships within county has at least three extension agents available to implement FFS in at least seven villages each. Because some administrative villages are rather large in land area (some as large as two square kilometers), we were informed by extension staff that recruiting farmers for the FFS would be challenging because many farmers are unwilling to travel long distances to attend weekly training sessions. Therefore, to increase the feasibility of implementing FFS within each village, we further divided each administrative village into all of its natural villages – known as production teams during the Mao era – and obtained data on the number of rice households in each. One natural village per administrative village was then randomly selected by the research team, provided that the number of households growing middle-season long-grained rice in that village met the MOA's minimum FFS requirement (viz. 25 FFS members) and that there were at least 10 additional rice farmers to serve as the exposed group.

Matching was conducted using village-level data. Each natural village leader was asked to complete a short survey on basic village-level information, based on which we conducted optimal nonbipartite matching. There is no consensus in the literature on the optimal number of variables upon which to match, implying that researchers should use substantive area knowledge, as well as matching metrics, to determine the optimal number of matching variables. The variables we used for matching are listed in Appendix A. We used optimal nonbipartite matching where each village was assigned to the match with whom it shared the shortest Mahalanobis distance. Because the number of villages within each township to be matched is odd, one additional "village" was used as a "sink" that was set to be matched as well to any other village. In the end, four unmatched villages (one left over from each township) were matched to one another.

While randomization by itself ensures that treatment and control samples are similar on average, both on observed and unobserved characteristics, in any particular allocation the samples can differ on certain dimensions, especially for smaller sample sizes. Pair-wise matching is one way to avoid imbalance. Bruhn and McKenzie (2009) argue that in smaller samples matching achieves greater balance than pure randomization. This approach helps ensure treatment and control groups have similar observable characteristic, while the randomization at the pairwise level means unobservables are also balanced on average.

To reduce inter-village transmission (treatment spillovers), we attempted to keep treated and control villages separated geographically. Spillover effects can be a concern because they would lead to control group contamination and biased (presumably downward) treatment effects, since farmers in non-treated villages experience some of the effects of receiving the treatment. To support this, in practice, during the matching process we assigned infinite Mahalanobis distance – a very large number – to adjacent villages to ensure they are not matched to each other as treatment and control pairs. Based on a matching algorithm using data at the village level, we selected 28 villages into the treatment group (farmers who received FFS training) and 28 into the control group (farmers who did not receive FFS training). Our aim was to have 15 farmers randomly selected from each treatment and control village. Moreover, in treatment villages, we randomly selected 10 farmers to be "exposed" farmers. There are farmers who reside in treated villages but are not assigned the FFS training, allowing us to assess desirable treatment spillovers. In total, this provides a target sample of 1120 farmers.

2.2. Program implementation and data collection

In 2011, before running FFS training sessions, we conducted a baseline survey of all farmers in our sample. In each treatment village, we randomly sent invitation letters to households, which explained the FFS approach and its features (e.g., participatory style, group formation, field experiment) and the farmers' responsibilities (i.e., whole-season participation and minimum dropout). The baseline survey included 1171 farmers: 519 FFS participants, 50 farmers that refused to participate, 170 exposed farmers in treated villages, and 432 farmers in control villages (Table 1).

The household survey covered basic household information and a set of detailed questions to test farmers' knowledge in rice production. For example, enumerators surveyed the age, education level, and employment of each household member. Respondents also provided information about their farm size and farm management in rice production. Unique to our study, each interviewee was administered a detailed knowledge test about their knowledge of rice production practices and methods. The knowledge test includes questions across four modules: nutrient management, pest management, cultivation (that includes land formation, irrigation, and other farm practices), and farmers' awareness of potential environment problems that are related to agricultural production.

