**Assessing the Impact of Farmer Field Schools on Fertilizer Use in China: Evidence from a Two-Province Randomized Experiment**

Nicholas Burger, Mary Fu, Kun Gu, Xiangping Jia, Krishna B. Kumar, Guo Mingliang[[1]](#footnote-1)\*

November 2015

Research discussed in this publication has been funded by the International Initiative for Impact Evaluation, Inc. (3ie) through the Global Development Network (GDN), award OW3 1216. The views expressed in this article are not necessarily those of 3ie or its members.

# Abstract

In China, a major agricultural challenge is the inefficient use of fertilizer and the environmental effects associated with its overuse. The Chinese Ministry of Agriculture (MoA) is addressing this problem by instituting farmer field schools (FFS), but the China’s FFS program has not been rigorously evaluated. We conduct a randomized control trial (RCT) to evaluate the initial rollout of the program in multiple counties across two provinces, Anhui and Hebei, where we focus on rice growers and tomato growers, respectively. Using a matched pairs approach drawing on village level data, we randomly selected 56 villages in Anhui province, assigning 28 villages into the treatment group (to received FFS training) and 28 into the control group. In Hebei province, we selected 36 villages and assigned 18 village to the two treatment and control groups. In each village we randomly surveyed 15 farmers, and in treatment villages, 10 farmers were randomly selected to be “exposed” farmers to study spillover effects. We collected pre- and post-intervention data on a range of relevant outcomes.

We find mixed evidence of program effectiveness across outcomes and crops. Since fertilizer usage is highly heterogeneous among farmers, a direct comparison of averages between the treatment and control groups masks one of the main expected contributions of the FFS, which is to educate the farmers about optimal fertilizer usage. Indeed, for rice, we find that farmers in the lower quintile increase their fertilizer usage, while those in the upper quintile reduce fertilizer use, and this effect is more pronounced for the treatment group. Participation in the FFS reduces the distance from the agronomists-determined optimal Nitrogen fertilizer usage. We find FFS participation increases potassium fertilizer usage, which is desirable from an agronomic perspective, and find also increased knowledge of farming practices. Using data on program implementation costs and treatment effects we argue that the Ministry of Agriculture should use caution when considering whether to scale up the FFS program in China.

# 1. Introduction

Chemical fertilizers play an important role in agriculture in China. China’s farmers use more fertilizer per hectare (more than 200 kg/ha) than farmers anywhere else in the world except for Japan, The Netherlands, and South Korea. Existing studies have shown that overuse of Nitrogen (N) fertilizer ranged from 30% to 50% in grain production (Huang et al., 2008). This excessive use has resulted in serious food safety and environmental problems, such as large N losses through NH3 volatilization and nitrogen leaching into ground water, rivers, and lakes (Xing & Zhu, 2000; Zhu & Chen, 2002). Because 70% of agricultural greenhouse gas (GHG) emissions originate from N fertilizers, improved N management is critical to increasing income of farmers, maintaining agricultural sustainability, as well as addressing climate change.

Insufficient farmer knowledge and information about the effects of excess fertilizer appear to be one reason for excessively high rates of nitrogen fertilizer application in China (Huang, et al., 2008). However, given the large heterogeneity in fertilizer usage, it is unclear whether all farmers are using fertilizer in excess or whether the problem is one of farmers not applying fertilizers optimally. Moreover, lack of accountability has made China’s current public agricultural extension system ineffective at delivering fertilizer training and knowledge to individual farmers (Hu et al., 2009). The Chinese Ministry of Agriculture (MoA) is addressing this problem by instituting farmer field schools (FFS), hoping to avoid the pitfalls of the traditional system by using local farmer-trainers to improve accountability and effectiveness through a participatory approach to agricultural extension. However, a rigorous evaluation of China’s FFS has not been conducted to date, and this is the gap we seek to fill. Besides assessing the effectiveness of FFS, our study might be able to shed light on issues surrounding the scaling up of FFS in a cost-effective way in China, should they be found effective.

While the intervention is based in China, the findings of our study will have implications beyond China. Recent reports suggested that overuse of fertilizers is a problem in India as well.[[2]](#footnote-2) Since China and India are the two most populous countries with large shares of agricultural labor force, any study that sheds light on improving farming decisions in these countries would have far-reaching implications.

The overall goal of this project is to evaluate the impact of fertilizer-related training provided by FFS to Chinese farmers. The following questions are of particular interest:

* Do FFS graduates apply N fertilizers and other agro-chemical inputs more optimally?
* Does the FFS program lead to improved perceptions of environmental problems related to excessive fertilizer usage?
* Is there any knowledge diffusion from trained farmers to other farmers?
* What are the socioeconomic impacts, e.g. impacts on farmers’ incomes, farm management capability, and farmers’ perception of and behavior toward local institutions, such as FFS?
* How cost-effective are FFS?
* How do the above impacts differ between greenhouse and grain farmers? Should China use FFS as one of the primary extension tools for its agricultural extension system?
* Should FFS be included in China’s national policy for climate change?

We address many of these questions in this report. We have collected rich data through our baseline and endline surveys[[3]](#footnote-3), which can allow us and other researchers to pursue remaining questions in detail.

The intervention was implemented and an impact assessment conducted in Anhui and Hebei provinces for rice and tomatoes, respectively (see Figure 1.1). Tomatoes are a greenhouse vegetable (GHV) and have significantly different fertilizer needs. By choosing two very different crops in two very different provinces, we hope to achieve some degree of generality in our conclusions about the effectiveness of FFS. Counties that were among the largest producers of rice and tomatoes were chosen. In Anhui the counties chosen were Tian Chang and Ju Cao, and in Hebei, we focused on Gao Cheng, Yong Qing, and Rao Yang. Farmers can adopt a short or a long growing season for tomatoes.

**Figure 1: Provinces in China Where FFS Implemented and Evaluated – Anhui and Hebei**



Source: Wikimedia Commons

Since the FFS program was delivered at the village level, we designed and implemented a clustered randomized control trial (RCT). We did detailed power calculations for each crop separately to decide on the number of villages and farmers per village. In Anhui (rice), we chose four townships and randomly selected 14 villages from each township for a total of 56 villages. Based on a matching algorithm that we ran based on data we collected at the village level, we selected 28 villages into the treatment group (received FFS training) and 28 into the control group (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 to study diffusion effects. This is a total of 1,120 farmers, as dictated by our power calculations. In practice, we chose more farmers to account for an estimated 15% attrition and non-compliance. In Hebei, we were constrained by the number of villages from the three selected counties, and therefore we chose 36 villages and again followed a matching algorithm to assign treatment and control villages. We chose farmers within these villages, as in Anhui, for a total of 720 farmers. Further details on the design and the farmer recruitment process are presented in an annex.

Overall we find that a simple comparison of means does not show a difference in fertilizer use between treatment and control villages. Fertilizer usage is highly heterogeneous, and a simple comparison of means masks the differential response to FFS at either end of the distribution. We find that farmers in the lower quintile increase their fertilizer usage and those in the upper quintile reduce it, and this effect is more pronounced for the treatment group.[[4]](#footnote-4) Perhaps most significantly, participation in the FFS reduces the distance from the agronomists-determined optimum N fertilizer usage, particularly for rice growers. Other results show that FFS increase potassium fertilizer (K fertilizer) usage, as desired from an agronomic perspective, and also increased knowledge of farming practices as captured by scores on a knowledge test (for rice farmers).

The rest of this report is organized as follows. In Section 2, we present the context of fertilizer usage in Chinese agriculture and the need for the FFS intervention. In Section 3, we describe the intervention itself, focusing in particular on the FFS curriculum, and present our theory of change. In Section 4 we discuss program implementation, especially some of the issues that arose during the course of implementation, and in Section 5, which constitutes the bulk of this report, present the results from our impact evaluation. We discuss diffusion effects in Section 6 and cost-effectiveness in Section 7. We discuss policy implications and recommendations in Section 8. Details such as experimental design, and power calculation, are presented in the annex.

# 2. Fertilizer use in China

Previous studies have shown that the overuse of N fertilizer in China ranged from 30 percent to 50 percent in grain and vegetable production, which has resulted in serious food safety and environmental problems. While there are a number of hypotheses for fertilizer overuse in China, “insufficient knowledge and information” is found to be the primary explanation. Huang et al. (2008) found that when farmers receive training and in-the-field guidance, they were able to reduce N fertilizer use by as much as 35 percent in rice production without lowering yield. Huang et al. (2010) also find that maize farmers reduce N fertilizer by 20 percent with just two hours of training.

As in many countries, public extension services in China are the most common method of providing widespread information and training to farmers. Nevertheless, as in any public bureaucracy, because extension personnel in China are politically accountable to a large number of public servants and private commercial activities, the quality of their extension work has become a secondary priority (Hu, et al., 2009). Chinese farmers are therefore unable to get the necessary institutionalized knowledge from the current public extension system, and China faces serious challenges in delivering technologies and practices to individual smallholder farmers.

It is in this context, as an alternative to the traditional agricultural extension, the FFS has been promoted and expanded to many developing countries (Van den Berg & Jiggins, 2007). By delivering training to a group of farmers through a participatory mode, the FFS aims to rectify the problem of accountability. The FFS is expected to ensure the quality and relevance of extension service provided to individual farmers.

Reforming the agricultural extension is a major program in China’s recent agricultural agenda. After three years of pilot FFS projects that disseminated technology to greenhouse vegetable farmers in Beijing, the Ministry of Agriculture (MoA) has proposed the FFS as a major tool for China’s agricultural extension service. Improving the efficiency of fertilizer use and pest management are major components of the FFS program.

The MoA will use results on the effectiveness of FFS on reducing excess fertilizer use (and the associated environmental and social-economic impacts) to guide scaling up its national FFS program in the coming years. Since a rigorous evaluation of the FFS has not been conducted in China, we seek to fill this gap by using an RCT to evaluate the impact of the FFS implemented by the MoA. Our findings will be useful to MoA in determining whether and how to scale up the FFS program in China. The results will also have implications in other countries, such as India, which face similar problems with high fertilizer usage by farmers.

# 3. The Farmer Field School Intervention

FFS training at the village level includes hands-on, farmer-managed learning on experimental plots, along with informal training prior to a single crop-growing season. Through group interaction, the goal of the FFS is to empower FFS graduates with skills in crop management, learning capabilities, and communication[[5]](#footnote-5). Working with the MoA, we selected one extension agent for every one or two villages. These extension agents were trained before the intervention on the unified course content. Throughout the entire crop season, they disseminated low carbon farming practices to the villager farmers who are in the treatment group through lecture, field experiment, as well as interactive communication.

To provide effective training that is targeted at local needs and conditions, the FFS curriculum was designed based on soil tests and fieldwork conducted by agricultural experts before the intervention and experiment began. In Anhui province, one of the main training goals for fertilizer was to adjust the total amount of N fertilizer application to 165-180 kg/ha, which is considered optimal by agronomists for “normal” weather. In other words, the aim for those farmers who apply fertilizer excessively was to reduce usage to 165-180 kg/ha, while for those who use less than the optimum, the aim was to increase their fertilizer use to improve yields.[[6]](#footnote-6) In addition, the FFS sought to increase K fertilizer use in this province to avoid “lodging” disease (described in detail in Section 5). In Hebei Province, guidance for tomato growers included recommendations for organic fertilizer use (typically cow manure) and chemical (manufactured) fertilizer. Chemical and organic fertilizers have different effects on soil quality, environmental impacts, and costs. We discuss differential application rates by farmers in Section 5, but we leave more detailed analysis of the specific impacts of each kind of fertilizer for future work.

### Beneficiary Populations

The intended beneficiaries of the FFS intervention and evaluation are:

* **Farmers,** who were taught improved farming practices
* **Extension agents**, who were trained initially on the FFS curriculum to become effective change agents
* **Chinese agricultural policymakers** at the local and MoA levels, who can use the results from the evaluation to decide whether and how to scale up the FFS program
* **The Chinese public**, who would benefit from a sustainable and environmentally friendly way of using fertilizers
* **Farmers and policy makers in other countries**,who could use the results from the evaluation to design similar programs to target excessive fertilizer use and other agriculture-related challenges

# 4. Experimental design and sample

The baseline survey for rice included 1339 farmers by design, while for tomato-growing counties we planned for 929 farmers. These sample sizes were larger than those dictated by our power calculations by 15% to allow for attrition and non-compliance. In each treatment village, we survey 18 farmers who accepted the invitation letters, two farmers who rejected the invitation letters, and 10 farmers who were not assigned the invitation letters and served as the exposed group.

Our baseline survey was done in two stages, the first to collect demographic and other information (Survey A), and the second to collect fertilizer usage (Survey B, in Figure 4.1). We denote our endline survey as Survey C. Tables 4.1 and 4.2 present details on attrition from our sample for rice and tomatoes, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4.1. Missing Sample in Survey Anhui (Rice), 2011-2012** | | | | | |
|  | **Total** | Sample by design (%) | | | |
| **T** | **R** | **E** | **C** |
| **(N=1,339)** | **(N=513)** | **(N=42)** | **(N=279)** | **(N=505)** |
| **Missing in Baseline survey B** | 168 | 61 | 7 | 27 | 73 |
| **Attrition rate (%)** | 13 | 12 | 17 | 10 | 14 |
| **Additional missing in Endline survey** | 148 | 47 | 5 | 23 | 73 |
| **Addl. attrition rate (%)** | 11 | 9 | 12 | 8 | 5 |
| **T**: Treatment (accepted invitation to participate in FFS in the treatment villages)  **R**: Refused (did not accept invitation in the treatment villages)  **E**: Exposed (not randomly assigned invitation letter in the treatment villages)  **C**: Control (farmers in the control villages) | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4.2. Missing Sample in Survey Hebei (Tomatoes), 2011-2013** | | | | | | |
|  | **Total** | **Sample by design (%)** | | | |
| **T** | **R** | **E** | **C** |
| **(N=766)** | **(N=325)** | **(N=1)** | **(N=117)** | **(N=323)** |
| **Missing in Baseline survey B** | 79 | 29 | 0 | 14 | 36 |
| **Attrition rate (%)** | 10 | 9 | 0 | 12 | 11 |
| **Additional missing in Endline survey** | 197 | 76 | 1 | 39 | 81 |
| **Addl. attrition rate (%)** | 26 | 23 | 100 | 33 | 25 |
| **T**: Treatment (accepted invitation to participate in FFS in the treatment villages)  **R**: Refused (did not accept invitation in the treatment villages)  **E**: Exposed (not randomly assigned invitation letter in the treatment villages)  **C**: Control (farmers in the control villages) | | | | | |

Since our experimental design (see annex) involved issuing an invitation to participate in the FFS and a farmer could accept of refuse, we distinguish between the group **T**, which accepts the invitation, and **R**, who refused. The “exposed” group, which will be used to study diffusion effects, is selected in treatment villages from non-invited farmers and is denoted by **E**. The farmers selected in the control villages are denoted by **C**.

