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Identifying entry points to improve fertilizer use efficiency in Taihu Basin, China

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ABSTRACT

Overuse of fertilizers in China causes environmental problems and high costs for farmers. In this paper we aim to identify entry points to improve fertilizer use efficiency in Taihu Basin, China. We use stochastic frontier analysis to estimate the technical and fertilizer use efficiency of rice production based on a survey held among 320 households in Wuxi, Zhenjiang and Changzhou, located upstream of Taihu Lake. Subsequently, Tobit model is applied to analyze factors influencing fertilizer use efficiency. The average technical efficiency and fertilizer use efficiency in this area in 2008 were 84.2% and 25.4% respectively. On average, rice production is thus efficient, but fertilizer use efficiency can be substantially improved. The results of the regression analyses explaining fertilizer use efficiency indicate that although extension services have stimulated the use of formula fertilizer in Taihu Basin, the use of formula fertilizer has not (yet) improved fertilizer use efficiency. Environmental awareness on water pollution and on the effect of fertilizers, off-farm income and a positive risk attitude have a significant positive effect on fertilizer use efficiency in Taihu Basin. Possessing a car or truck, labor intensity and the occurrence of disasters, on the other hand, have a significant negative effect on fertilizer use efficiency. Policies aimed at improving fertilizer use efficiency may therefore focus on increasing knowledge on the environment and fertilizer management, improving extension services and encouraging farmers to migrate or work off-farm.

Introduction

Fertilizer use is a major determinant of grain yields. According to the Food and Agriculture Organization (FAO), fertilizer globally contributes 40% to 60% to yield increases. In China the figure was 57% between 1978 and 2006 (Wang and Xiao, 2008). Fertilizer use, especially the use of nitrogen (N) in China, however, faces severe problems of overuse and low efficiency. Fertilizer input intensity in China is around 60% higher than the world average. N use efficiency only reaches 25% to 30%, which is much lower than the world average (Zhang et al., 2008). The overuse and inefficient use of fertilizer has generated negative environmental consequences, such as water eutrophication and pollution (Uri, 1997), biodiversity loss (Asai et al., 2010), imbalance of soil nutrients and soil compaction and salinization (Feng, 2010), and climate change (Ru, 2008).

Taihu Basin, an agriculturally productive region in China, is characterized by the high application of fertilizers. Fertilizer use in the area, especially the use of N, is 50% higher than the national average (Wang et al., 2003). N use efficiency is only about 19.9% in Jiangsu, a province located upstream of Taihu Basin (Peng et al., 2002). Water eutrophication and pollution is extremely serious in this region. It caught public attention because of a major blue-green algae bloom, which led to a public drinking water crisis in Wuxi, taking over the Taihu Lake in May 2007. Agricultural non-point source pollution, caused by fertilizers and pesticides from arable farming, the emission of animal waste from livestock breeding and inputs of feedstuff and fertilizers in aquaculture, have become the most important causes of water eutrophication and pollution in the Taihu Basin (Zhang et al., 2001; Qin et al., 2007), and contributed around 59% to total nitrogen (TN) and 30% to total phosphorus (TP) in Taihu Lake in 2000 (Yang and Wang, 2003). Fertilizer use contributed an estimated 43.9% to agricultural non-point source pollution in Jiangsu province (Ge, 2011), indicating the influence of arable farming.

Available research on factors affecting fertilizer (over)use and fertilizer use efficiency can be divided into two groups. One group examines determinants of fertilizer application in order to identify ways to reduce fertilizer input in agriculture (Zhou et al., 2010; Li et al., 2012; Beshir et al., 2012). Household head characteristics, farm characteristics and off-farm employment are the main determinants examined in these studies. The other group examines fertilizer use efficiency and its influencing factors in order to increase fertilizer use efficiency in agriculture. Stochastic frontier functions estimated from yearbook data, from 1996 to 2009, or survey data, collected in 2007, provide efficiency score estimates that range from 0.3 to 0.5 (Wu, 2011; Yang and Han, 2011). In

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these studies, household characteristics, farm characteristics and extension services are the main factors investigated.

Formula fertilizer (FF) is considered to be an effective technology to increase fertilizer use efficiency, because the contents of nitrogen, phosphorus and potassium in the fertilizer are adapted to the requirements of the fields. This technology has been promoted in the region to reduce fertilizer use, and specifically nitrogen, since 2005. To our knowledge, there has been no research that analyses the effect of FF use on fertilizer use efficiency in China. The factors driving fertilizer overuse and fertilizer use efficiency are rather unclear. Our research intends to (1) estimate the technical and fertilizer use efficiency of rice producing households in the Taihu Basin, as rice is the dominant crop in this area, and (2) examine how FF and other factors affect fertilizer use efficiency among these households, based on farm household survey data. The results are used to identify potential entry points for improving fertilizer use efficiency as a way to reduce the environmental burden caused by fertilizer overuse in the basin.