Before the FFS was conducted, MOA carried out training for the facilitators. Because all the facilitators were recruited from township extension stations and they had no experience in using the FFS approach, MOA conducted a set of training of trainer (TOT) workshops during 2010–2011. The extension staffs worked have used top-down extension approaches for a long time in the public extension system, thus the TOT program first highlighted non-formal education (NFE) methods and the participatory nature of FFS. During the initial TOT workshop, the facilitators learned NFE methods with emphasis on what, when, and how to use NFE in FFS. The following TOT workshop covers the key elements of FFS – such as curriculum, ground work, regular FFS meetings, and participatory technology development (PTD) with emphasis on low-carbon farm practices. By combining lecture and field demonstration, together with knowledge sharing from experienced facilitators in existing FFS programs, the TOT workshops delivered by the MOA aimed to empower the extension workers in using the FFS approach, such as sharing, problem solving exercises, panel discussions, and brainstorming.

The FFS was implemented throughout the entire rice production season in the treated villages in 2012. Each FFS consisted of a group of farmers (roughly 20–25) and two facilitators. Unlike the FFS programs practiced in Indonesia, where farmers met about 10 times during the rice season, given the emerging off-farm employment in rural China, the Chinese FFS program allowed for a streamlined number of regular FFS meetings. On average, the facilitators conducted five to seven FFS meetings, including an inception and graduation meeting. Each of the training sessions was conducted shortly before significant stages in rice production. The facilitators communicated with farmers about the timing, location, and topics of discussions. Sustainable and low-carbon farm management technologies were integrated in each of the regular meetings, together with farmers' specified topics. Farmers usually worked in smaller subgroups and devoted considerable time to agro-ecosystem analysis, in which they were encouraged to make observations of important processes and relationships. The FFS facilitator (typically an extension agent) encouraged farmers to draw the results of the analysis on flip-chart paper and discuss them with the larger group. Each FFS had two "experimental plots," conventional and demonstrated practices, so that farmers could observe the results of their decisions.

The post-intervention survey was conducted after the FFS program. During November and December 2012, after rice was harvested, we returned to the research sites and conducted a follow-up survey on all study participants. For the FFS graduates in the treated villages, we first asked about their participation in the program (including the participating individuals, numbers of FFS meetings, key themes and activities during the training) and their view of the FFS approach. We repeated the knowledge test, asking the same questions as in the baseline survey.

Attrition was an important challenge we encountered during our research. Due to prevalent off-farm employment in the study area, about 16 percent of our sample was not successfully traced in the endline survey. The attrition rate is slightly higher in control villages partly because, in treated villages, additional efforts were made to resurvey the of FFS graduates (Table 1). For some households a different individual responded to the baseline and endline survey, and here we eliminate additional 170 households where this mismatch occurred. Our final data set includes 711 households.

3. Results and discussion

3.1. Farmers characteristics before and after FFS participation

Survey results confirm that our RCT design was carried out effectively; there is no significant differences in village characteristics between treated and control villages. As shown in Table 2, treated villages were balanced with control villages in farm size,

Table 1
Household samples by design and by implementation in the farmer field school (FFS) program in 2011–2012.

	Total	Treated villages			Control villages
		FFS	Refused	Exposed	
Sample by design	1171	519	50	170	432
Attrition rate (%)	16	12	18	22	19
Sample by implementation	981	456	41	133	351
Sample with the same respondent	711	337	35	91	248

Notes: "FFS" denotes that farmers in treated villages received a randomly assigned invitation and accepted the invitation to be a FFS graduate.
"Refused" denotes that farmers in treated villages received a randomly assigned invitation but decided to refuse the invitation to be FFS graduates. Note that we did a baseline survey of those who refused to participate as well.
"Expose" denotes that farmers in treated villages were not assigned the invitation of FFS program but being surveyed during the baseline and endline survey.
"Control villages" denotes farmers in the control villages where the FFS program was not placed.
"Sample by implementation" denotes actual compliance in treated villages and control villages. In treated villages, some farmers who agreed to join FFS training at the baseline survey were not available and thus missed the FFS training. To ensure the minimum members of FFS, additional farmers were recruited from 'exposed' farmers who were not invited. This caused inconsistency between research design and implementation.
"Sample with same respondent," refers to cases where the same respondent appeared in both baseline and endline surveys. Different individuals of a family may attended baseline and endline surveys, and this will cause inconsistency in knowledge test. In the remaining analysis, we use sample of this type unless indicated otherwise.