As seen in row 2 of Table 4.1, in the time between the two components of the baseline survey (A and B), 13% of rice farmers attrited. This attrition rate does not differ significantly across the groups T, E, and C. Between the baseline survey B and the endline survey in 2012, we lost an additional 11% of the sample to attrition. The main explanation for this non-trivial attrition based on field inquiries, appears to be the extensive amount of off-farm activities (non-agricultural jobs) in which farmers participate.

In Table 4.2, 10% of tomato farmers dropped out between survey A and B, and the attrition rate does not vary significantly across the group T, E, and C. However, between baseline survey B and endline survey C, an additional 26% of the sample was lost to attrition. Based on field inquiries, the high attrition rate has three main causes. First, tomato farmers have very busy schedules, even more so than rice farmers, and especially during the growing season, so it is hard for them to guarantee attendance of the FFS. Second, the continuity of tomato farming is not as good as rice. Many surveyed plots were diverted to other plants based on the projection of farmers’ market demand. Third, greenhouse tomato is a cash crop, which returns a relatively high profit. The average net income of greenhouse tomato farmers can reach above 100,000 RMB per year. The affordability of agricultural inputs such as fertilizer, pesticide, and technical tools that comes with such high incomes draws many agricultural dealers and extension staff to hold trainings. Hence, for farmers, FFS is not the only source of agricultural information; indeed some of the training, especially by agricultural dealers, could even run counter to the teachings of the FFS.

What are the implications of such attrition? The attrition between Baseline surveys A and B caused data on fertilizer usage to be incomplete. Therefore, we are unable to conduct analysis on whether fertilizer usage is systematically related to subsequent attrition or non-compliance among those who were missing in Baseline B. The remaining analysis is based on the sample of 1,171 (1339 planned – 168 attrition) rice farmers for whom Baseline B data exists. In addition, in future analysis we will analyze attritors in greater detail. Since we still have Baseline A information even for those missing in Baseline B, we compare demographic information (such as land size, off-farm employment, household characteristics, etc.) of those present in Baseline B and those missing to see if there are systematic differences.

**Table 4.3. Sample by Design and by Implementation in Anhui (Rice), 2011-2012**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample by design** | **N** | **Sample by implementation** | | | | |
| **T** | **R** | **E** | **C** | **Missing in Endline survey** |
| **1,171** | **472** | **51** | **142** | **359** | **147** |
| **T** | 452 | 356 (79%) | 16 (4%) | 33 (7%) | 0 (0%) | 47  (10%) |
| **R** | 35 | 12 (34%) | 18 (51%) | 0 (0%) | 0 (0%) | 5 (14%) |
| **E** | 252 | 104 (41%) | 17 (7%) | 109 (43%) | 0 (0%) | 22 (9%) |
| **C** | 432 | 0 (0%) | 0  (0%) | 0 (0%) | 359 (83%) | 73 (17%) |
| **T**: Treatment (accepted invitation to participate in FFS in the treatment villages)  **R**: Refused (did not accept invitation in the treatment villages)  **E**: Exposed (not randomly assigned invitation letter in the treatment villages)  **C**: Control (farmers in the control villages) | | | | | | | | |

Note: The percentages refer to the breakdown of the design groups according to how they ended up in the implementation; that is, the column percentages should add up to 100% for each row.

Table 4.2 shows a “transition matrix” of how the four rice sample groups were intended to be and how they ended; in other words, how the intended (by design) sample breakdown differed from the eventual sample breakdown (by implementation). As mentioned above, for rice farmers, we focus only on the sample of 1,171, who were not missing in the Baseline B survey. If the experiment had proceeded exactly according to design, the off-diagonal elements in the above matrix would have been zero. In the rest of this document, we concatenate the subgroup by design and subgroup by implementation to refer to the transition of a group from design to implementation. For example, R-T, refers to one type of noncomplying group: refused to be part of the treatment group when invited, but eventually became part of that group.

The Chinese Ministry of Agriculture program guidelines dictates that each FFS must have an enrolment of at least twenty farmers. In the initial experimental design seventy-nine percent of group T participants were compliers. As such, some FFS did not have sufficient enrollment to meet program guidelines. To comply with the Ministry of Agriculture guidelines, we recruited additional participants randomly by sending a second round of invitation letters to farmers in group R (composed of farmers who refused to participate in FFS when the first-round invitations were sent) and group E (composed of farmers who did not receive an invitation to participate in FFS in the first round). Individuals who accepted the second round invitations from group R and group E are denoted “R-T” and “E-T”, respectively. Twenty-eight percent of group R individuals and thirty-seven percent of group E individuals agreed to participate in FFS after the second round invitations were sent.

Farmers who converted themselves from group T to group R or group E are denoted T-R or T-E. In the implementation, four percent of group T farmers, those who accepted the early invitations, somehow refused to attend FFS when extension staff reached out to them. Seven percent of group T farmers could not be reached by extension staff, but they were surveyed and categorized in group E. Because the T-E farmers received and accepted early invitation while farmers in initial group E didn’t, the T-E farmers could be a potential source of bias in measuring program impact.

The attrition rate varies by group. The attrition rate is almost the same for groups T and E, suggesting random attrition. The attrition rate is higher in the group R because of higher off-farm employment – this is likely the reason they rejected participation in the first place. Large-scale land consolidation in group C has led to the highest attrition rate. Rural land consolidation has emerged as an important phenomenon in the entire area. Given the MoA program, the consolidation program has been suspended in the treatment villages, but not in the control villages, which has led to high attrition. It could also possibly influence fertilizer usage in control villages independent of the FFS. In the next section we discuss how we can deal with the “non-diagonal” transitions.

**Table 4.4. Household sample of RCT by design and by implementation in Hebei (Tomato), 2011-2013.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample by design** | **N** | **Sample by implementation** | | | | |
| **T** | **R** | **E** | **C** | **Missing in Endline survey** |
| **687** | **219** | **4** | **64** | **206** | **147** |
| **T** | 296 | 196  (65%) | 2  (1%) | 25  (8%) | 0 | 73  (25%) |
| **R** | 1 | 0 | 0 | 0 | 0 | 1  (100%) |
| **E** | 103 | 23  (22%) | 2  (2%) | 39  (38%) | 0 | 39  (38%) |
| **C** | 287 | 0 | 0 | 0 | 206  (72%) | 81  (28%) |

**T**: Treatment (accepted invitation to participate in FFS in the treatment villages)

**R**: Refused (did not accept invitation in the treatment villages)

**E**: Exposed (not randomly assigned invitation letter in the treatment villages)

**C**: Control (farmers in the control villages)

Note: The percentages refer to the breakdown of the design groups according to how they ended up in the implementation; that is, the column percentages should add up to 100% in each row.

Table 4.4 shows how the intended (by design) tomato sample breakdown differed from the eventual sample breakdown (by implementation). As with the rice FFS, to comply with the enrollment requirement of the MOA, additional participants for rice were recruited. But unlike rice, in addition to the farmers converted from group E, extension staff also recruited farmers who were not even considered for the program initially. Since these farmers did not take the baseline survey, we do not include them into the analysis.

The attrition rate varies by group. The attrition rates are very close for groups T and C, suggesting random attrition. The attrition rates are higher in the group R and E; however, it must be noted that their sample sizes are also much smaller.

We also compared average characteristics of households from FFS with those of non-FFS villages, in the terms of demographic characteristics, number of times nutrients (fertilizer) and pesticides were applied, the amount of fertilizer and pesticides applied, off-farm employment time, whether the farmer received rice agricultural skills training in the past 3 years, the number of total plots, the size of the biggest plot, cost of fertilizer and pesticides, etc. Table 4.5 and Table 4.6 show that the equality in means between treatment and control groups cannot be rejected for almost all but two characteristics for rice and one for tomato. Most of the characteristics are equal in means between treatment group and exposed group. In other words, our randomization seems to have worked well to produce a balanced sample.

**Table 4.5. Balance table for the rice farmer sample**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Treatment group | Exposed group | Test of means | Control group | Test of means |
|  |  |  | (treatment/  exposure) |  | (treatment/  control) |
| Number of observation | 450 | 247 | - | 432 | - |
|  |  |  |  |  |  |
| Knowledge score of rice production (full mark 100) | 35.7 | 35.6 | 0.84 | 36.6 | 0.15 |
|  |  |  |  |  |  |
| Yield (kg/ha) | 7434 | 7315 | 0.53 | 7245 | 0.31 |
|  |  |  |  |  |  |
| Times of nutrient application | 2 | 2.1 | 0.41 | 2.1 | 0.75 |
|  |  |  |  |  |  |
| Total nutrient input (kg/ha) | 324 | 334 | 0.61 | 314 | 0.56 |
|  |  |  |  |  |  |
| N fertilizer use (kg/ha) | 235 | 242 | 0.62 | 224 | 0.36 |
|  |  |  |  |  |  |
| Times of pesticides application | 2.8 | 2.8 | 0.86 | 2.9 | 0.11 |
|  |  |  |  |  |  |
| Amount of pesticide use (kg/ha) | 19.7 | 20.2 | 0.76 | 19.4 | 0.79 |
|  |  |  |  |  |  |
| Sex (fraction of male) | 0.53 | 0.55 | 0.54 | 0.58 | 0.12 |
|  |  |  |  |  |  |
| Age | 54 | 53 | 0.46 | 53 | 0.35 |
|  |  |  |  |  |  |
| Education (years) | 3.9 | 4.9 | 0.00 | 4.4 | 0.05 |
|  |  |  |  |  |  |
| Experience of rice farming for the primary labor (years) | 31.5 | 31.2 | 0.75 | 30.6 | 0.29 |
|  |  |  |  |  |  |
| Fraction of farmers received advice from extension people in the rice production in 2011 | 0.27 | 0.23 | 0.29 | 0.23 | 0.13 |
|  |  |  |  |  |  |
| Fraction of farmers received advice from agro-chemical sellers in rice production in 2011 | 0.73 | 0.76 | 0.35 | 0.75 | 0.48 |
|  |  |  |  |  |  |
| Fraction of participated in rice agricultural skills training in the past 3 years | 0.07 | 0.09 | 0.35 | 0.09 | 0.29 |
|  |  |  |  |  |  |
| The number of total plots | 6 | 6 | 0.45 | 7 | 0.00 |
|  |  |  |  |  |  |
| The size of the largest plot growing middle season long-grained rice (ha) | 40 | 36 | 0.35 | 35 | 0.18 |
|  |  |  |  |  |  |
| Cost of fertilizer (yuan/kg) | 1.9 | 1.9 | 0.69 | 1.9 | 0.64 |
|  |  |  |  |  |  |
| Cost of pesticides (yuan/kg) | 71 | 79.8 | 0.54 | 106.7 | 0.00 |
|  |  |  |  |  |  |

**Table 4.6. Balance table for tomato farmer sample**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Treatment group | Exposed group | Test of mean (treatment/exposure) | Control group | Test of mean (treatment/control) |
|  |
| Number of observation | 296 | 103 |  | 287 |  |
|  |  |  |  |  |  |
| Knowledge score of tomato production (full mark 100) | 58 | 56 | 0.07 | 59 | 0.66 |
|  |  |  |  |  |  |
| Yield (kg/ha) | 74128 | 82992 | 0.08 | 78458 | 0.28 |
|  |  |  |  |  |  |
| N fertilizer use (kg/ha) | 449 | 459 | 0.87 | 455 | 0.90 |
|  |  |  |  |  |  |
| Amount of pesticide use (kg/ha) | 22 | 28 | 0.08 | 23 | 0.50 |
|  |  |  |  |  |  |
| Sex (fraction of male) | 0.7 | 0.8 | 0.03 | 0.8 | 0.01 |
|  |  |  |  |  |  |
| Age | 45 | 48 | 0.01 | 44 | 0.30 |
|  |  |  |  |  |  |
| Education (years) | 8 | 8 | 0.27 | 8 | 0.51 |
|  |  |  |  |  |  |
| Experience of vegetable farming for the primary labor (years) | 13 | 14 | 0.04 | 12 | 0.95 |
|  |  |  |  |  |  |
| Fraction of participated in vegetable agricultural skills training in the past 3 years | 0.4 | 0.45 | 0.33 | 0.47 | 0.06 |
|  |  |  |  |  |  |
| The size of the largest plot growing tomato (ha) | 0.08 | 0.06 | 0.00 | 0.08 | 0.51 |

# 5. Effects of FFS Treatment on Core Outcomes

The overall objective is to study the effect of FFS on suboptimal (*a priori*, excessive) fertilizer use. In this section, we focus on this primary aim and discuss diffusion in the next section. We expect significant contamination effects on the exposed group because of the unintentional deviation between the experimental design and implementation discussed in detail in the previous section.

Given the non-trivial crossover across the groups captured in the transition matrices in Tables 4.3 and 4.4, we start with a comparison of T-T and C-C, which offers the simplest and cleanest comparison. We then compare the most inclusive treatment group (which include farmers transiting from other groups into treatment) and the control group. In the Annex we present results for groups with an intermediate level of inclusion into the treatment group.

## 5.1 Treatment Group (T-T) vs. Control Group (C-C) Results

We first evaluate the effect of FFS on fertilizer use by compare the change in the mean fertilizer use between the pure (that is, complying) treatment and pure control groups.

### 5.1.1. Difference in means

We compare the differences in mean fertilizer use between groups T-T (the treated by implementation) and group C-C (the control) for rice in Table 5.1.

**Table 5.1. Effect of FFS on Chemical Fertilizer Use in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sample | Nitrogen | | |  | Potassium | | |
| Baseline | Endline | Delta | Baseline | Endline | Delta |
| Treatment(T-T) | 356 | 180 | 147 | -32 |  | 32 | 46 | 14 |
| Control(C-C) | 359 | 174 | 137 | -37 |  | 35 | 43 | 8 |
| Difference b/w T-T and C-C |  | 6 | 10 | 5 |  | -3 | 3 | 6\* |
| p-value |  | 0.33 | 0.06 | 0.45 |  | 0.2 | 0.3 | 0.05 |

*Note: \* p<0.05, \*\* p<0.01*

Endline Nitrogen fertilizer use reduced dramatically in *both* treatment group and control group. One main reason is likely the unexpected weather pattern in Anhui in the baseline survey year 2011. From June to October of 2011, rainfall was much higher than usual. Cloudy and wet weather reduces [photosynthesis](http://www.iciba.com/photosynthesis) and further leads to insufficient tiller, which affects the growth of rice. Meanwhile, long-term immersion in the water made land heating impossible, so that the root of rice rotted in such damp and oxygen-deficient environment leading to a crop disease called “lodging.” In addition, excessive nitrogen fertilizer application aggravates lodging since unbalanced nutrients reduces the capacity of rice to survive in the face of extreme weather. Because farmers applied fertilizer in June and July and didn’t realize the impact of excessive rainfall until harvest, their usage of fertilizer in baseline was not influenced by unusual weather. However, it is common knowledge among farmers that lodging could be addressed by reducing fertilizer use, so in the endline year 2012, farmers reduced fertilizer use in general due to the worry about potential rainy weather. This “common trend” across both TT and CC groups explains why reduction in fertilizer use happened simultaneously in both groups.

