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Research article

Knowledge training and the change of fertilizer use intensity: Evidence from wheat farmers in China

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ABSTRACT

High fertilizer use intensity is a serious issue throughout China, with adverse environmental and economic impacts. The lack of knowledge of Chinese farmers has been found to be the primary constraint. Using a propensity score matching (PSM) method to create a credible counterfactual analysis, this study examines the causal effects of two kinds of knowledge training approaches, traditional one-time training and in-field guidance, on the change of fertilizer use intensity of wheat farmers in China. The estimated results provide evidence that the traditional one-time training approach has a small effect on fertilizer use intensity reduction (only a 4% average), while the in-field guidance has a larger effect on fertilizer use intensity reduction (a 17% average). Moreover, we also found knowledge training has heterogeneous treatment effects. The reduction in fertilizer use intensity is larger for the farmers who are male and middle aged, have acquired a middle level of education, receive a lower share of off-farm income, collect a lower income, and operate a larger farm.

1. Introduction

The widespread use of fertilizer has greatly contributed to the huge increases in food production in China. China is now the world's largest producer, consumer, and importer of fertilizer, consuming over one-third of the world's fertilizer and accounting for approximately 90% of the global fertilizer consumption increase since 1981 (Liu and Diamond, 2005). However, several studies provide conclusive evidence that high fertilizer use intensity has become widespread across China (Ma et al., 2008; Yan et al., 2012; Ha et al., 2015). High fertilizer use intensity has contributed to a range of environmental problems, including greenhouse gas emissions, water-borne pollution, the degradation of soil and water quality, and the loss of biodiversity and ecosystem services (Smith and Siciliano, 2015; Meng et al., 2017; Li et al., 2017). A recent study indicated that an approximate 50% reduction of fertilizer-induced nitrous oxide emissions could be achieved in China's cropland without impacting the crop yield by managing the currently overused fertilizers (Tian et al., 2012). Moreover, according to China's National Development and Reform Commission (NDRC), fertilizer expenditures accounted for the largest component of cost for all of the staple crops in the country (approximately 25%–40%) in 2014. Thus, reducing fertilizer use intensity is of great importance to improving farmer incomes, protecting the environment, creating sustainable agricultural production, and mitigating climate change in China (Huang et al., 2015).

A number of factors have caused high fertilizer use intensity in China. Increasingly scarce land, falling real input prices, and relatively favorable trade policies that reduced the implicit tax on agriculture all encouraged the farmers to use even more fertilizer in their production during the 1980s. However, the primary reason for high fertilizer use intensity is rooted in the lack of knowledge and information by the end users because the majority of the hundreds of millions of Chinese farmers have received limited education on the value and the use of plant nutrients (Huang et al., 2008). Many empirical studies have verified that knowledge training can lead to decreased fertilizer use intensity, again with no loss of the yield. For

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example, a number of studies show that through knowledge training, fertilizer use intensity could be reduced by approximately 15%–30% in rice production in China without compromising the yield or even increasing the yield (Hu et al., 2007; Huang et al., 2008, 2015). Similar effects were also found in maize and wheat studies. For example, Huang et al. (2012) and Jia et al. (2013) found that knowledge training was effective in reducing fertilizer use intensity by 20%–22% in maize production. Jia et al. (2015) showed that knowledge training effectively reduced nitrogen use intensity by 7% with no impact on the yields in wheat production.

We identity some drawbacks from the existing literature. First, the previous studies do not properly control for potential differences between the trained farmers and the farmers in the comparison group (non-trained farmers), making it difficult to draw definitive conclusions. The observed difference could arise from the non-random strategic program placement or from farmer self-selection for participation in knowledge training. For instance, knowledge training villages were often purposively selected for the irrelative advantages in economic development level (Guo et al., 2015). Participation in knowledge training programs is not random and is strongly correlated with unobservable farmer characteristics (e.g., managerial skill and motivation) that may be correlated to fertilizer use intensity. Failure to properly account for the program assignment or the self-selection issues in an evaluation exercise would lead to biased inferences about the impact of the program.

Second, we also do not know the treatment effect of different knowledge training approaches. Previous literature examining the effect of knowledge training often broadly defined knowledge training as the number of training sessions offered or the number of participants in a region. As Huang et al. (2015) noted, these measures may not be able to adequately capture the true effect of knowledge training. Having an understanding of the effects of various training approaches (e.g., one-time training vs. in-field guidance) may help in designing future extension programs that encourage the farmers to adopt sustainable agriculture technologies in China and in other developing countries.