In this paper, we first estimate the extent to which rice production can increase, and fertilizer input could be saved under existing technologies. Subsequently, we investigate the factors that influence fertilizer use efficiency. Finally, we identify entry points that may be used to improve the efficiency. The paper is organized as follows. Study area and data source section presents an overview of the study area and data sources. Model choice section presents the frontier analysis method that we use. Model specification section discusses model specification and estimation methods of technical efficiency, fertilizer use efficiency and its influencing factors. Estimation results section provides the estimation results and discusses the major findings. The paper ends with a conclusion and a discussion of policy implications in Conclusions section.

Study area and data source

Taihu Basin is located in the eastern part of China (Fig. 1), with superior natural conditions which provide a good basis for agricultural production (Ellis and Wang, 1997; Reidsma et al., 2011). The area has 36 million inhabitants, i.e. 2.9% of the population of China, of which around one half is engaged in agriculture. The urbanization rate is 52.9%, but more and more people are moving from the rural area to urban area. The arable land area is 22.6 million mu (1.5 million ha), which is 1.8% of the arable land in China. Of the arable land, 18.6 million mu (1.2 million ha) are irrigated land, and 4.1 million mu (0.27 million ha) are dry land. Agricultural production on these two land types are respectively 100% and 37% higher than the average agricultural production per mu in China.

To capture the agricultural production activities and the households' characteristics of Taihu Basin, a farm household survey was conducted in 2008 in three municipalities, Zhenjiang, Wuxi and Changzhou. These three municipalities are located upstream of Taihu Lake in Jiangsu Province, from where 70% of the total amount of water flows into the lake. Rice is the dominant crop in the Taihu Basin, with 90% of the arable land being used for growing rice paddy. The information collected during the survey includes inputs and outputs of crop production, and farm and farmers' characteristics. Out of the 320 households that were interviewed, 221 households (97 in Wuxi, 77 in Changzhou and 47 in Zhenjiang) provided sufficient information on rice production and characteristics that can be used for our analysis.

Model choice

A farm is technically efficient if inputs are used in an efficient way to produce one or more outputs. Two methods, data envelopment analysis (DEA) and stochastic frontier analysis (SFA), are most often used in technical efficiency analysis. DEA, known as the non-parametric method, can solve multi-output problems, and assumes no measurement or sampling error. SFA, the parametric method, however, measures technical efficiency based on a specific production functional form, and its results are more robust and hardly influenced by outliers. Following Feng (2008) and Tan et al. (2010), we chose SFA as the method to analyze rice production efficiency in

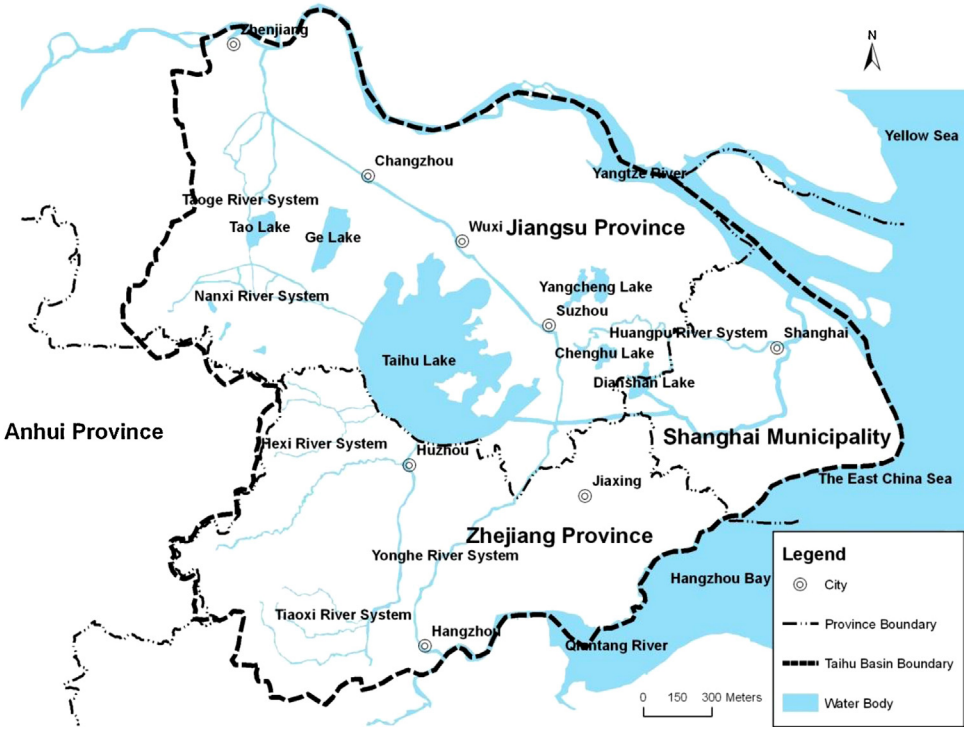

Fig. 1. Location of Taihu Basin and three cities.