Although there is no significant difference in average nitrogen application between TT and CC, as we discuss below there are heterogeneous effects, and identifying and addressing them might have well been the primary impact of the FFS.

The application of K fertilizer increased after intervention in both of the two groups and treatment group has greater increase in K fertilizer use comparing to control group. It is also common knowledge among farmers that K fertilizer can increase the capacity of the rice crop against lodging, even if only by a small amount. Most of the farmers only care about nitrogen fertilizer because K fertilizer is so expensive that some farmers did not even use it. On one hand, it is possible that farmers increased K fertilizer use to prevent loss caused by lodging and the possibility of unusual weather in the endline year as well. This may explain why farmers in both treatment group and control group increased K fertilizer use. On the other hand, given the relatively low level of local K fertilizer use, teaching farmers about the benefits of using more K fertilizer was one of the main content in the FFS curriculum. This could have been the underlying reason for a greater increase in the K fertilizer use in the treatment group over the control group.

**Table 5.2. Effect of FFS on Chemical Fertilizer Use in Tomato Planting**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | N | Nitrogen |  | Potassium |
| Baseline | Endline | Delta |  | Baseline | Endline | Delta |
| Treatment(T-T) | 193 | 368 | 482 | 114 |  | 456 | 591 | 134 |
| Control(C-C) | 206 | 501 | 488 | -13 |  | 628 | 588 | -40 |
| Difference b/w T-T and C-C |  | -133\* | -6 | 127\*\* |  | -171\* | 3 | 174\*\* |
| p-value |  | 0.03 | 0.86 | 0.01 |  | 0.03 | 0.96 | 0.01 |

Note: \* *p<0.05, \*\* p<0.01*

Table 5.2 presents the analogue of Table 5.1 for tomatoes. In the endline year nitrogen fertilizer use greatly increased in the treatment group while it actually slightly decreased in the control group. K fertilizer shows similar trends. Since the baseline fertilizer usage in the treatment group was significantly lower, both groups ended up with very similar usage in the endline.

Since fertilizer usage is highly heterogeneous among farmers, a direct comparison of averages between the TT and CC group might mask one of the main expected contributions of the FFS, which is to educate the farmers about optimal fertilizer usage. The average suggested optimum for N fertilizer by agricultural experts for growing rice is 165-180 kg/ha under normal weather conditions. In other words, one of the anticipated effects of the FFS is for farmers whose fertilizer use is below the optimal level to increase usage while those who are using excessive fertilizer should reduce the application. If this indeed happened, the distribution of fertilizer use in the treatment group should be closer to the optimal level in the endline year than in the baseline year when compared with the corresponding difference in control group. To explore whether this is true, we examine at the distribution of fertilizer use of treatment and control groups between the baseline and endline surveys.

**Figure 5.1: Distribution of Chemical Nitrogen fertilizer Use in Rice Planting, 2011-2012**

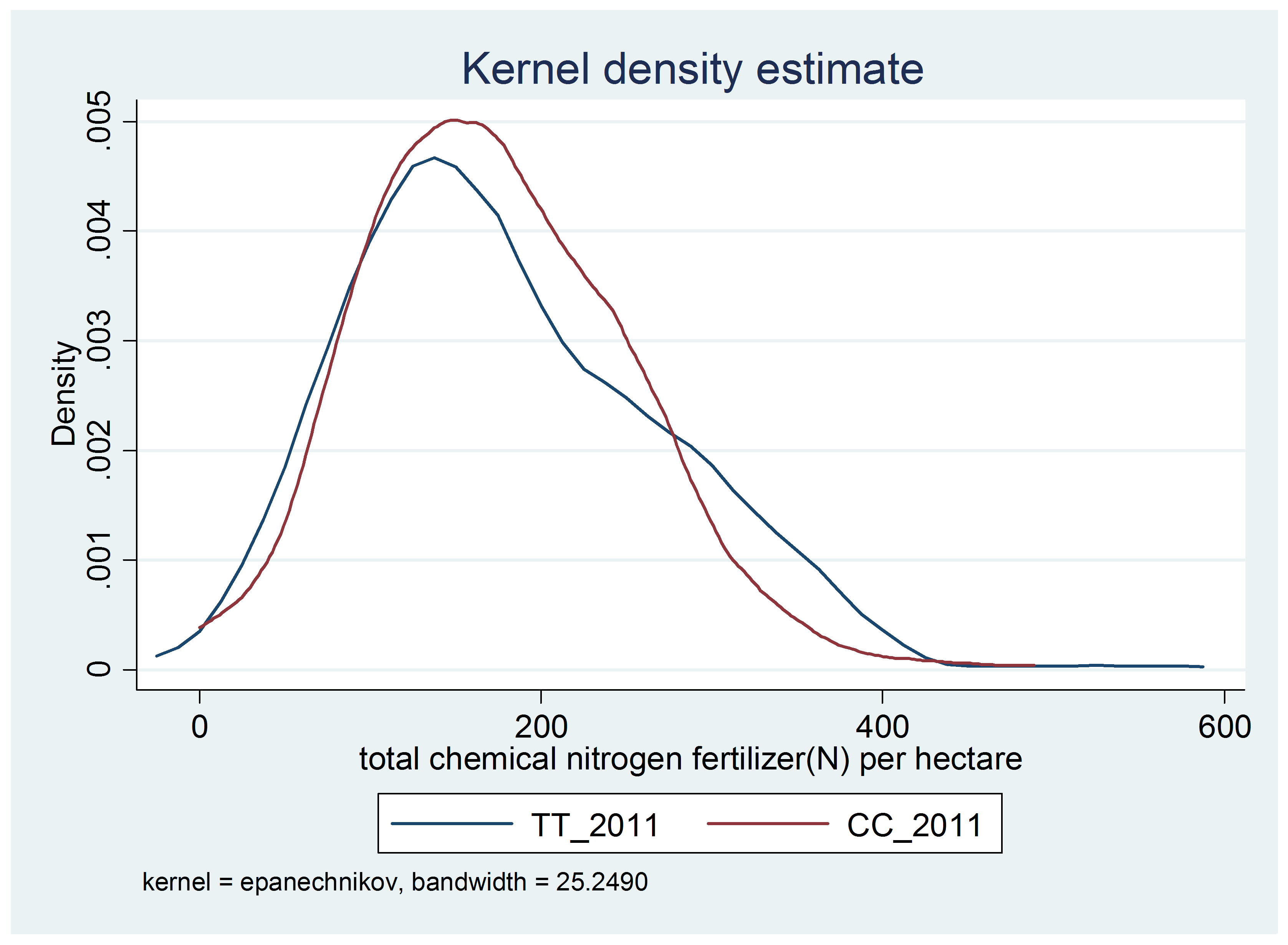
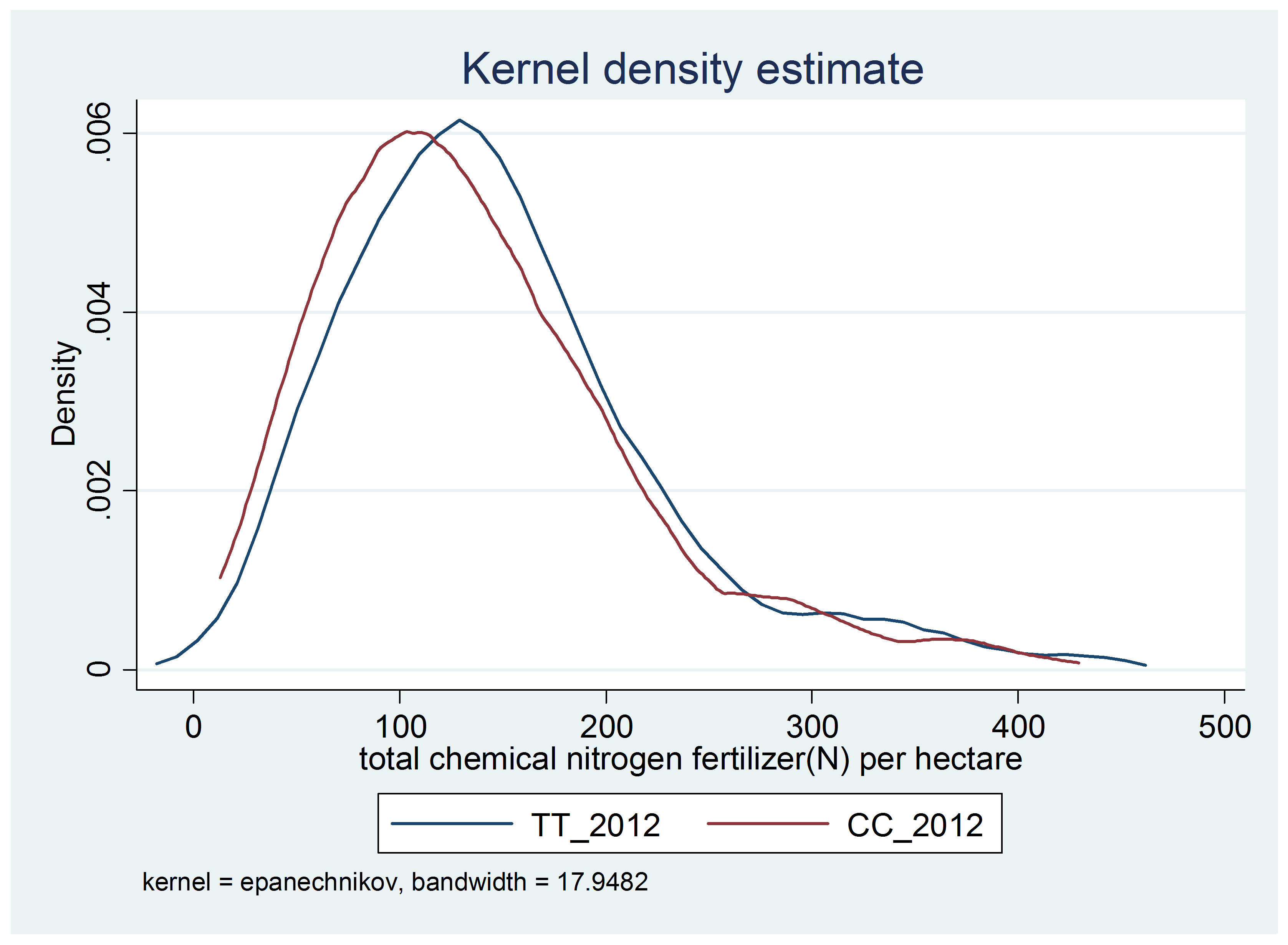
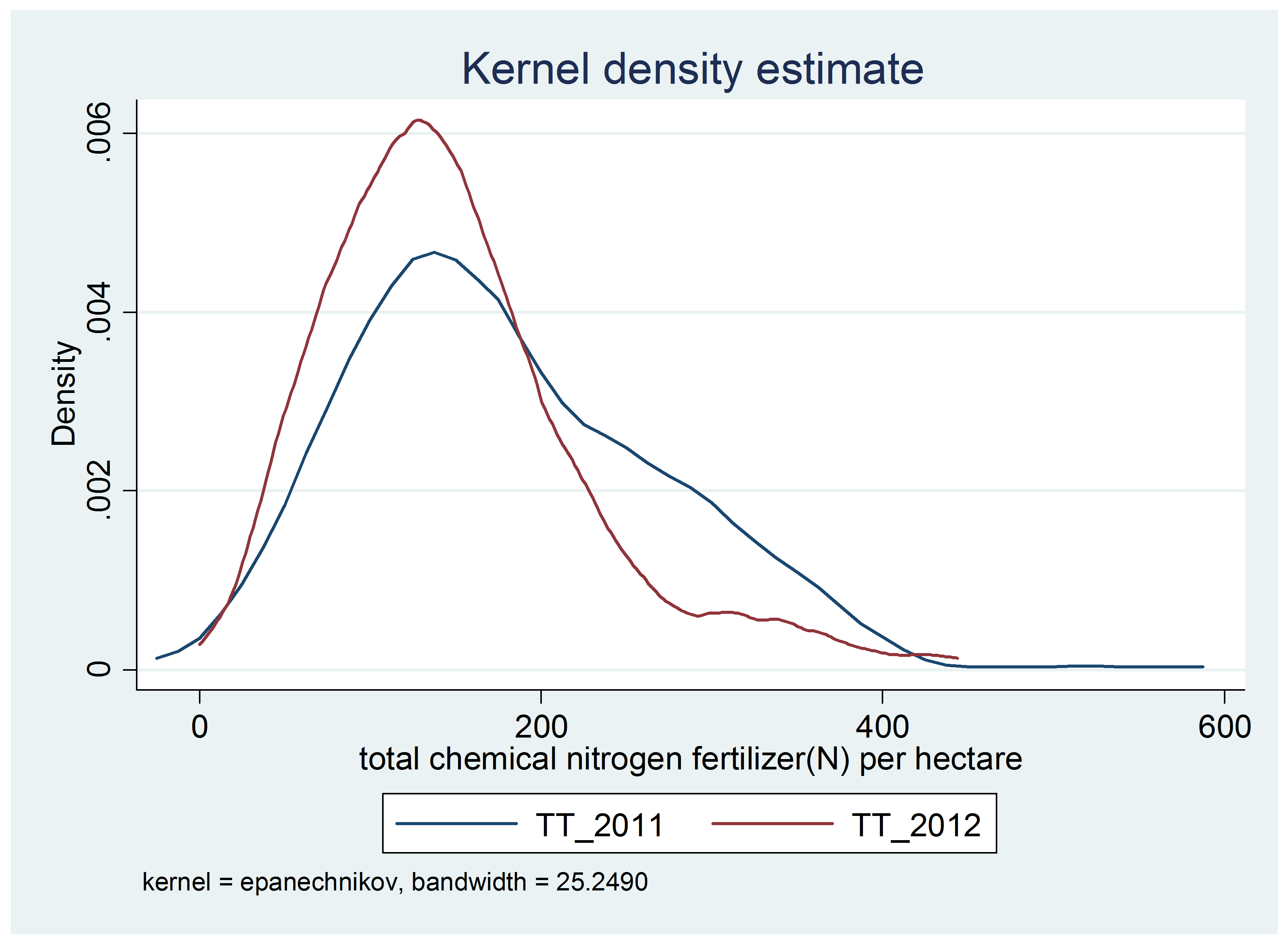
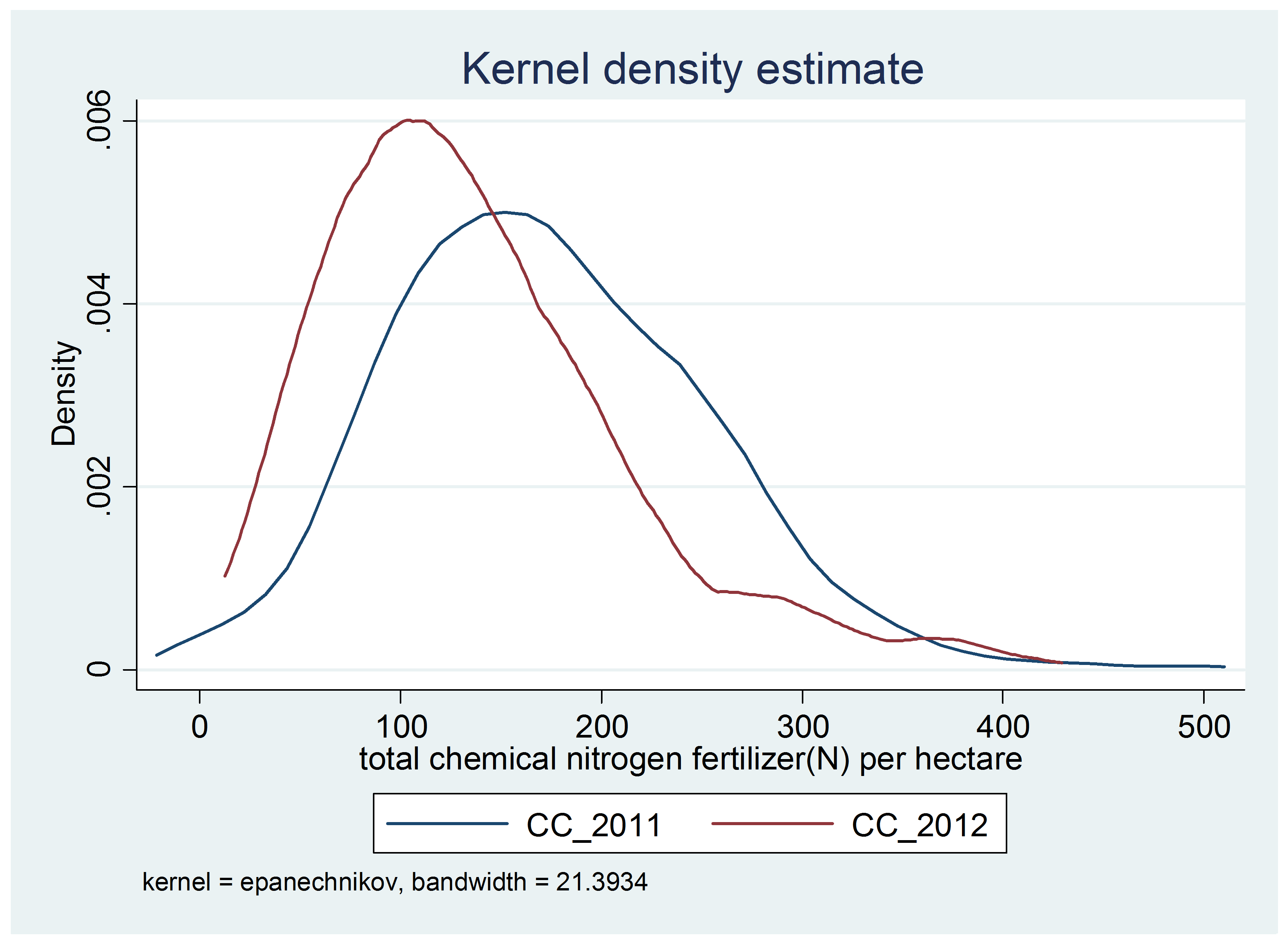
   