Table 2
Characteristics of villages and households in treated and control villages in baseline year (2011).

	Total	Treated villages			Control villages
	($N=711$)	FFS ($N=337$)	Refused ($N=35$)	Exposed ($N=91$)	($N=248$)
Household and individual characteristics					
Percentage of female respondent (%)	42	41	37	52[a]	39
Age of respondent (year)	55	55	52	55	54
Durable consumption asset per capita (1000 yuan/person)	36	39	33	35	34

	Total ($N=54$)	Treated villages ($N=28$)	Control villages ($N=26$)
Village characteristics			
Cultivating area per household (ha/household)	0.36	0.35	0.37
Distance to township (km)	5.8	6.4	5.2
Number of extension demonstration farmers	5	5	5
Percentage of labor with off-farm job	0.7	0.7	0.7

Note: Household samples were selected in 56 villages, 8 township, and 2 countries in Province of Anhui, China. *t*-test was conducted be referring to the column in the control village.
[a] Significance at 5%.

road infrastructure, access to public extension system, and other social and economic indicators. Basic household characteristics (such as percentage of female respondents and the age of interviewees) also were not different between FFS participants and non-FFS households in control villages. The random assignment of the FFS program provides a strong basis for a rigorous impact assessment.

Farmers' knowledge of sustainable rice production was limited in the study area, and there was no significant difference between FFS graduates and farmers in control villages before the intervention. The results of the knowledge test show that farmers in the study area had very low knowledge in sustainable farm management in rice production. Out of a possible 100 points, the average score was only 36 in the baseline year. Importantly, there was no significant differences between farmers in the treatment and control villages.

Farmers' knowledge varied across different technologies of sustainable rice production in China. Farmers exhibited the highest knowledge in cultivation, including land formation and irrigation (Table 3). This kind of knowledge is obtained primarily through years of experience. In contrast, farmers knew less about nutrient and pest management – partly because these practices are more site specific and dependent on more formal learning. Finally, farmers' knowledge and awareness of potential environmental impacts related to agricultural production is extremely low, averaging 18 points in both treated and control villages. We believe this level of knowledge is insufficient to support sustainable agricultural production in the study area.

The FFS seems to be effective at increasing farmer knowledge acquisition, but the effectiveness varies for different technologies. As shown in Table 4, the increase in average knowledge is significantly higher for FFS graduates than for farmers in control villages (6 points versus 4 points). Nevertheless, when we break down aggregate knowledge gains across different technologies, we see heterogeneity effects. Farmers showed larger improvements in pest management and environment than for other practices (such as nutrient management and cultivation). Although the knowledge gain was only 4 points for environment, when considering the low knowledge score in the baseline year (18 points, Table 3), the increase of knowledge in agro-environment was dramatic – equivalent to 22 percent on average. In the next section we explore the program evaluation results on knowledge in greater detail.

The score and changes for the refused and exposed group are slightly different from the FFS members. The exposed group does not exhibit significant changes relative to the control group, which suggests there are no diffusion effects in knowledge attainment. Being exposed to farmers who have undergone FFS does not seem to increase knowledge; rather one has to fully participate in the FFS. Given the intense, participatory, and long-term nature of FFS, perhaps this is not surprising.

The baseline scores for the refused groups are somewhat lower (in a statistically significant way) before the FFS program than for the control group; small deviations in balance along a few dimensions are not uncommon in RCTs, although for the farmers that refused to participate in the FFS the difference is scores may

Table 3
Farmer's knowledge score on sustainable farm management in rice production in baseline year (2011).

