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Analysis

The Role of Agricultural Training on Fertilizer Use Knowledge: A Randomized Controlled Experiment

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ABSTRACT

Improving farmers' knowledge of fertilizer use through agricultural training has been considered a prerequisite to scientific fertilizer management. However, empirical evidence of the effect of agricultural training on farmers' fertilizer management knowledge is inconclusive. Based on a randomized controlled experiment involving 687 farmers that mitigates selection bias in the data, this paper identifies the treatment effect of agricultural training on farmers' fertilizer management knowledge in Chinese rice production. Results indicate that the fertilizer management knowledge of field-guidance farmers improved by almost 40%. However, such knowledge acquisition did not occur for curriculum-trained farmers. We also find that there is no evidence of knowledge diffusion from trained farmers to exposed farmers in the same village.

1. Introduction

Numerous studies provide conclusive evidence that Chinese farmers apply too much fertilizer in agricultural production (Gong et al., 2011; Sun et al., 2016). The rate of fertilizer over-application in rice production is approximately 10%–30% in China (Huang et al., 2008; Jiang and Li, 2016). Negative environmental consequences occur because of fertilizer over-application, including global warming, soil acidification, and water eutrophication in China (Ha et al., 2015; Zhu and Chen, 2002). It is estimated that the greenhouse gas (GHG) emissions from fertilizer usage contribute around 30% of the GHG emissions in agriculture, which is equal to 5% of China's total GHG emissions (Huang et al., 2015). In the past two decades, excessive fertilizer use decreased potential of hydrogen (pH) of soil for 0.5 units in the major crop production regions (Guo et al., 2010). Fertilizer over-application increased river nutrient loads, which results in eutrophication in many Chinese rivers (e.g., Yangtze, Yellow and Pearl rivers) and seas (e.g., Bohai Gulf, Yellow sea and South China sea) (Bellarby et al., 2017). In addition, fertilizer expenditures account for around 25%–40% of the total production cost in crop production. Thus, decreasing fertilizer usage is of great importance to protecting the environment, improving farmer incomes, creating sustainable agricultural production, and mitigating climate change in China (Huang et al., 2015).

It is widely acknowledged that inappropriate fertilizer management is the main reason for fertilizer over-application (Smith and Siciliano, 2015). The Chinese government has implemented several policies, such as soil testing, fertilizer recommendation programs, and an organic fertilizer subsidy to induce farmers to adopt appropriate fertilizer management practices (Zhang et al., 2016). However, there has been little change in farmers' inappropriate fertilizer management (Luo et al., 2014). The proportion of farmers using soil-tested fertilizer and organic fertilizer is less than 15%, and most farmers still apply much more fertilizer than recommended (Smith and Siciliano, 2015).

A primary explanation for fertilizer over-application is that farmers lack adequate knowledge of fertilizer management (Guo et al., 2015; Huang et al., 2015). In particular, according to Kaiser and Fuhrer (2003), and Redman and Redman (2014), farmers are lacking three different domains of knowledge. The first is the effectiveness knowledge which addresses the awareness associated with impacts of fertilizer over-application. For example, Huang et al. (2008) declared that many farmers in China simply do not know that they are overusing fertilizer. They have insufficient knowledge about the effects of fertilizer over-application. Zhu and Chen (2002) reported that only 20% of farmers know that fertilizer over-application will result in water eutrophication and agricultural system degradation. The second is the procedural knowledge which refers to how to use fertilizer in an effective way. Most farmers hold the view that more fertilizer use always leads to higher crop yields and a reduction of overall fertilizer use will

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result in a definite yield loss (Jia et al., 2015; Huang et al., 2015). The third is the declarative knowledge. It refers to the basic knowledge of fertilizer use and how it might work in agricultural systems. Knowledge acquisition is generally considered a prerequisite to the adoption of environmentally-friendly technologies, such as fertilizer management technologies (Feder, 1979). Effectiveness knowledge can enhance farmers' perceptions about how or even if their fertilizer use behaviors really impact the environment, which is assumed to determine behavioral change. Procedural knowledge correlates closely with the potential inhibiting factors which is important in fostering behavior change regarding fertilizer use. Declarative knowledge reduces farmers' uncertainty regarding fertilizer reduction which allows farmer to reduce fertilizer over-application (Ajzen et al., 2011; Kaiser and Fuhrer, 2003).

Agricultural training provided by extension technicians is a primary channel of farmers' fertilizer management knowledge acquisition (Genius et al., 2014). Since the late 1980s, reforms in the Chinese agricultural extension system have enabled it to become financially self-sufficient (Hu et al., 2009). In contemporary China, the agricultural extension system faced great challenges in providing appropriate knowledge to millions of farmers owing to limited budgets, low accountability, and poor performance incentives for extension technicians (Jin et al., 2015). Hence, understanding the effectiveness of agricultural training on farmers' fertilizer management knowledge may help Chinese governments design agricultural training programs that encourage farmers to manage fertilizer in a more environmentally-friendly manner, thus limiting some of the environmental damage of fertilizer.