Figure 5.1 shows the kernel density estimates on N fertilizer use in rice planting during the baseline and endline. We show the distributions for both groups for each year as well across years for each group. The most striking aspect of these distributions is the substantial heterogeneity that exists in fertilizer usage across farmers.

Based on result of Kolmogorov-Smirnov test, fertilizer usage across groups in baseline and endline year follows the same distribution function. However, fertilizer usage of the treatment and control groups across survey years do not have the same distribution function. The distribution of the treatment group is more concentrated in the endline than in the baseline and shifts toward the left. For the control group, the trend is similar, but the shift is more apparent than the move towards concentration.

**Figure 5.2: Distribution of Chemical Nitrogen fertilizer Use in Tomato Planting, 2011-2013**





**Figure 5.3: Distribution of Manure Nitrogen fertilizer Use in Tomato Planting, 2011-2013**





Figure 5.2 and Figure 5.3 show the kernel density estimates on chemical and organic N fertilizer use in tomato planting during the baseline and endline. The substantial heterogeneity also exists in fertilizer usage across farmers.

For chemical fertilizer (Figure 5.2), although the N fertilizer usages across groups in baseline and endline year have similar distribution functions, the tails of the distribution functions in the endline year become much shorter than those in the baseline year. However, due to the low level fertlizer use in the baseline year, the distribution of treatment group is less concentrated in the endline year, and shifts to the right slightly.

For organic fertilizer used for tomatoes (Figure 5.3), not only does the N fertilizer usage across groups in baseline and endline year follows the same distribution function, but also the fertilizer usages of the treatment and control groups across survey year have the same distribution function. But the distribution of the treatment group in the endline year 2013 is more concentrated compared to that in the baseline year 2011. For the control group, the trend is similar.

To further explore the heterogeneity in fertilizer usage, we break N fertilizer usage by quintile. This is shown for rice in Table 5.3.

**Table 5.3. Comparison of N fertilizer Usage by Quintile in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quartile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=72 | n=71 | n=71 | n=71 | n=71 |
| 356 | nitrogen baseline | 180 | 69 | 124 | 164 | 223 | 320 |
| nitrogen endline | 148 | 114 | 124 | 142 | 152 | 206 |
| delta of nitrogen | -32 | 45 | 0 | -22 | -71 | -114 |
|  | % change | -18% | 65% | 0 | -13% | -32% | -36% |
| **CC** |  |  |  | n=72 | n=72 | n=72 | n=72 | n=71 |
| 359 | nitrogen baseline | 174 | 75 | 128 | 167 | 213 | 287 |
| nitrogen endline | 137 | 95 | 114 | 132 | 154 | 190 |
| delta of nitrogen | -37 | 20 | -14 | -35 | -59 | -97 |
|  | % change | -21% | 27% | -11% | -21% | -28% | -34% |

In Table 5.3, nitrogen use increased in the first quintile (0-20%) in both control and treatment groups while nitrogen use reduced for the other quintiles (except quintile 20%-40% in treatment group, where it stayed the same). The reduction is the highest in the top quintile compare to other quintiles in both treatment and control group. However, the increase in the first quintile for the treatment group is substantially higher than in the control group and decreases in the top two quintiles are slightly higher.

As mentioned earlier, increasing Potassium usage was also one of the aims of the rice FFS. Table 5.4 shows Potassium usage, also by quintile.

**Table 5.4. Comparison of K fertilizer Usage by Quintile in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=114 | n=29 | n=76 | n=76 | n=61 |
| 356 | potassium baseline | 32 | 0 | 13 | 28 | 46 | 87 |
| potassium endline | 46 | 33 | 38 | 46 | 50 | 68 |
| delta | 14 | 33 | 25 | 18 | 4 | -19 |
|  | % change | 44% | - | 192% | 64% | 9% | -22% |
| **CC** |  |  |  | n=95 | n=52 | n=74 | n=75 | n=63 |
| 359 | potassium baseline | 35 | 0 | 17 | 31 | 48 | 93 |
| potassium endline | 43 | 34 | 36 | 47 | 43 | 54 |
| delta | 8 | 34 | 19 | 16 | -5 | -39 |
|  | % change | 23% | - | 112% | 52% | -10% | -42% |

Potassium use increased dramatically in the first quintile (0-20%) in both control and treatment groups. The use of potassium reduced significantly in both groups in the top quintile 80-100%, but reduction of control group is much higher compared to treatment group. It is useful to reiterate the priors of agronomists that K use is too low for most farmers, and one of the aims of the FFS was to increase it on average.

We also break down fertilizer usage by quintile for tomato. This is shown in Table 5.5 and 5.6. To build the foundation of greenhouses, farmers have to remove the surface of the soil, which contains more nutrients and more suitable for farming. Therefore, a great amount of fertilizer has to be applied to the deep-level soil to make them arable. This explains why the total amount of fertilizer in tomato is higher than that in rice.

**Table 5.5. Comparison of N fertilizer Usage by Quintile in Tomato Planting**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | | | | | | |
| 0-20 | 20-40 | | 40-60 | | | 60-80 | | 80-100 |
|
| **TT** |  |  |  | n=39 | n=39 | | n=38 | | | n=39 | | n=38 |
| 193 | nitrogen baseline | 368 | 108 | 218 | | 291 | | | 428 | | 803 |
| nitrogen endline | 482 | 441 | 332 | | 463 | | | 450 | | 729 |
| delta of nitrogen | 114 | 333 | 114 | | 172 | | | 22 | | -74 |
|  | % change | 31% | 308% | 52% | | 59% | | | 5% | | -9% |
| **CC** |  |  |  | n=42 | | n=41 | | n=41 | n=41 | | n=41 | | |
| 206 | nitrogen baseline | 501 | 155 | | 269 | | 367 | 492 | | 1233 | | |
| nitrogen endline | 489 | 399 | | 413 | | 444 | 470 | | 719 | | |
| delta of nitrogen | -12 | 244 | | 144 | | 77 | -22 | | -514 | | |
|  | % change | -2% | 157% | | 54% | | 21% | -4% | | -42% | | |

**Table 5.6. Comparison of K fertilizer Usage by Quintile in Tomato Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=39 | n=39 | n=38 | n=39 | n=38 |
| 193 | potassium baseline | 456 | 123 | 252 | 361 | 499 | 1058 |
| potassium endline | 591 | 398 | 509 | 571 | 578 | 904 |
| delta of potassium | 135 | 275 | 257 | 210 | 79 | -154 |
|  | % change | 30% | 224% | 102% | 58% | 16% | -15% |
| **CC** |  |  |  | n=42 | n=41 | n=41 | n=41 | n=41 |
| 206 | potassium baseline | 628 | 170 | 315 | 436 | 602 | 1627 |
| potassium endline | 588 | 524 | 464 | 431 | 701 | 821 |
| delta of potassium | -40 | 354 | 149 | -5 | 99 | -806 |
|  | % change | -6% | 208% | 47% | -1% | 16% | -50% |

In Table 5.5, nitrogen use increased in the first quintile (0-20%) in both control and treatment groups, but the increase in the treatment group is significantly higher than that in the control group. The reduction is the highest in the top quintile compared to others in both treatment and control group. Since the mean of the top quintile in the control group is much higher than that in the treatment group in the baseline year, although both groups reduced to around 720 kg/ha in the endline year, the reduction in the top quintile of the control group is substantially higher than that in the treatment group. Similar trends can be found in the Table 5.6.

As mentioned in Section 4, the high-income tomato farmers attract many agricultural dealers and extension staff to hold trainings. Hence, for farmers, FFS is not the only source of agricultural information; indeed some of the training, especially by agricultural dealers, could even run counter to the teachings of the FFS. This could be a potential source of confounding reflected in the tomato results, especially at the upper end.

### 5.1.2. DID in distance from the optimum

Tables 5.3 and 5.5 provide suggestive results that the effect of the FFS might have been to increase the usage of fertilizer among the lowest quintiles and decrease it at the highest quintile, and more so for the treatment group. This leads us to go beyond the direction of change and examine the change in the distance from the optimum fertilizer usage.

Distance here is defined as the absolute distance from optimum range of the 165-180 kg/ha for rice determined by agronomists for N fertilizer usage. We examine whether this distance reduced between the endline and baseline more for the treatment than the control group.

The first column of Table 5.7 shows the regression of the differences in distance from the optimum between endline and baseline on participation. Participation in FFS is significantly and negatively associated with this difference in distance. As seen from the regression in the second column, this result is robust to including other farmer household controls. These regressions show that. participation in FFS reduced the distance from the optimum.[[7]](#footnote-7)

**Table 5.7. Regression of Differences in Distance from Optimum (Rice)**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| FFS Treatment | -15.731\*\* | -15.799\*\* |
|  | (-3.33) | (-3.34) |
| Education |  | 0.589 |
|  |  | (0.9) |
| Female |  | -3.388 |
|  |  | (-0.56) |
| Years farming rice |  | 0.111 |
|  |  | (0.54) |
| Organic |  | 1.362 |
|  |  | (0.13) |
| Own consumption |  | 10.986\* |
|  |  | (2.14) |
| Constant | 7.926\*\* | -15.402 |
|  | (2.38) | (-1.17) |
| N | 715 | 715 |

Note: *organic* is an indicator variable that is 1 if the farmer uses organic fertilizer; *own consumption* is a indicator variable if the farmer’s household consumes the crop grown on the plot; \* p<0.05, \*\* p<0.01

We also ran regressions with extension agent fixed effects and did observe significant coefficients (results omitted for the sake of brevity). Based on an extension agent survey we conducted, we will study how the effect of reducing the distance from the optimum varies by the characteristics of extension agents.

It is possible to conduct a similar “distance from the optimum” analysis for tomato farmers, but recommendations for optimal usage vary by farm location, crop type (long vs. short season), and farm age. Some of these details are provided in Tables 3.2 and 3.3, but guidance provided to farmers though the FFS was tailored to their specific farm characteristics. In subsequent analysis we will analyze the more complex optimal N fertilizer use for tomato farmers, but we are awaiting further consultation with agricultural experts to determine the correct optima.

## 5.2. Treatment with Non-compliers Analysis (T-T+E-T+R-T)

In this section we expand the treatment group of rice farmers to include non-compliers: farmers that were in the exposed group but participated in the treatment (E-T) and farmers that refused to participate initially but later took part in the FFS (R-T). This is the most inclusive treatment group we can consider.[[8]](#footnote-8) Looking at non-compliers allows us to expand the sample and check whether the initial results are robust to inclusion of additional groups of FFS farmers. We analyze summary data from the experiment and then use IV methods in an encouragement design framework to address self-selection.

### 5.2.1. Difference in means

In Table 5.8, we compare the differences in mean fertilizer use between groups T-T + E-T + R-T (the treated by implementation) and group C-C (the control). In this scenario, we got results similar to those in the previous two scenarios, so we further break down the fertilizer use by quintile to examine the heterogeneity of fertilizer use. Results in the quintile comparison are similar as well. Nitrogen use increased in the first quintile (0-20%) in both control and treatment groups while nitrogen use reduced for the other quintiles (Table 5.9). The reduction is the highest in the top quintile compare to others in both treatment and control group. However, the increase in the first quintile and decrease in the top two quintiles of treatment group are higher than those in control group. Potassium use increased dramatically in the first quintile (0-20%) and reduced a lot in the top quintile (80%-100%) in both control and treatment groups (Table 5.10). Overall, it again implies that farmers in treatment group use more K fertilizer than those in control group.