	Average score (full mark = 100)	Knowledge score by different technology (full mark = 100)			
		Nutrient management	Pest management	Cultivation	Agro-environment
Total	36	38	34	53	18
Treated villages					
FFS	36	39	34	54	20
Refused	30***	32*	30**	47**	13*
Exposed	33**	36	31***	51	15*
Control villages	36	38	35	54	18

Note: *t*-test is conducted by referring to farmers in control villages (last row) in each column. The household samples are the same as those presented in Table 2.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
Difference of knowledge score before and after FFS program in both treated and control villages.

	Average knowledge change (full score = 100)	Knowledge score changes by technology (full score = 100)			
		Nutrient management	Pest management	Cultivation	Agro-environment
FFS	6^{***}	7	9^{***}	3	6^{*}
Exposed	3	4	4	2	3
Control villages	4	6	4	2	2

Note: *t*-test is conducted by referring to farmers in control villages (last row) in each column.
$^{*}p < 0.10$.
$^{***}p < 0.01$.

also suggest that this group differs from the treated and control groups. We did not conduct the knowledge test in the endline survey for the refused group and will therefore not be studying the effect of FFS on knowledge scores for this group. Since the exposed group starts with a lower score, instead of comparing the absolute scores after the intervention, we compare changes in scores.

3.2. Impacts of farmer field school on farmers' knowledge acquisition: multivariate analysis

In this section, we specify a multivariate model that allows us estimate the impacts of training in greater detail, in particular the heterogeneous effects of FFS among various population groups. The regression-based approach allows us to parsimoniously report treatment effects, including those for the exposed group of farmers.

To estimate the impacts of FFS training on a farmer's knowledge acquisition regarding sustainable and low-carbon farm management in rice production, the basic empirical model is specified as:

$$\mathrm{Delta}Y_{ik} = a_0 + a\cdot\mathrm{FFS}_i + b\cdot\mathrm{Expose}_i + \varepsilon_{it} \tag{1}$$

where dependent DeltaY_i measures the change in knowledge before and after the FFS training for each farmer *i* and each (of five) knowledge measure *k* ($k = 0$ for average score across all four dimensions; $k = 1$ for nutrient management, $k = 2$ for pest management; $k = 3$ for cultivation; and $k = 4$ for agro-environment).

The key independent variable of interest on the right-hand side of Eq. (1), FFS$_i$ refers to FFS graduates in treated villages during the program. This is an indicator variable that equals one if a household was assigned FFS training and attended the seasonal training in the treated villages, otherwise it equals 0. Likewise, Expose$_i$ is an indicator variable that equals one if a farmer was in a treated village but was not assigned the FFS program (i.e., part of the exposed group). The reference group is farmers in the control villages; the coefficients, *a* and *b*, thus measure change in knowledge for treatment and exposed groups, respectively, when compared with farmers in the control villages.

We also look at heterogeneous treatment effects, since the FFS program may have affected sub-groups of farmers in different ways. To examine these effects, we specify an extension of Model (1) by interacting the treatment variable, FFS$_i$, with several demographic characteristics of FFS participants:

$$\mathrm{Delta}Y_{ik} = a_0 + a\cdot\mathrm{FSS}_i + a_1\cdot\mathrm{FSS}_i \times \mathrm{Female}_i + a_2\cdot\mathrm{FSS}_i \times \mathrm{Age4060}_i + a_3\cdot\mathrm{FSS}_i \times \mathrm{Age60}_i + b\cdot\mathrm{Expose}_i + \varepsilon_{it} \tag{2}$$

where Female$_i$ is an indicator variable that denotes a female FFS participant. Other variables Age4060$_i$ and Age60$_i$ are two indicator variables to identify FFS participants being in age 40–60 (Age4060$_i$) and those over 60 (Age60$_i$). We set the reference as the young group (younger than 40).

The specification of Model (2) allows us to examine heterogeneous treatment effects of the FFS program on farmers' knowledge acquisition. For example, the coefficient a_1, when controlling other factors, measures the differential effect of the FFS on farmers' knowledge acquisition for female participants. Likewise, a_2 and a_3 capture the effects of FFS on farmers' knowledge acquisition for participants in older age groups relative to that for young FFS participants.