Third, previous studies ignore the heterogeneous treatment effects of knowledge training. We do not know which groups of the trained farmers, such as gender groups or farmers who have large-scale farms or secondary employment, are more responsive to the knowledge training program. This is important and relevant to Chinese agriculture because of the emerging role of off-farm employment for rural labor and scale farming of agriculture. On the one hand, a large number of rural residents have been moving from the countryside to the city, from underdeveloped economic areas to developed areas. In 2013, 19% of rural labor engaged in off-farm employment in a local town, and 31% of labor in rural areas migrated out of the local town (Liu et al., 2016). Farming is now often the responsibility of women who have young children and elderly and middle-aged residents who have limited education (Smith and Siciliano, 2015). Consequently, the proportion of net income from off-farm income has become the most disequalizing component of rural household incomes (Fang and Rizzo, 2011). On the other hand, in the past, farming in China has been dominated by smallholder farmers who have on average approximately 0.7 ha of farmland. However, in recent years, the Chinese government has been encouraging large-scale farming by promoting land transfer to capable farmers. Consequently, scale farming in China has developed rapidly. By the end of 2014, 870,000 farm families on average cultivated 14 ha of rural land, and 3.17 million specialized households on average cultivated 7 ha of rural land (Zuo et al., 2015). Against this background, identifying the groups of farmers who are more responsive to knowledge training can support future program targeting and is crucial for China if the country wants knowledge training to be an effective tool for agricultural and ecosystem advisory services.

The objective of this study is to empirically examine the effects of knowledge training on the change of fertilizer use intensity of the wheat farmers in China. Specifically, we aim to answer two questions. First, does knowledge training have any effect on the change of farmers' fertilizer use intensity? If so, which knowledge training approach is more effective? Second, which type of farmer is more responsive to knowledge training? This paper contributes to a growing impact evaluation literature in at least two ways. The first contribution of the paper is to identify the casual effect of different knowledge training approaches on the farmer's fertilizer use intensity in China, employing a non-experimental evaluation strategy. By further differentiating the different approaches of knowledge training, one can compare and determine the more suitable approaches for agricultural extension agencies to reach out to the farmers. The second contribution is the paper's use of key socioeconomic characteristics of the sample farmers to document the evidence for the heterogeneous treatment effects of the knowledge training program.

2. Data and methodology

2.1. Data collection

This analysis, conducted by the authors in April 2014, used data that were collected from a nearly national representative survey of 1060 wheat farmers in 6 provinces of rural China. The samples were selected through stratified random sampling. First, 6 provinces were selected from China's major agro-ecological zones from a list of provinces arranged in descending order of gross value of industrial output (GVIO). GVIO was used on the basis of the conclusion of Rozelle (1996) that GVIO is one of the best predictors of the standard of living and development potential and is often more reliable than net rural per capita income. According to the above procedure, Jiangsu (representing the southeast coastal wheat production areas of Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan), Hebei (representing the central wheat production areas of Anhui, Hubei, Jiangxi, and Hunan), Shandong and Henan (representing the northern wheat production areas of Beijing, Tianjin, Hebei, Shanxi, Shandong, and Henan), Heilongjiang (representing the northeastern wheat production areas of Jilin, Liaoning, Heilongjiang, and Inner Mongolia), Sichuan (representing the southwestern wheat production areas of Sichuan, Chongqing, Guizhou, Guangxi, Yunnan, and Tibet) were selected.

From each province, 3 counties were randomly selected. Within each selected county, 3 villages were chosen, following the same procedure as the province selection. Hence, in each sample province, we selected 9 villages (1 province × 3 counties × 3 villages). Altogether, we selected 54 villages. Finally, we randomly selected 20 farmers according to the roster of each village. As a result, a total of 1060 wheat farmers in 54 villages from 18 counties and 6 provinces were surveyed using the standardized survey instrument.

A structured questionnaire was used to obtain the primary data. The questionnaire basically has three parts. The first part relates to the information regarding household-level and farm-level characteristics, including the householder's age, education level, off-farm income, cultivated areas, and soil quality. The second part collected information about knowledge training participation of farmers. The third part involved the farmer's fertilizer use intensity and other inputs in wheat production. Besides the questionnaire, we also conducted a village survey to collect valuable information about the socioeconomic characteristics and the knowledge training program characteristics of the village.