Our findings in the previous section for rice – the effect of the FFS is to significantly increase fertilizer usage at the lowest quintile of the distribution and decrease it slightly at the highest quintile – appear to be robust to allowing for potential contamination and choosing the most inclusive treatment group.

**Table 5.8. Comparison of Means: (TT+ET+RT) v CC**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T + E-T + R-T) | Control (C-C) | Difference | p-value |
| Nitrogen Baseline | 186 | 174 | 12\* | 0.04 |
| Nitrogen Endline | 148 | 137 | 11\* | 0.04 |
| Delta in nitrogen | -38 | -37 | -1 | 0.83 |
| Potassium Baseline | 33 | 35 | -2 | 0.4 |
| Potassium Endline | 47 | 43 | 4 | 0.1 |
| Delta in potassium | 14 | 8 | 6\* | 0.04 |

**Table 5.9. Comparison of N fertilizer Usage by Quintile**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | | Quintile | | | | | | | | | |
| 0-20 | | 20-40 | | 40-60 | | 60-80 | | 80-100 | |
|
| **TT** |  |  |  | | n=95 | | n=94 | | n=96 | | n=93 | | n=94 | |
| 472 | nitrogen baseline | | 185 | | 73 | | 130 | | 173 | | 234 | | 323 | |
| nitrogen endline | | 149 | | 108 | | 126 | | 143 | | 157 | | 208 | |
| delta of nitrogen | | -36 | | 35 | | -4 | | -30 | | -77 | | -115 | |
|  | % change | | -19% | | 48% | | -3% | | -17% | | -33% | | -36% | |
| **CC** |  |  | |  | | n=72 | | n=72 | | n=72 | | n=72 | | n=71 | |
| 359 | nitrogen baseline | | 174 | | 75 | | 128 | | 167 | | 213 | | 287 | |
| nitrogen endline | | 137 | | 95 | | 114 | | 132 | | 154 | | 190 | |
| delta of nitrogen | | -37 | | 20 | | -14 | | -35 | | -59 | | -97 | |
|  | % change | | -21% | | 27% | | -11% | | -21% | | -28% | | -34% | |

**Table 5.10. Comparison of K fertilizer by Quintile**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=140 | n=49 | n=107 | n=94 | n=82 |
| 460 | potassium baseline | 33 | 0 | 15 | 30 | 48 | 88 |
| potassium endline | 47 | 34 | 38 | 44 | 55 | 70 |
| delta | 14 | 34 | 23 | 14 | 7 | -18 |
|  | % change | 44% | - | 153% | 47% | 15% | -20% |
| **CC** |  |  |  | n=95 | n=52 | n=74 | n=75 | n=63 |
| 359 | potassium baseline | 35 | 0 | 17 | 31 | 48 | 93 |
| potassium endline | 43 | 34 | 36 | 47 | 43 | 54 |
| delta | 8 | 34 | 19 | 16 | -5 | -39 |
|  | % change | 23% | - | 112% | 52% | -10% | -42% |

### 5.2.2. IV regression

Given the imperfect treatment group and the presence of non-compliers, we use instrumental variable regressions to address possible selection bias. A dummy variable, which indicates whether a participant was invited, is used as an IV for FFS attendance. DID in distance from the optimum, as in Table 5.7, is used as the dependent variable. While this IV might address selection from the E group, it might not address selection from the R group (though the R-T group rather small).

In the first-stage regression (see Table 5.11), the variable of invitation is significantly associated with actual participation in FFS. In the second stage, after controlling household characteristics, participation in FFS is significantly and negatively to a distance from the optimum fertilizer use. As before, participation in FFS reduces the distance from the optimum relative to the control group. Indeed, the coefficient and significance improve relative to those in Table 5.7.

**Table 5.11. IV Regression of DID in Distance from Optimum**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| First-stage regressions |  |  |  |  |
| Source SS | df MS |  | Number of obs | 831 |
|  |  |  | F( 6, 824) | 1471.67 |
| Model 186.504279 | 6 31.0840466 |  | Prob > F | 0 |
| Residual 17.4042645 | 824 .02112168 |  | R-squared | 0.9146 |
|  |  |  | Adj R-squared | 0.914 |
| Total 203.908544 | 830 .245672944 |  | Root MSE | 0.14533 |
|  |  |  |  |  |
| participation Coef. | Std. Err. t | P>t | [95% Conf. | Interval] |
| education .000919 | .001402 0.66 | 0.512 | -0.0018329 | 0.003671 |
| female .0242342 | .012866 1.88 | 0.06 | -0.0010198 | 0.049488 |
| years farming rice .0003279 | .000438 0.75 | 0.454 | -0.0005318 | 0.001188 |
| organic .0037721 | .0227516 0.17 | 0.868 | -0.0408858 | 0.04843 |
| own cons. -.0136577 | .0110141 -1.24 | 0.215 | -0.0352767 | 0.007961 |
| invitation .9590151 | .0102387 93.67 | 0 | 0.9389181 | 0.979112 |
| cons .0133347 | .0285409 0.47 | 0.64 | -0.0426867 | 0.069356 |

|  |  |
| --- | --- |
| Instrumental variables (2SLS) regression |  |
| Source SS df MS | Number of obs = 831 |
|  | F( 6, 824) = 3.58 |
| Model 79752.58 6 13292.0967 | Prob > F = 0.0017 |
| Residual 3338331.25 824 4051.37287 | R-squared = 0.0233 |
|  | Adj R-squared = 0.0162 |
| Total 3418083.83 830 4118.17329 | Root MSE = 63.65 |
|  |  |
| did\_distance Coef. Std. Err. t | P>t [95% Conf. Interval] |
| participation -17.31973 4.675786 -3.70 | 0.000 -26.49759 -8.141879 |
| education .7007726 .6142121 1.14 | 0.254 -.5048318 1.906377 |
| female -.6960448 5.64091 -0.12 | 0.902 -11.76829 10.3762 |
| years farming rice .155268 .1919001 0.81 | 0.419 -.2214025 .5319386 |
| organic -3.979887 9.964507 -0.40 | 0.690 -23.53869 15.57892 |
| own cons. 10.91893 4.821577 2.26 | 0.024 1.454912 20.38295 |
| \_cons -16.47292 12.50903 -1.32 | 0.188 -41.02623 8.08038 |
|  |  |
| Instrumented: participation |  |
| Instruments: education female key\_rcyear mn\_yn | own consumption invitation dummy |

## 5.3. Impact of FFS on yield

Whether FFS graduates have higher net yields and incomes (or at the lest not lower amounts) and if they better able to resolve farming production problems in the context of an altered fertilizer regimen are a couple of concerns we turn to next. In the three scenarios for rice (Table 5.12 through Table 5.14), yield in the endline year increased greatly and by almost equivalent amounts in both treatment and control groups. One possible reason for growth in both groups is that the unusual weather in the baseline year influenced the yield, so with the return of normal weather, the yield jumped back to the normal level as well. In the two different scenarios for tomatoes (Table 5.15 and Table 5.16), even though the yield of the treatment and control groups both increase in the endline survey, the growth in yield of the treatment group is much higher than the control group.

**Table 5.12. Rice Yield Comparison: T-T v C-C**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T) | Control(C-C) | Difference | p-value |
| Yield Baseline | 7581 | 7456 | 124 | 0.23 |
| Yield Endline | 8252 | 8134 | 118 | 0.24 |
| Delta in yield | 672 | 678 | -6 | 0.95 |

**Table 5.13. Rice Yield Comparison: (T-T+E-T) v C-C**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T + E-T) | Control(C-C) | Difference | p-value |
| Yield Baseline | 7630 | 7456 | 173 | 0.07 |
| Yield Endline | 8300 | 8134 | 166 | 0.07 |
| Delta in yield | 670 | 678 | -8 | 0.93 |

**Table 5.14. Rice Yield (kg/ha) Comparison: (T-T+E-T+R-T) v C-C**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T + E-T + R-T) | Control  (C-C) | Difference | p-value |
| Yield Baseline | 7630 | 7456 | 174 | 0.07 |
| Yield Endline | 8301 | 8134 | 167 | 0.07 |
| Delta in yield | 670 | 678 | -7 | 0.94 |

**Table 5.15. Tomato Yield (kg/ha) Comparison: T-T v C-C**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T) | Control(C-C) | Difference | p-value |
| Yield Baseline | 70950 | 79902 | -8952 | 0.08 |
| Yield Endline | 84610 | 83916 | 694 | 0.87 |
| Delta in yield | 13290 | 4321 | 8969 | 0.09 |

**Table 5.16. Tomato Yield (kg/ha) Comparison: (T-T+E-T) v C-C**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatment (T-T + E-T) | Control(C-C) | Difference | p-value |
| Yield Baseline | 71904 | 79902 | -7999 | 0.11 |
| Yield Endline | 86621 | 83916 | 2704 | 0.50 |
| Delta in yield | 14383 | 4321 | 10062 | 0.05 |

We next explore the heterogeneous effect of FFS on yield in greater detail. A particular avenue for analysis would be to see if in the highest quintile, reductions in fertilizer usage have any negative effect on yield. Based on the figures in Table 5.17 which presents rice yield (in kilograms per hectare) by quintile of fertilizer use, yield increases in all of the quintile bins, especially in the first two quintile bins (0%-20% and 20%-40%) presumably due to the increased usage of fertilizer. The highest quintile bin had the greatest reduction of fertilizer use, but yield was not negatively impacted by this decrease.

**Table 5.17. Comparison of Rice Yield (kg/ha) by Quintile Fertilizer Use**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group |  |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  | n=356 | n=72 | n=71 | n=71 | n=71 | n=71 |
| N fertilizer | nitrogen baseline | 180 | 69 | 124 | 164 | 223 | 320 |
| nitrogen endline | 148 | 114 | 124 | 142 | 152 | 206 |
| delta of nitrogen | -32 | 45 | 0 | -22 | -71 | -114 |
| % change | -18% | 65% | 0 | -13% | -32% | -36% |
| yield | yield baseline | 7581 | 7397 | 7330 | 7210 | 7875 | 8095 |
| yield endline | 8252 | 8416 | 8028 | 8055 | 8576 | 8184 |
| delta of yield | 671 | 1019 | 698 | 845 | 701 | 89 |
| % change | 9% | 14% | 10% | 12% | 9% | 1% |
| **CC** |  |  | n=359 | n=72 | n=72 | n=72 | n=72 | n=71 |
| N fertilizer | nitrogen baseline | 174 | 75 | 128 | 167 | 213 | 287 |
| nitrogen endline | 137 | 95 | 114 | 132 | 154 | 190 |
| delta of nitrogen | -37 | 20 | -14 | -35 | -59 | -97 |
| % change | -21% | 27% | -11% | -21% | -28% | -34% |
| yield | yield baseline | 7456 | 7167 | 7368 | 7792 | 7542 | 7413 |
| yield endline | 8134 | 8220 | 8147 | 8198 | 8052 | 8052 |
| delta of yield | 678 | 1053 | 779 | 406 | 510 | 639 |
| % change | 9% | 15% | 11% | 5% | 7% | 9% |

Based on the figures in Table 5.18, which presents tomato yield (in kilograms per hectare) by quintile of fertilizer use, treatment group yield increases in all of the quintile bins, and the increase in the treatment group is significantly higher than that in the control group for each bin except the quintile 20-40%. Yield in the treatment group in the top quintile shows a 12% increase despite the greatest reduction of fertilizer use, while yield in the control group was negatively impacted by this decrease.

**Table 5.18. Comparison of Tomato Yield (kg/ha) by Quintile Fertilizer Use**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group |  |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** | N fertilizer |  |  | n=39 | n=39 | n=38 | n=39 | n=38 |
| nitrogen baseline | 368 | 108 | 218 | 291 | 428 | 803 |
| nitrogen endline | 482 | 441 | 332 | 463 | 450 | 729 |
| delta of nitrogen | 114 | 333 | 114 | 172 | 22 | -74 |
| % change | 31% | 308% | 52% | 59% | 5% | -9% |
| Yield | nitrogen baseline | 70950 | 61958 | 63545 | 73147 | 72106 | 84398 |
| nitrogen endline | 84610 | 73172 | 79285 | 84069 | 92290 | 94739 |
| delta of nitrogen | 13660 | 11214 | 15740 | 10922 | 20184 | 10341 |
| % change | 19% | 18% | 25% | 15% | 28% | 12% |
| **CC** | N fertilizer |  |  | n=42 | n=41 | n=41 | n=41 | n=41 |
| nitrogen baseline | 501 | 155 | 269 | 367 | 492 | 1233 |
| nitrogen endline | 489 | 399 | 413 | 444 | 470 | 719 |
| delta of nitrogen | -12 | 244 | 144 | 77 | -22 | -514 |
| % change | -2% | 157% | 54% | 21% | -4% | -42% |
| Yield | nitrogen baseline | 79902 | 88449 | 73228 | 66997 | 72320 | 98310 |
| nitrogen endline | 83916 | 84930 | 91524 | 70126 | 74962 | 97678 |
| delta of nitrogen | 4014 | -3519 | 18296 | 3129 | 2642 | -632 |
| % change | 5% | -4% | 25% | 5% | 4% | -1% |

## 5.5. Impact of FFS on knowledge score

The FFS training focuses not only on reducing excessive fertilizer use, but also promoting environmentally sound practice in general, like crop protection, scientific cultivation, and enhancing the environmental and ecological awareness of farmers. The effectiveness of the curriculum in bringing these benefits can be tested using the questions we included in the surveys. Table 5.19 shows the details of the knowledge test for rice farmers at the baseline. We conducted a detailed comparison of knowledge scores between pre- and post-intervention surveys by group.

Based on the statistical tests (see Table 5.20a/b), farmers in treatment group (no matter whether the farmer is a complier or not) get a significantly higher knowledge score than those in control group. More specifically, fertilizer, pest, cultivation, and environment sub-scores for the treatment group are all higher than those of control group. In addition, we see no significant difference between knowledge scores of farmers in exposed group and control group.