Several recent studies have focused on the effectiveness of agricultural training on farmers' fertilizer management knowledge. However, empirical evidence on their impact has been mixed. Based on data collected in Yunnan Province in China, Yang et al. (2008) found that farmers' knowledge improves considerably after participating in a farmer field school (FFS), but the knowledge of curriculum-trained farmers has not improved. Huang et al. (2015) also found agricultural training has a positive impact on Chinese farmers' fertilizer management knowledge acquisition. In addition, based on a FFS program conducted in the Anhui and Hebei provinces in China, a recent study by Burger et al. (2016) confirmed that trained farmers obtained significantly more fertilizer management knowledge than non-trained farmers. However, Guo et al. (2015) did not find a statistically significant improvement in the knowledge of fertilizer management among FFS farmers.

Although considerable research has been devoted to examining the effectiveness of agricultural training on farmers' fertilizer management knowledge, far less attention has been paid to the following aspects of agricultural training impact studies, including controlling for selection bias, treatment effect of different agricultural training approaches and knowledge diffusion effect of agricultural training.

First, the previous studies did not control for the econometric problem of selection bias in agricultural training, which may have affected the estimation results. Selection bias in impact assessments of agricultural training arises from the non-random placement of the program, or from farmers' self-selection into the program (Godtland et al., 2004; Schreinemachers et al., 2016). For instance, villages with a higher income and closer to cities were often purposely chosen to receive agricultural training because they typically perform better in the program examination (Guo et al., 2015). Farmers who are more productive, better-educated, and have larger operations, are more likely to receive agricultural training. Therefore, data regarding knowledge acquisition of trained farmers does not reveal the actual knowledge gain of trained farmers in the absence of agricultural training.

Second, previous studies appear to ignore the impact of different agricultural training approaches. There are various approaches to agricultural training in China, including lectures, training and visits, field guidance, and FFSs (Jia et al., 2015). Understanding the effectiveness of different agricultural training approaches on farmers' fertilizer management knowledge is essential for the effective design of agricultural extension programs that promote environmentally-friendly agriculture development in China.

Third, it is also not clear whether agricultural training has a diffusion effect on farmers' fertilizer management knowledge. Diffusion effect means that non-trained farmers in the trained village may improve their fertilizer management knowledge by learning from the trained farmers (Rola et al., 2002). Estimating the diffusion effect of agricultural training has great practical importance for the design of more cost-effective agricultural training programs, and is useful in reducing the government's financial burden associated with publicly funded extension systems in China.

With these previous studies in mind, we use a randomized controlled experiment (RCT) to correct for the non-random selection bias problem (Ansell and Bartenberger, 2016; Greenstone and Gayer, 2009). We explore whether agricultural training can improve farmers' fertilizer management knowledge and which types of agricultural–training approaches are more effective in enhancing farmers' fertilizer management knowledge. We are also interested in whether agricultural training has knowledge diffusion effect. To achieve these goals, we first estimate the effects of agricultural training, in general, on farmers' fertilizer management knowledge. Second, we compare the heterogeneous effects of different agricultural training approaches by separately estimating the impact of both curriculum training and field guidance on farmers' fertilizer management knowledge. Third, we explore the diffusion effects of agricultural training on farmers' fertilizer management knowledge. To address the possible endogeneity problem, we also use the instrumental variable (IV) regressions for robustness check.

This work contributes to the current literature on treatment effect of agricultural training on knowledge in at least two ways. First, we estimate the impact of agricultural training on knowledge using a RCT involving 687 rice farmers in China. The RCT ensures farmers are randomly selected to participate in agricultural training programs, mitigating selection bias and resulting in a more precise casual-inference estimation (Greenstone and Gayer, 2009; Bulte et al., 2014). The advantages of RCTs listed above are the reason behind that method's increasing popularity in treatment effects (Duflo et al., 2007). As such, more RCTs should be conducted (Elisabeth et al., 2016). The second contribution is our investigation into the effects of different agricultural training approaches. By further differentiating the different approaches of agricultural training, one can compare and determine the most suitable approaches for agricultural extension agencies to implement.

We have organized the rest of this paper in the following way. Section 2 gives detailed information on the design of the RCT. Section 3 develops a conceptual framework underlying the impact of agricultural training on farmers' fertilizer management knowledge and describes the estimation approach used. Section 4 describes the data employed to evaluate agricultural training impacts on farmers' fertilizer management knowledge. Section 5 shows the estimation results. Section 6 discusses the limitations of the study and makes recommendations for further research. The final section gives conclusions.

2. Design of the Randomized Controlled Experiment

2.1. Experiment Site Description

We implemented a RCT in Gaoyou city (GY) of Jiangsu Province and Yichun city (YC) of Jiangxi Province in 2013 (Fig. 1). The reason that we selected these two provinces as experiment sites is that Jiangsu and Jiangxi are the major rice producing provinces in China. In 2013, the rice production of these two provinces accounted for approximately 20% of Chinese rice production. Furthermore, Jiangsu and Jiangxi are located in the eastern and central areas of China, respectively. Selecting two different provinces enables us to verify the generality of the effects