We estimate Eqs. (1) and (2) through a difference-in-different model. The results are presented in Table 5 and 6. The results indicate that the impact of FFS on farmer knowledge acquisition in rice production is consistent with our expectations based on the descriptive statistics in Section 3.

The results show that FFS improved farmer knowledge of sustainable and low carbon farm management in rice production. The coefficient is positive and statistically significant for FFS

Table 5
Estimated results of impacts of FFS program on farmers' knowledge scores by OLS regression.
Source: Authors' survey.

	Average knowledge score changes	Knowledge score changes by technology			
	(1)	Nutrient management (2)	Pest management (3)	Cultivation (4)	Agro-environment (5)
FFS graduates (Yes = 1; No = 0)	2.73[c] (2.94)	1.37 (0.63)	4.80[c] (4.90)	1.12 (0.73)	3.61[a] (1.94)
Exposed farmers (Yes = 1; No = 0)	−0.37 (−0.27)	−1.65 (−0.52)	0.049 (0.03)	−0.31 (−0.14)	0.43 (0.16)
Constant	3.68[c] (5.22)	6.05[c] (3.69)	3.99[c] (5.36)	2.37[b] (2.04)	2.32 (1.64)
R^2	0.02	0.00	0.04	0.00	0.01

Notes: 1) The sample of estimation is 676 and we remove the rejecting samples. 2) The figures are marginal effects. 3) The figures in parentheses are absolute *t* ratios of estimates.
[a] Statistical significance at the 10% level.
[b] Statistical significance at the 5% level.
[c] Statistical significance at the 1% level.

Table 6
Estimated results of impacts of FFS on farmers' knowledge scores.
Source: Authors' survey.

	Average knowledge score changes	Knowledge score changes by technology			
		Nutrient management	Pest management	Cultivation	Agro-environment
	(1)	(2)	(3)	(4)	(5)
1. FFS graduates (Yes = 1; No = 0)	9.05[c] (3.30)	9.93 (1.55)	12.11[c] (4.18)	3.00 (0.66)	11.14[b] (2.02)
2. Interaction of FFS and female participant	−2.33[a] (−1.85)	−7.25[b] (−2.47)	−1.41 (−1.06)	4.00[a] (1.92)	−4.64[a] (−1.84)
3. Interaction of FFS and participants age (40–60)	−4.62[a] (−1.74)	−4.28 (−0.69)	−6.95[b] (−2.47)	−4.37 (−0.99)	−2.90 (−0.54)
4. Interaction of FFS and participants age (>60)	−7.26[c] (−2.64)	−8.33 (−1.30)	−7.42[b] (−2.55)	−2.82 (-0.62)	−10.47[a] (−1.89)
5. Exposed farmers (Yes = 1; No = 0)	−0.37 (−0.27)	−1.65 (−0.52)	0.05 (0.03)	−0.31 (−0.14)	0.43 (0.16)
6. Constant	3.68[c] (5.25)	6.05[c] (3.70)	3.98[c] (5.38)	2.37[b] (2.04)	2.32[a] (1.65)
R^2	0.03	0.01	0.05	0.01	0.02

Notes: 1) The sample is 676. 2) The estimated coefficients are marginal effects. 3) The figures in parentheses are absolute *t* ratios of estimated coefficients.
[a] Statistical significance at the 10% levels.
[b] Statistical significance at the 5% levels.
[c] Statistical significance at 1% level.

(2.73, Table 5), showing that ceteris paribus the FFS program led to a knowledge score increase of 2.73 points or 7.6 percent compared with the farmers in control group.

The coefficient on the exposed variable captures knowledge changes by farmers in treatment villages who did not participate in the FFS. As seen in row 2 in Table 5, we find no spillover effects of the FFS on exposed farmers. All of the coefficients are near zero and not significant.