**Table 5.20a. Difference of farmer test score between 2011 and 2012 in Anhui, China**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Sample | Total score5 |
|  | Fertilizer6 | Pest6 | Cultivation6 | Environment6 |
| 1 | Total | 1171 | 142 | 37 | 34 | 53 | 19 |
| 2 | **FFS graduate in treatment villages**1 | **472** | **143** | **38** | **33\*** | **53** | **19** |
| 3 | T-T | 356 | 143 | 38 | 33 | 53 | 19 |
| 4 | R-T2 | 12 | 131 | 39 | 29 | 45 | 19 |
| 5 | E-T2 | 104 | 143 | 38 | 33 | 53 | 19 |
| 6 | **Non-compliance farmers in treatment villages**1 | **51** | **123\*\*** | **32** | **30\*\*** | **48\*** | **13** |
| 7 | T-R3 | 16 | 130 | 34 | 32 | 49 | 14 |
| 8 | R-R | 18 | 133 | 32 | 32 | 51 | 18 |
| 9 | E-R3 | 17 | 124 | 34 | 29 | 46 | 15 |
| 10 | **Expose farmers in treatment villages**1 | **141** | **138** | **36** | **32\*\*\*** | **52** | **18** |
| 11 | T-E4 | 33 | 130 | 34 | 28\* | 51 | 17 |
| 12 | E-E | 108 | 140 | 37 | 33 | 52 | 18 |
| 13 | **Farmers in control villages** | **359** | **145** | **38** | **35** | **53** | **19** |
| 14 | **Missings**1 | **147** | **137** | **34** | **33\*** | **50\*** | **20** |
| 15 | T | 47 | 139 | 36 | 35 | 49 | 19 |
| 16 | R | 5 | 126 | 20 | 31 | 55 | 20 |
| 17 | E | 22 | 143 | 36 | 36 | 51 | 21 |
| 18 | C | 73 | 135 | 34 | 31 | 51 | 20 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 5.20b. Difference of farmer test score between 2011 and 2012 in Anhui, China** | | | | | | | | | | | |
|  |  | Delta of total score5 |  | Delta of each component | | | | | | | |
|  |  | Fertilizer6 |  | Pest6 |  | Cultivation6 |  | Environment6 | | |
| 1 | Total | 19 |  | 7 |  | 6 |  | 3 |  | 3 | | |
| 2 | **FFS graduate in treatment villages**1 | **24\*\*** |  | **7** |  | **8\*\*\*** |  | **4** |  | **5\*** | | |
| 3 | T-T | 24 |  | 7 |  | 9 |  | 4 |  | 4 | | |
| 4 | R-T2 | 37 |  | 6 |  | 13 |  | 13 |  | 6 | | |
| 5 | E-T2 | 25 |  | 9 |  | 8 |  | 2 |  | 6 | | |
| 6 | **Non-compliance farmers in treatment villages**1 | **47\*\*\*** |  | **16\*** |  | **9\*\*** |  | **10\*** |  | **12\*\*** | | |
| 7 | T-R3 | 30 |  | 11 |  | 6 |  | 8 |  | 5 | | |
| 8 | R-R | 5 |  | 2 |  | 5 |  | -1 |  | -1 | | |
| 9 | E-R3 | 57\*\* |  | 20\* |  | 10 |  | 10 |  | 18\* | | |
| 10 | **Expose farmers in treatment villages**1 | **10** |  | **4** |  | **4** |  | **2** |  | **0** | | |
| 11 | T-E4 | 13 |  | 3 |  | 6 |  | 6 |  | -2 | | |
| 12 | E-E | 13 |  | 5 |  | 4 |  | 2 |  | 2 | | |
| 13 | **Farmers in control villages** | **12** |  | **5** |  | **3** |  | **2** |  | **1** | | |
| *Note*: The code of the farmer type is explained in the text above.  1 t-test is conducted be referring to farmers in control villages (row 13). 2 t-test is conducted by referring to T-T (in row 3). 3 t-test is conducted by referring to R-R (in row 8). 4 t-test is conducted by referring to E-E (in row 12).  5 Full marks=400  6 Full marks=100 | | | | | | | | | | |

Table 5.21 shows the details of the knowledge test of greenhouse tomato farmers. Through the detailed comparison of knowledge scores between pre- and post-intervention surveys by group, we find that farmers in the treatment group get slightly higher knowledge scores as a whole and in the fertilizer test, and a more noticeable improvement in the environment protection test.

Compared with rice farmers, tomato farmers have higher knowledge scores. The main explanation is that the education level of the tomato farmers (8 years) is much higher than that of rice farmers (4.8 years). As mentioned earlier the tomato farmers have higher incomes, and the higher education is presumably a contributing factor.

**Table 5.21. Comparison of Test Scores between Treatment and Control Groups of Tomato Famers in Hebei, 2011-2013 China**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Group | total test score | test score about fertilizer | test score about pesticide | test score about cultivation | test score about environment protection |
| Baseline | TT | 58.98 | 65.98 | 59.21 | 59.07 | 35.75 |
| CC | 58.65 | 64.28 | 59.76 | 58.25 | 31.92 |
| P-value | 0.77 | 0.24 | 0.65 | 0.61 | 0.08 |
| Endline | TT | 65.63 | 69.95 | 67.65 | 62.82 | 36.79 |
| CC | 65.35 | 69.66 | 67.66 | 62.99 | 33.37 |
| P-value | 0.79 | 0.87 | 0.99 | 0.92 | 0.22 |

**5.6. Robustness Checks**

The optimal range of fertilizer for rice use was proposed by soil scientists based on local experiments, then calibrated by local extension experts based on local soil type, seed varieties, and cropping patterns. Most of this work was based on field communication. In the DID in distance analysis in Sections 5.1 and 5.2, we defined distance as the absolute distance from the whole optimum range of the 165-180 kg/ha. In this subsection, we try three different definitions: distance from middle point of optimum range, distance from the lower bound of optimum range, and distance from the upper bound of optimum range to test the robustness of our results. The results got from the three different regressions are similar to those obtained in Table 5.7 using the whole optimum range.

**Table 5.22. Regression of Differences in Distance from Middle Point of Optimum Range (Rice)**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| treatment | -16.176\*\* | -16.233\*\* |
|  | (-3.39) | (-3.40) |
| education |  | 0.638 |
|  |  | (0.97) |
| female |  | -3.575 |
|  |  | (-0.58) |
| years growing rice |  | 0.128 |
|  |  | (0.62) |
| organic fert. |  | 1.365 |
|  |  | (0.13) |
| own consumption |  | 10.476\* |
|  |  | (2.02) |
| constant | 8.516\* | -14.731 |
|  | (2.53) | (-1.11) |
| N | 715 | 715 |

Note: *organic* is an indicator variable that is 1 if the farmer uses organic fertilizer; *own consumption* is a indicator variable if the farmer’s household consumes the crop grown on the plot; \* p<0.05, \*\* p<0.01

**Table 5.23. Regression of Differences in Distance from Lower Bound of Optimum Range (Rice)**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| treatment | -14.920\*\* | -14.947\*\* |
|  | (-3.10) | (-3.10) |
| education |  | 0.584 |
|  |  | (0.88) |
| female |  | -3.533 |
|  |  | (-0.57) |
| years growing rice |  | 0.052 |
|  |  | (0.25) |
| organic fert. |  | -0.749 |
|  |  | (-0.07) |
| own consumption |  | 11.371\* |
|  |  | (2.17) |
| constant | 4.704 | -17.258 |
|  | (1.38) | (-1.28) |
| N | 715 | 715 |

Note: *organic* is an indicator variable that is 1 if the farmer uses organic fertilizer; *own consumption* is a indicator variable if the farmer’s household consumes the crop grown on the plot; \* p<0.05, \*\* p<0.01

**Table 5.24. Regression of Differences in Distance from Upper Bound of Optimum Range (Rice)**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| treatment | -16.450\*\* | -16.539\*\* |
|  | (-3.48) | (-3.50) |
| education |  | 0.628 |
|  |  | (0.96) |
| female |  | -3.196 |
|  |  | (-0.53) |
| years growing rice |  | 0.178 |
|  |  | (0.86) |
| organic |  | 3.434 |
|  |  | (0.33) |
| own consumption |  | 10.704\* |
|  |  | (2.09) |
| constant | 11.149\*\* | -14.128 |
|  | (3.35) | (-1.07) |
| N | 715 | 715 |

Note: *organic* is an indicator variable that is 1 if the farmer uses organic fertilizer; *own consumption* is a indicator variable if the farmer’s household consumes the crop grown on the plot; \* p<0.05, \*\* p<0.01

# 6. Diffusion Effects on Exposed Farmers

Farmer-to-farmer knowledge diffusion implies that untreated farmers in the same village at treated farmers may change their farming behavior, presumably by coming into contact with treated farmers.

## 6.1 Comparison of the “pure” treatment and exposed groups

Table 6.1 compares the mean fertilizer usage for the pure treatment and pure exposed groups. In later subsections we compare results for other groups.

**Table 6.1. Exposed Effect of FFS on fertilizer Use in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sample | Nitrogen | | |  | Potassium | | |
| Baseline | Endline | Delta | Baseline | Endline | Delta |
| Control (C-C) | 359 | 174 | 137 | -37 |  | 35 | 43 | 8 |
| Treatment(T-T) | 356 | 180 | 148 | -32 |  | 32 | 46 | 14 |
| Exposed(E-E)1 | 108 | 178 | 131\* | -47 |  | 36 | 40 | 4\* |

Note: \* *p<0.05, \*\* p<0.01; 1 t-test is conducted by referring to T-T*

Endline nitrogen fertilizer use reduced dramatically in *both* treatment group and exposed group and the reduction is even higher in exposed group. The decrease of fertilizer use in exposed group is likely the result of knowledge diffusion from FFS graduates to exposed farmers. Another reason may be the unexpected weather pattern in Anhui in the baseline survey year 2011 that we mentioned earlier. The common weather explains a lot for the simultaneous reduction of fertilizer in both groups but it may also swamp the diffusion effect.

The application of potassium fertilizer increased after intervention in both groups and treatment group has greater increase in potassium fertilizer use comparing to exposed group. It is common knowledge among farmers that potassium fertilizer can increase the capacity of the rice crop against lodging, even if only by a small amount. It is possible that farmers use more potassium fertilizer to avoid lodging due to the worry that unusual weather may happen again in endline year. However, given the fact that potassium fertilizer is so expensive that some farmers did not even use it, the increase of potassium fertilizer use in exposed group is likely the result of knowledge diffusion from FFS graduates who were taught about the benefits of using more potassium fertilizer.

**Table 6.2. Exposed Effect of FFS on fertilizer Use in Tomato Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sample | Nitrogen | | |  | Potassium | | |
| Baseline | Endline | Delta | Baseline | Endline | Delta |
| Control (C-C) | 206 | 501 | 488 | -13 |  | 628 | 588 | -40 |
| Treatment(T-T) | 193 | 368 | 482 | 114 |  | 456 | 591 | 134 |
| Exposed(E-E)1 | 39 | 381 | 781\*\* | 401\*\* |  | 431 | 940\*\* | 509\*\* |

Note: \* *p<0.05, \*\* p<0.01; 1 t-test is conducted by referring to T-T*

From the results of Table 6.2, the fact that there is no significant difference in the baseline fertilizer use between the treatment and exposed group makes the exposed group a good counterfactual (with the caveat of the much smaller sample size). The application of nitrogen and potassium fertilizer increased after intervention in both of the treatment and exposed groups， but the exposed group has greater increase.

Since fertilizer usage is highly heterogeneous among farmers, we breakdown N fertilizer usage by quintile. This is shown in Table 6.3.

**Table 6.3. Comparison of N fertilizer Usage by Quintile in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quartile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=72 | n=71 | n=71 | n=71 | n=71 |
| 356 | nitrogen baseline | 180 | 69 | 124 | 164 | 223 | 320 |
| nitrogen endline | 148 | 114 | 124 | 142 | 152 | 206 |
| delta of nitrogen | -32 | 45 | 0 | -22 | -71 | -114 |
|  | % change | -18% | 65% | 0 | -13% | -32% | -36% |
| **EE** |  |  |  | n=22 | n=22 | n=21 | n=22 | n=21 |
| 108 | nitrogen baseline | 178 | 78 | 136 | 172 | 216 | 292 |
| nitrogen endline | 131 | 93 | 126 | 129 | 134 | 174 |
| delta of nitrogen | -47 | 15 | -10 | -43 | -82 | -118 |
|  | % change | -26% | 19% | -7% | -25% | -38% | -40% |
| **CC** |  |  |  | n=72 | n=72 | n=72 | n=72 | n=71 |
| 359 | nitrogen baseline | 174 | 75 | 128 | 167 | 213 | 287 |
| nitrogen endline | 137 | 95 | 114 | 132 | 154 | 190 |
| delta of nitrogen | -37 | 20 | -14 | -35 | -59 | -97 |
|  | % change | -21% | 27% | -11% | -21% | -28% | -34% |

Nitrogen use increased in the lowest quintile in all of the groups while nitrogen use reduced for the other quintiles (except quintile 20 percent-40 percent in the treatment group, where it stayed the same). The reduction is the highest in the topmost quintile; however, the reduction in the other four quintiles for the exposed group larger than the treated or control groups, while the increase in the first quintile for exposed group is lower than the other two groups.

As mentioned earlier, increasing Potassium usage was also one of the aims of the FFS. Table 6.4 shows Potassium usage, also by quintile.

**Table 6.4. Comparison of K fertilizer Usage by Quintile in Rice Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=114 | n=29 | n=76 | n=76 | n=61 |
| 356 | potassium baseline | 32 | 0 | 13 | 28 | 46 | 87 |
| potassium endline | 46 | 33 | 38 | 46 | 50 | 68 |
| delta | 14 | 33 | 25 | 18 | 4 | -19 |
|  | % change | 44% | - | 192% | 64% | 9% | -22% |
| **EE** |  |  |  | n=27 | n=17 | n=23 | n=20 | n=21 |
| 108 | potassium baseline | 36 | 0 | 17 | 33 | 49 | 87 |
| potassium endline | 40 | 27 | 30 | 37 | 70 | 43 |
| delta | 4 | 27 | 13 | 4 | 21 | -44 |
|  | % change | 11% | - | 76% | 12% | 43% | -51% |
| **CC** |  |  |  | n=95 | n=52 | n=74 | n=75 | n=63 |
| 359 | potassium baseline | 35 | 0 | 17 | 31 | 48 | 93 |
| potassium endline | 43 | 34 | 36 | 47 | 43 | 54 |
| delta | 8 | 34 | 19 | 16 | -5 | -39 |
|  | % change | 23% | - | 112% | 52% | -10% | -42% |

Potassium use increased dramatically in the lowest quintile in all of the groups. The use of potassium reduced significantly in both groups in the highest quintile, but reduction of exposed group is much higher compared to the other two groups. In addition, the increase in the first three quintiles (0-60 percent) for exposed group is lower than that in control group.

In summary, the reduction in fertilizer usage of rice farmers in the highest quintiles is higher in the exposed group than in the control group (and surprisingly even higher than in the treatment group), which is suggestive of diffusion effects.

**Table 6.5. Comparison of N fertilizer Usage by Quintile in Tomato Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=39 | n=39 | n=38 | n=39 | n=38 |
| 193 | nitrogen baseline | 368 | 108 | 218 | 291 | 428 | 803 |
| nitrogen endline | 482 | 441 | 332 | 463 | 450 | 729 |
| delta of nitrogen | 114 | 333 | 114 | 172 | 22 | -74 |
|  | % change | 31% | 308% | 52% | 59% | 5% | -9% |
| **EE** |  |  |  | n=8 | n=8 | n=8 | n=8 | n=7 |
| 39 | nitrogen baseline | 381 | 186 | 251 | 315 | 429 | 771 |
| nitrogen endline | 781 | 1180 | 643 | 871 | 649 | 533 |
| delta of nitrogen | 400 | 994 | 392 | 556 | 220 | -238 |
|  | % change | 105% | 534% | 156% | 177% | 51% | -31% |
| **CC** |  |  |  | n=42 | n=41 | n=41 | n=41 | n=41 |
| 206 | nitrogen baseline | 501 | 155 | 269 | 367 | 492 | 1233 |
| nitrogen endline | 489 | 399 | 413 | 444 | 470 | 719 |
| delta of nitrogen | -12 | 244 | 144 | 77 | -22 | -514 |
|  | % change | -2% | 157% | 54% | 21% | -4% | -42% |

For tomato (Table 6.5), the reduction of nitrogen fertilizer use is the highest in the top quintile; however, the reduction in the control and exposed groups larger than the treated group. In addition, the increase in the first three quintiles for exposed group is higher than the other two groups. Essentially, the problem of parallel training that we mentioned before does not allow us to draw clear conclusions on diffusion for tomatoes.

**Table 6.6. Comparison of K fertilizer Usage by Quintile in Tomato Planting**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | N |  | Mean | Quintile | | | | |
| 0-20 | 20-40 | 40-60 | 60-80 | 80-100 |
|
| **TT** |  |  |  | n=39 | n=39 | n=38 | n=39 | n=38 |
| 193 | potassium baseline | 456 | 123 | 252 | 361 | 499 | 1058 |
| potassium endline | 591 | 398 | 509 | 571 | 578 | 904 |
| delta of potassium | 135 | 275 | 257 | 210 | 79 | -154 |
|  | % change | 30% | 224% | 102% | 58% | 16% | -15% |
| **EE** |  |  |  | n=8 | n=8 | n=8 | n=8 | n=7 |
| 39 | nitrogen baseline | 431 | 125 | 276 | 387 | 505 | 925 |
| nitrogen endline | 940 | 1600 | 811 | 514 | 805 | 976 |
| delta of nitrogen | 509 | 1475 | 535 | 127 | 300 | 51 |
|  | % change | 118% | 1180% | 194% | 33% | 59% | 6% |
| **CC** |  |  |  | n=42 | n=41 | n=41 | n=41 | n=41 |
| 206 | potassium baseline | 628 | 170 | 315 | 436 | 602 | 1627 |
| potassium endline | 588 | 524 | 464 | 431 | 701 | 821 |
| delta of potassium | -40 | 354 | 149 | -5 | 99 | -806 |
|  | % change | -6% | 208% | 47% | -1% | 16% | -50% |

Potassium use increased dramatically in the first two quintiles in all of the groups, especially the exposed group (Table 6.6). The use of potassium reduced in the topmost quintile in the treatment and control groups, but increased in the exposed group. As we mentioned above, the sample size of each bin in the exposed group is much smaller than the others.

### 6.1.2. DID in distance from the optimum

Tables 6.1 and 6.3 provide suggestive observations on the diffusion effect of FFS knowledge. Table 6.7 shows regressions for the differences in distance from the optimum between endline and baseline on participation in FFS, exposed farmers, and other farmer household controls. The first two regressions show that although participation in FFS is significantly and negatively associated with this difference in distance, the diffusion effect is not significant in exposed group. In other words, exposed farmers did not reduce the distance from the optimum significantly.

**Table 6.7. Regression of Differences in Distance from Optimum**

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
| exposed | 0.187 | -0.107 |
|  | (0.03) | (-0.02) |
| treatment | -10.949\* | -11.376\*\* |
|  | (-2.56) | (-2.66) |
| education |  | 0.47 |
|  |  | (0.85) |
| female |  | -0.793 |
|  |  | (-0.16) |
| years growing rice | | 0.004 |
|  |  | (0.02) |
| organic |  | -0.294 |
|  |  | (-0.03) |
| own consumption |  | 11.215\*\* |
|  |  | (2.63) |
| constant | 3.145 | -16.8 |
|  | (1.18) | (-1.54) |
| F-test | 3.52 | 2.40 |

Note: *organic* is an indicator variable that is 1 if the farmer uses organic fertilizer; *own consumption* is a indicator variable if the farmer’s household consumes the crop grown on the plot; \* p<0.05, \*\* p<0.01

# 7. Policy Implications

China is the largest fertilizer user in the world. Chemical fertilizer per hectare is also one of the highest in the world. The current rate of nitrogen fertilization in China not only does not significantly improve crop yield, but also leads to serious food safety and environmental problems. The FFS is a mechanism being used in China and other countries to improve farmer knowledge and farming outcomes. This study used a rigorous RCT evaluation to estimate the causal impact of farmer field schools on multiple environmental, social, and economic outcomes.

Reforming the agricultural extension is a major program in China’s agricultural agenda. After three years of pilot FFS projects that disseminated knowledge to greenhouse vegetable farmers in Beijing, the Ministry of Agriculture is considering using FFS as one of the core tools for China’s agricultural extension program. The effectiveness of FFS in reducing excess fertilizer use with its environmental and social-economic impacts is critical information that will be used by Ministry of Agriculture in decisions about scaling up its national FFS program during the upcoming years. The results of this impact evaluation have implications for environmental quality and agricultural sustainability and are relevant to China’s future agricultural policy decisions.

**This evaluation was conducted in an institutional environment that led to diverse implementation outcomes, which provides insights into the potential and limitation of FFS scale-up.** Current economic analysis of FFS in China has provided circumstantial justification for many projects, but these studies tell an incomplete story. When existing studies do not identify the detailed and highly localized institutional settings that make FFS work or not, policy-makers and donors do not know what works, where, and why. Insufficient knowledge of institutions and context also runs the danger of adopting a one-size-fits-all approach to FFS. In our experience, the enthusiasm with which the FFS was embraced and the care with which the protocols were implemented varied significantly. Not all county officials or village heads were equally motivated to ensure the FFS was properly implemented and had a chance to succeed. The recruitment of farmers (sometimes from the explicitly earmarked exposed or refused groups) in order to satisfy a minimum enrollment criterion is but one of the challenges we encountered, not to mention the conducting of parallel training sessions by fertilizer dealers who could have objectives antithetical to the FFS. If our surveys taught us that the farmer use of fertilizers was highly heterogeneous, our field experience taught us that the institutional environment was no less heterogeneous. To us these challenges seem symptomatic of a deep institutional heterogeneity that needs to be first addressed before issues of broad-based adoption and scale up can even be addressed in a systematic way. It is in this spirit, that the recommendations we give in this section are to be taken.

**The evaluation results show mixed FFS effectiveness and therefor suggest that policy makers should revisit plans to scale up FFS in China in the future.** A primary motivation for conducting this study was to guide decisions about whether to scale up FFS programs throughout China to deal with excessive fertilizer use. Based on the results discussed above, we find some evidence—particularly for rice farmers—that FFS participation is significantly associated with balanced fertilizer use by encouraging farmers who use too little fertilizer to increase the amount of fertilizer they are using and guiding farmers who overuse fertilizer to reduce their application. However, the changes in fertilizer use are not dramatic, particularly in terms of reducing overuse, and the effects for tomato farmers are much weaker. While there is some evidence—again, for rice farmers—that the treatment increased farming knowledge and increased yields (only for tomato farmers), control groups saw not insubstantial changes in these outcomes without the FFS mechanism. Overall, while the treatment had some positive impacts, we do not believe the results unambiguously recommend broad-based use or scale up of the FFS program.

**The FFS program is not clearly cost-effective, and MOA should proceed cautiously when considering how to change or expand the program.** FFS is a relatively expensive approach to improving farm practices, and cost-effectiveness has always been a big concern for extension agents and policy makers. Hence, we conducted a basic cost-effectiveness analysis to inform future decisions about continuing or expanding the FFS program in China. FFS expenditures consist of start-up (fixed) costs and operating (variable) costs. Fixed costs included the “training of trainers” workshop and a subsequent “motivation” workshop, costs that do not scale directly with the number of villages targeted or farmers trained. Variable costs are those MOA incurred when running the FFS program in the field, including technical assistance by the project management unit, travel, equipment, etc. We focus primarily on variable costs, because fixed costs could vary significantly in a future FFS rollout. Our analysis found that an FFS program costs between $2,500 and $3,300 per village (~$100-130 per farmer), depending on the crop.[[9]](#footnote-9) A full cost-benefit analysis is necessary to determine whether social benefits outweighed the costs to MOA, but that analysis is beyond the scope of this study. However, given the ambiguous impacts on fertilizer, farmer knowledge, and crop yields, we cannot conclude that the FFS program we evaluated *was* cost-effective. The MOA should consider carefully the value of different outcomes (including private benefits to farmers) when considering scaling up the FFS program.

**FFS training should be designed and rolled out based on local needs, including crops-specific considerations.** Our evaluation results were heterogeneous across crops and famer characteristics, and this should inform future farmer field schools. For example, fertilizer impacts were largest for rice farmers, but those farmers have lower fertilizer use on average. Similarly, rice farmers saw the largest improvements in farmer knowledge, but these farmers have lower educational attainment than tomato farmers, which could be driving the result. Future FFS for rice could focus more increasing general knowledge and yield-improving techniques, while tomato FFS could be designed to leverage farmer knowledge and place greater emphasis on fertilizer use (including reduction). Any existing agricultural census (conducted for gross domestic product calculations) could be very informative in identifying these specific target groups.

**FFS implementation quality was heterogeneous, and MOA should assess ways to improve implementation and quality control if they decide to continue to use or expand the FFS program.** As in most high quality impact evaluations, we worked closely with the implementer (MOA) to ensure the program was carried out as closely to the experimental design as possible. Nevertheless, extension staff in different provinces and counties conducted the FFS with varying levels of motivation and dedication. Consequently, the results from our experiment have high external validity if no major changes are made to FFS implementation. In other words, we believe the results could have been stronger had the program implementation been carried out under more stringent ‘laboratory’ settings. If MOA decides to expand FFS use, we recommend they focus on improving the quality of FFS implementation where feasible.

# References

He, F., Jiang, R., Chen, Q., Zhang, F., & Su, F. (2009). Nitrous Oxide Emissions from an Intensively Managed Greenhouse Vegetable Cropping System in Northern China. Environmental Pollution, 157, 1666–1672.

Hu, R., Yang, Z., Kelly, P., & Huang, J. (2009). Agricultural Extension System Reform and Agent Time Allocation in China. China Economic Review, 20(2), 303-315.

Huang, J., Hu, R., Cao, J., & Rozelle, S. (2008). Training Programs and in-the-Field Guidance to Reduce China's Overuse of Fertilizer without Hurting Profitability. Journal of soil and water conservation, 63(5).

Huang, J., Jia, X., Xiang, C., Hu, R., & Hou, L. (2010). Farmers' Adoption of Nitrogen Management Practice of Upland Summer Maize in North China: An Experimental Design Paper presented at the 117th EAAE Seminar "Climate Change, Food Security and Sesilience of Food and Agricultural Systems in Developing Countries: Mitigation and Adaptation Options" , November 25-27, 2010.

Ju, X.-T., et al. (2009). Reducing Environmental Risk by Improving N Management in Intensive Chinese Agricultural Systems. Proc Natl Acad Sci U S A., 106(9), 3041–3046.

Mangan, J., & Mangan, M. S. (1997). A Comparison of Two Ipm Training Strategies in China: The Importance of Concepts of the Rice Ecosystem for Sustainable Insect Pest Management. Agriculture and Human Values, 15, 209-221.

Ooi, P. A. C. et al. (2005). "The Impact of the FAO-EU IPM Programme for Cotton in Asia." Pesticide Policy Project, Universität Hannover, Germany, Special Issue, Publication Series 9: 139.

PEW Climate Center. (2007). “Climate Change Mitigation Measures In The People’s Republic Of China.” Available online: http://www.pewclimate.org/docUploads/International%20Brief%20-%20China.pdf

Quizon, J., Feder, G., & Murgai, R. (2001). Fiscal Sustainability of Agricultural Extension: The Case of the Farmer Field School Approach. Journal of International Agricultural and Extension Education, 8, 13-24.

The Economist. (2009, Dec 30th). Climate Change after Copenhagen China's Thing About Numbers.

Van den Berg, H., & Jiggins, J. (2007). Investing in Farmers-the Impacts of Farmer Field Schools in Relation to Integrated Pest Management. World Development, 35(4), 663-686.

Xing, G. X., & Zhu, Z. L. (2000). An Assessment of N Loss from Agricultural Fields to the Environment in China. Nutrient Cycling in Agroecosystems, Volume 1.

Yang, P., et al. (2008). Effects of Training on Acquisition of Pest Management Knowledge and Skills by Small Vegetable Farmers. Crop Protection, 27(12), 1504 -1510.

Zhu, Z. L., & Chen, D. L. (2002). Nitrogen fertilizer Use in China – Contributions to Food Production, Impacts on the Environment and Best Management Strategies. Nutrient Cycling in Agroecosystems, 63(2-3).