The knowledge gains from FFS varied across the components of the integrated technology package. For example, the FFS coefficient for knowledge of nutrient management and cultivation (column 2 and 4, Table 5) are not statistically significant, while knowledge of pest management (4.8, column 3) and agro-environment (3.61, column 5) are both significant and larger than the average knowledge gain effect.

Turning to the heterogeneous treatment effects for gender and age, we see strong evidence that the FFS was more successful for certain subgroups. As shown in Table 6, the knowledge gains for female farmers (row 2, column 1, Table 6) were 2.33 points lower (significant at the 10 percent level) than for male participants, who saw a knowledge score increase of 9.12 points. In addition, the effectiveness of FFS on knowledge acquisition was lower reduced for older participants. For example, in comparison to young participants, the effects of FFS on knowledge score were 4.5 points (row 3, column 1) lower for individuals aged 40–60, and 7.34 points lower for farmers older than 60 (row 4, column 1).

In general female and older participants showed weaker knowledge gains across the different technologies, although the differences are not all statistically significant. In general female and older participants showed weaker knowledge gains across the different technologies, although the differences are not all statistically significant. Female FFS graduates showed relatively lower performance in knowledge gains for nutrient management and agro-environment (columns 2 and 5). We do not see the same results for pest management and cultivation, and for cultivation female farmers showed stronger gains than the reference group, although the coefficient is only weakly significant. Older farmer show weaker knowledge gain in the areas of pest management and agro-environment relative to the comparison group (columns 3 and 5).

4. Conclusions

In this paper we analyze the results of a large-scale randomized control trial designed to improve farm practices in China. We focus specifically on measured knowledge gains for rice farmers in Anhui province, and we find that the treated farmers show measurable improvements in knowledge based on a multi-component knowledge test. However, the results are not consistent across knowledge categories, and our results suggest that the FFS program worked better for some population subgroups, particularly young male farmers. We also find no evidence of knowledge spillovers to farmers in treated villages who did not participate in the FFS.

More than 93% of invited farmers were willing to participate in the FFS program, showing emerging demand for knowledge and information of farming. However, the low score of farmers who refused to participate is concerning and worth further investigation in future work. Given the emerging importance of off-farm employment, while the treatment had some positive impacts, we are less confident that the results unambiguously recommend broad-based use or scale up of the FFS program. Our evidence of heterogeneous treatment effects has important implications for future FFS rollout in China. The FFS program we studied was significantly less effective at improving knowledge for female and older aged farmers, although as with the average treatment effects these results varied by knowledge component. This suggests that if China wants to achieve broad-based knowledge gains among farmers, the FFS—as currently designed—may not be the best tool. Further analysis could help to identify whether the curriculum or FFS approach could be adjusted to lead to better performance across all knowledge categories and for key population groups.

We acknowledge the important question of whether suggestive changes in knowledge can be the channel to better agricultural practices. Perceptual theory of psychology suggests that human behavior is a broad and complex process in which each individual possesses a unique and different "package" of knowledge, experience, values and goals (Verduin et al., 1977). We plan to deal with these important issues in future work.

The pedagogical practices of FFS, such as the application of problem-solving strategies, the promotion of reflection and group dialogue, engagement of active pedagogy rooted in the cultural practices and importance of fostering initiative among participants through learner-centered teaching, are based on concepts of transformative and non-formal learning (Taylor et al., 2012). Such an approach is sophisticated and embedded with social and economic context at the local level. The heterogeneity of impacts for participants of different gender and age should be a concern for designing future programs.

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Appendix A. Matching variables used for RCT

Irrigable area
Area of cultivated land
Area of polder area for rice
Average annual income
Number of households growing middle-season long-grained rice
Number of agro-chemical shops
Number of people growing middle-season long-grained rice
Number of rice farmers
Percentage of male rice farmers
Percentage of female rice farmers
Percentage of people working outside the township
Total labor force
Number of demonstration households
Whether this village is a demonstration village*
Distance to township government*
Whether the village participated in the national Soil Fertilizer project*
Whether village is a demonstration base or part of a demonstration group*

*Variable is at the administrative village level.

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