# Annexes

## A. Sample design

**General Notes**

* Clustered, blocked randomized control trial
  + FFS program delivered at village level = cluster level
  + T & C villages to be matched prior to group assignment
* Power calculations and sampling scheme for Hebei (greenhouse tomatoes) and Anhui (rice) provinces are separate and different
  + need to credibly claim pre-post changes separately for each crop
  + FFS program is tailored to each crop, therefore treatment will differ
* TREATMENT VILLAGES
  + FFS target = 25 FFS participants, of whom 18 will be identified from the beginning, followed, and surveyed in treatment villages
  + therefore in smaller villages where the number of households < 37 (25 FFS + 12 exposed), we have 2 options:
    - no exposed group
    - exposed group comprised of other greenhouse vegetable farmers

**Hebei** (greenhouse tomatoes): Gao Cheng (10 villages), Yong Qing (10 villages), and Rao Yang (16-18 villages)

* 36 villages for 20% pre-post change
* survey target: 15 FFS , 10 exposed farmers and X non-compliers per treatment village; 15 farmers and X non-compliers per control village = **720 + 36X farmers**
  + to account for 15% attrition, recruit: 30 (18T + 12E) and X non-complying farmers in treatment villages and 18 farmers + X non-compliers in control villages = **864 + 36X farmers**
* sampling scheme
  + 3 counties chosen based on 1) total sowing area for greenhouse tomatoes and 2) willingness of county government to participate in study
  + select all villages available: 36
  + match and assign T & C villages after some village data collection

**Anhui** (mid-season rice): Tian Chang & Ju Cao counties

* 56 villages for 15% pre-post change
* target: 15 FFS, 10 exposed farmers, and X non-compliers per treatment village; 15 farmers and X non-compliers per control village = **1120** **farmers + 36X farmers** 
  + to account for 15% attrition, recruit: 30 (18T + 12E) and X non-complying farmers in treatment villages and 18 farmers + X non-compliers in control villages = **1344 + 56X** **farmers**
* sampling scheme
  + 2 counties chosen based on 1) total sowing area for rice and 2) willingness of county government to participate in study
* within each county, eliminate townships in which FFS is not possible for various reasons (see decision log), then sample to achieve geographic/terrain representativeness as cropping data is found to be inaccurate (for example, divide county into 4 quadrants, and sample 1 township from each quadrant)
* then randomly select 7 villages from each township
* because rice villages are large in distance, randomly sample natural village from those in which number of rice households >= 37 (25 FFS + 12 exposed) + 60% refusal rate (estimate from field work) = 60
* match and assign T & C villages after some village data collection at both administrative and natural village levels

**Farmer Recruitment Process**

* eligibility criterion: must grow greenhouse tomatoes/rice this SPRING season (baseline) AND next SPRING season
* TREATMENT group in treatment villages
  + - survey enumerators will screen and select households in the sample that meet the eligibility criterion until they reach 18 eligible households (round 1)
    - once a household has been determined to be eligible, survey enumerators will personally invite farmers to participate in the FFS program by describing the nature of the program, terms and conditions
    - farmers will have one full day to decide whether or not they would like to participate, after which survey enumerators will ask both refusing and accepting households to participate in baseline survey
    - all round 1 farmers will be surveyed, regardless of accepting or declining
    - in round 2 and thereafter, additional farmers will be invited equal to the number of declining farmers in the previous; however only accepting farmers from round 2 onward will be surveyed (see below diagram), and information on declining households will be upweighted by the overall declining rate
    - after we reach 18 target survey HH, we will extend 7 more invitations to other households to fill the minimum FFS quota of 25

example invitation process for first 18 HH

10 accept 🡪 survey

18

8 decline 🡪 survey

invite 8 more

6 accept (survey) 2 decline (do not survey)

invite 6 more

all 6 accept (survey) 0 decline

* total invited: 32 households
* total declined: 10 households
* total declined and surveyed: 8 households
* true declining rate = 10/32 = 31.25%
* surveyed declining rate = 8/32 = 25% 🡪use survey weights to upweight data
* EXPOSED group in treatment villages
  + survey enumerators will screen and select households in the second sample that meet the eligibility criterion until they reach 12 eligible households
  + once a household has been determined to be eligible, survey enumerators will ask whether it would be interested in participating in a survey
  + willing households will be interviewed
* CONTROL group in control villages
  + survey enumerators will screen and select households in the sample that meet the eligibility criterion until they reach 18 eligible households
  + once a household has been determined to be eligible, survey enumerators will ask whether it would be interested in participating in a survey
  + willing households will be interviewed

## B. Power calculations

Based on existing publications (Chen et al., 2006; Cui, 2005; He et al., 2009; Ju et al., 2009; Zhu & Chen, 2002), second-hand statistics (viz. China’s National Agricultural Costs and Returns compilation 2010), previous fieldwork conducted by CCAP (Hu et al., 2007; Huang et al., 2008; Jia & Fan, 2010), and personal communication with local researchers, we obtained and calibrated means and standard deviations for nitrogen fertilizer usage rate for both types of crops: rice and greenhouse vegetables. The two crops yielded similar standardized effect sizes, and we adopted the slightly more conservative one (rice) and conducted power calculations for a range of minimum desired effect sizes, from 10 to 20 percent. In our power calculations, we have also allowed for various correlations between farmer outcome variables, ranging from 0.05 to 0.20. In the proposal we set *n*, or the number of farmers per cluster (village), at 20 treatment and 20 control (in FFS treatment villages, we also include 20 additional farmers who are in the “exposed” group), but it is feasible to use somewhat smaller group sizes, as the number of individuals within a cluster does not have as large of an effect on overall power as the number of clusters itself.

We anticipate approximately a three percent attrition rate in the survey sample, based on previous CCAP field work in surveying farmers in which the authors found that farmers tended to drop out of similar agricultural studies at a rate of no more than three percent (Huang et al., 2010; Huang et al., in press).

We also predict a drop-out rate of no more than 10% for FFS treatment group farmers based on the following reasons. First, the farmers will receive invitation letters before they make their decisions to participate in the FFS program, thereby ensuring their interest in the program. Second, the FFS program is a new and participatory process that has been shown by previous pilot studies to attract farmers to participate in China. And third, farmers understand that knowledge of pest management and fertilizer use is highly related to yield outcomes and income.

Given the above, the choice of 20 farmers per group conservatively incorporates the range of attrition rates that we believe we will encounter over the duration of the study. Even if we were to lose five farmers per group (equivalent to an attrition rate of 25 percent), we would retain enough power to detect the desired effects (see line highlighted in green in Table 1). We believe this consideration is important for possible contingencies that may arise.

Table C.1 shows the power calculation parameters that were used in our power calculations. The power is set at 80 percent and the significance level at 0.05. The top half of the table presents a conservative benchmark against which we varied each of the parameters, which are in turn highlighted in bold font. The bottom half of the table presents a slightly less conservative benchmark, varying the same parameters. The lines highlighted in grey indicate the parameters that allow us to remain within our survey budget, and the line highlighted in yellow indicates the design with the most conservative parameters that still lies within the survey budget. This is the sample design that we adopt. It assumes a 15 percent minimum detectable change in nitrogen fertilizer usage before and after the FFS intervention. We allow intra-cluster correlation to reach a correlation of 0.10, and we conservatively assume that no other covariates will have any additional explanatory power. This sample design calls for 52 villages (26 treatment and 26 control) and 1,560 farmers. We conservatively account for attrition with the figure of 20 farmers per group.

**Table C.1. Power Calculations**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | alpha = 0.05, power = 80% | | | | |  |  |
|  | **Parameters** | | | | |  |  |
|  | **delta** | **rho** | **n** | **covariate** | **N** | **total sample size** | **# FFS** |
| conservative benchmark | **0.206** | 0.20 | 20 | 0.00 | 182 | 5,460 | 91 |
|  | **0.310** | 0.20 | 20 | 0.00 | 81 | 2,430 | 41 |
|  | **0.413** | 0.20 | 20 | 0.00 | 48 | 1,440 | 24 |
|  | 0.206 | **0.15** | 20 | 0.00 | 145 | 4,350 | 73 |
|  | 0.206 | **0.10** | 20 | 0.00 | 111 | 3,330 | 56 |
|  | 0.206 | **0.05** | 20 | 0.00 | 75 | 2,250 | 38 |
|  | 0.206 | 0.20 | **15** | 0.00 | 191 | 4,298 | 96 |
|  | 0.206 | 0.20 | **10** | 0.00 | 210 | 3,150 | 105 |
|  | 0.206 | 0.20 | 20 | **0.10** | 166 | 4,980 | 83 |
|  | 0.206 | 0.20 | 20 | **0.15** | 159 | 4,770 | 80 |
|  | 0.206 | 0.20 | 20 | **0.20** | 151 | 4,530 | 76 |
| less conservative benchmark | **0.310** | 0.10 | 20 | 0.10 | 48 | 1,440 | 24 |
|  | **0.413** | 0.10 | 20 | 0.10 | 28 | 840 | 14 |
|  | **0.206** | 0.10 | 20 | 0.10 | 104 | 3,120 | 52 |
|  | 0.310 | **0.15** | 20 | 0.10 | 61 | 1,830 | 31 |
|  | 0.310 | **0.20** | 20 | 0.10 | 75 | 2,250 | 38 |
|  | 0.310 | **0.05** | 20 | 0.10 | 34 | 1,020 | 17 |
|  | 0.310 | 0.10 | **15** | 0.10 | 52 | 1,170 | 26 |
|  | 0.310 | 0.10 | **10** | 0.10 | 62 | 930 | 31 |
|  | 0.310 | 0.10 | 20 | **0.15** | 46 | 1,380 | 23 |
|  | 0.310 | 0.10 | 20 | **0.20** | 44 | 1,320 | 22 |
|  | 0.310 | 0.10 | 20 | **0.00** | 52 | 1,560 | 26 |

## C. FFS Curriculum

**Table C.1. FFS Curriculum: Recommended Technology Guidance in Anhui (rice farming)**

|  |  |
| --- | --- |
| **Technology** | **Content** |
| Fertilizer use | * Total amount of nitrogen fertilizer use should be 165-180 kg/ha * Appling earing fertilizer * Increasing potassium fertilizer use to avoid lodging |
| Crop protection | * Helping farmers to identify main plant diseases through participation of FFS（False smut, Leaf blast, Panicle rice blast, Sheath blight, Plant-hoppers, Leaf-roller, Rice stem borer） * Teaching farmers commonly used control methods and integrated control measures * Changing commonly wrong conceptions and methods on fertilizer use * Enhancing the environmental and ecological awareness of the farmers |
| Cultivation | * Recommending anti-lodging varieties * Improving and enhancing the transplanting density * Drying paddy field in sunshine to ensure effective tillers * Changing “cutting down water supply in the late period” behavior |
| Response to unusual weather | * Early drought (adjusting seeding and transplanting time) * High temperature damage in flowering period (delaying sowing date) * Irrigation and drainage during typhoon period (and lasting rain period) * Sheath blight and False smut caused by typhoon and lasting rain * Pre- and post-low temperature period (selection of species) |

**Table C.2. FFS Curriculum: Recommended Technology Guidance in Hebei**

**(tomato farming, short growing season)**

|  |  |
| --- | --- |
| **Technology** | **Content** |
| Irrigation and fertilization | 1) Control excessive application of organic fertilizers. Base fertilizer should be 30,000 – 45,000 kg/ha (if using cow manure, then it should be 45,000-60,000 kg/ha). Old vegetable plots that have been used over 5 years should apply 15,000 – 30,000 kg/ha of Straw compost or bio-organic fertilizer.  2) Base chemical fertilizer should use 900-1200 kg/ha of superphosphate. [Phosphatic fertilizer](http://www.iciba.com/phosphatic_fertilizer) should use 10-15% less for old vegetable plots. Do not use chemical nitrogen and K fertilizer.  3) The total amount of after fertilizer used during the whole growth period should be 300-375 kg/ha of nitrogen and 450-600 kg/ha of K2O. After fertilizer should reduce 15-20% every time for old vegetable plots.  4) After fertilizer should be applied based on the growth stage. The first fertilizer starts when the fruit enlarged to the size of walnut. 4-5 times of after fertilizer is fine.  5) Strictly control the amount of irrigation to prevent excessive humidity, which may cause diseases. |

**Table C.3. FFS Curriculum: Recommended Technology Guidance in Hebei (tomato farming, long growing season)**

|  |  |
| --- | --- |
| **Technology** | **Content** |
| Irrigation and fertilization | 1) Control excessive application of organic fertilizers. Base fertilizer should be 45,000 – 60,000 kg/ha (if using cow manure, then it should be 60,000-75,000 kg/ha). Old vegetable plots that have been used over 5 years should apply 30,000 – 45,000 kg/ha of Straw compost or bio-organic fertilizer.  2) Base chemical fertilizer should use 1200-1500 kg/ha of superphosphate. [Phosphatic fertilizer](http://www.iciba.com/phosphatic_fertilizer) should use 10-15% less for old vegetable plots. Do not use chemical nitrogen and K fertilizer.  3) The total amount of after fertilizer used during the whole growth period should be 525-600 kg/ha of nitrogen and 525-600 kg/ha of K2O. After fertilizer should reduce 15-20% every time for old vegetable plots.  4) After fertilizer should be applied based on the growth stage. The first fertilizer starts when the fruit enlarged to the size of walnut. 6-8 times of after fertilizer is fine.  5) Strictly control the amount of irrigation to prevent excessive humidity, which may cause diseases. |

1. \* Authors are listed in alphabetical order. Burger and Kumar are with RAND, Fu and Gu with the Pardee RAND Graduate School, and Jia and Mingliang are with the Chinese Center for Agricultural Policy (CCAP), Beijing, China. Corresponding author: Krishna B. Kumar, RAND, 1776 Main Street, Santa Monica, CA 90401, [kumar@rand.org](mailto:kumar@rand.org). We thank 3ie and its and its anonymous reviewers for feedback that has considerably improved this report. We are also grateful to Dr. Jikun Huang, CCAP, for his tremendous technical advice and organizational support, and Dr. Fusuo Zhang, CAU, for his many insights into Chinese agriculture. Thanks to our research assistant, Ma Tao, for excellent research and field support. [↑](#footnote-ref-1)
2. “Green Revolution in India Wilts as Subsidies Backfire.” February 22, 2010. http://online.wsj.com/article/SB10001424052748703615904575052921612723844.html [↑](#footnote-ref-2)
3. Survey questionnaires are available from the authors upon request [↑](#footnote-ref-3)
4. While measuring the direct environmental impact is beyond the scope of this project, it is worth noting that increased fertilizer usage at the lower end of the distribution would cause increased greenhouse gases offsetting any declines from reduced fertilizer usage at the upper end. [↑](#footnote-ref-4)
5. The details of the FFS curriculum are provided in the annexes. [↑](#footnote-ref-5)
6. This optimum range is consistent with generally optimal fertilizer use recommended by agronomists. In his 2002 paper on nitrogen fertilizer use in China, Zhu notes, *“*Crop yield is governed by a series of factors, some of which are difficult to predict. Therefore, even if the optimum N application rate is a rough range, it is still much better than applying without guidance. From the data obtained in some long-term field experiments conducted on the major crops in agricultural regions, a general range of N application rate for cereal crops is recommended as 150–180 kg N ha−1 (Zhu, 1998a). In practice, it should be adjusted according to the local conditions (such as variety, irrigation, etc.).” [↑](#footnote-ref-6)
7. When we control for the distance from the optimum in the baseline (to allow for potential lack of balance between the groups and the unusual weather in the baseline), participation is still significantly negative at the 10% level, showing that the FFS was effective in reducing the distance from optimal fertilizer usage. [↑](#footnote-ref-7)
8. Additional results for an intermediate level of inclusiveness that does not include the R-T group are available upon request to the authors. [↑](#footnote-ref-8)
9. These amounts include only variable costs, not fixed costs; including fixed costs will only increase the average cost per village in many cases further decreasing cost-effectiveness. [↑](#footnote-ref-9)