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Does land perform well for corn planting? An empirical study on land use efficiency in China

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ABSTRACT

To assess land quality for cropping, this study developed a land performance indicator (LPI), namely efficiency of total land productivity potential (TLPP), by incorporating the heterogeneity of land quality for individual agricultural production units when evaluating the performance of land for corn planting, using stochastic frontier analysis. Without taking into account land quality, the technical efficiency (TE) of corn production cannot be reasonably compared across regions because the variation in land quality is significant. The estimated mean TE was 0.77, which illustrates that there is still potential to increase output by 23%, without increasing inputs, if all agricultural production units emulate the best performing production units. The results demonstrated that the mean LPI was 0.273, with a maximum value of 1.0, implying that a large gap exists between the minimum optimum use of TLPP and observed TLPP. This finding indicates that corn planting units can achieve the same outputs with less land inputs through improving the land productivity per unit. The results also revealed that operational units with greater farm area are likely to be more efficient than with those with a smaller area, which suggests that enlarging farm area and promoting household cooperation and joint management practices are imperative to achieve agricultural modernization, enhance the competitiveness of China's agricultural production in the global market, and effectively disengage labor from agricultural production and transfer the resulting surplus labor to cities.

1. Introduction

China's future agricultural development will pay increasing attention to food nutrition, food safety, efficiency, and effectiveness, according to the 13th Five Year Plan (Long et al., 2016; Long, 2014a; Brødsgaard, 2016; Jin et al., 2016). This period is critical for transformation and reconstruction of China's agricultural development, and sustainable use of the land resource and ensuring food safety will be keys to development. Corn planting has played an important role in China's food system because the area planted and output of corn increased dramatically since 1940s, which makes corn surpassed rice to become the largest single crop produced in China (Gale et al., 2014). Estimating the productivity and technical efficiency (TE) of agricultural corn planting by regarding land performance as a primary input will consequently play an essential role in China's agricultural transformation and development.

Area of cultivated land is indisputably a necessary input for assessing agricultural production efficiency. Although it is frequently reported that there is inverse relationship between farm size and yield per unit (Feder, 1985), agricultural productivity and efficiency analysis regarding farm size continues (Carter, 1984; Feder, 1985; Jayne et al., 2016; Mellor and Malik, 2016; Sheng et al., 2016). Almost all the literature to date focuses on the effect of farm size on general grain production or agricultural production, while there is a lack of research examining the relationship between corn planting efficiency and farm size for China's corn farmers from an economic perspective. In this paper, we analyze the TE and productivity of different farm sizes: small (individual households), medium-sized (family farms), and large (major cooperatives).

Apart from farm size, land quality should be considered when

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planning to increase agricultural technical efficiency and agricultural productivity. Many studies have used the area of cultivated land (i.e., farm size) available to a household as one of the primary inputs (Battese, 1992; Lansink et al., 2002; Pascual, 2005; Brümmer et al., 2006; Chen et al., 2009; Zhang and Brümmer, 2011; Asante et al., 2014). However, it is important (although difficult) to incorporate the heterogeneity of land quality as influenced by soil nutrients, soil type, or soil conservation when evaluating land performance in corn planting (Latruffe et al., 2005; Hoang and Alauddin, 2012; Marchand and Guo, 2012; Rao et al., 2012). Without taking into account land quality for each individual agricultural production unit, the TE for corn planting cannot be properly compared across regions because the variation in land quality is significant.

Besides farm size and land quality, some other elements also affect the technical efficiency of agricultural production. For example, Bayacag and Rola (2016) examined whether slope affected soil quality and thus had an influence on agricultural production, while Watkins et al. (2014) investigated whether an area with flat terrain needed less inputs for agricultural production and thus had higher production efficiency. Tang et al. (2015) studied whether improving farmers' income would promote agricultural production. Deininger et al. (2012) considered whether rental land would increase farmers' income and thus increase agricultural production efficiency, and Huang et al. (2017) found renting-in grassland improved the technical efficiency significantly.

To investigate the effect of land quality on productivity, in this study we developed a land performance indicator (LPI), namely the efficiency of total land productivity potential (TLPP), defined as the ratio of the minimum feasible TLPP needed for corn planting with the same output to the observed total cultivated land productivity, conditional on observed levels of the other inputs and outputs (Fig. 1). In this case, the smaller the LPI, the greater the input of the observed TLPP compared with the minimum feasible TLPP. Consequently, a small value of LPI could indicate over-use of the TLPP, which is generated as the product of cultivated land area and productivity per unit.

The overall objective of this research was to quantitatively evaluate the performance of the land resource (both area and quality) by treating it as an input for corn planting, in order to inform sustainable land policy in an era of agricultural transformation and development. The remainder of the paper is structured as follows. We describe the theoretical model in Section 2 and the study area and data in Section 3. The empirical model specification and estimation strategy are presented in Section 4. The results of the study are illustrated and discussed in section 5, and the conclusions of the study are presented in Section 6.

2. Theoretical model

To estimate the TE and values of LPI for agricultural corn planting, we developed a corn planting function incorporating TLPP as one of the inputs. Corn planting households use inputs x to produce y (Aigner

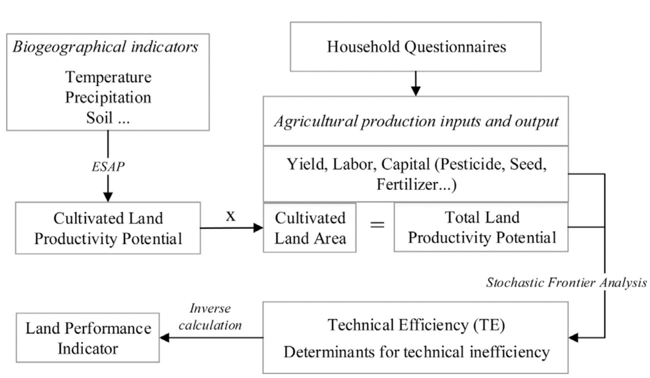

Fig. 1. The general framework of this study.

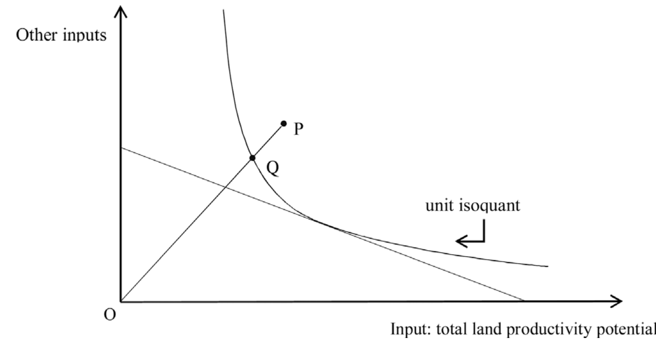

Fig. 2. Description of technical efficiency.

et al., 1977). For a given i^{th} production unit, we devised a one-output multi-input production function:

$$y_i = f(x_i; \beta)\exp(v_i - u_i) \quad i = 1,2,\cdots,N. \tag{1}$$

The translog functional form is specified as:

$$\ln(y_i) = \beta_0 + \sum_{k=1}^{3} \beta_k \ln x_{ik} + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} \beta_{kl} \ln x_{ik} \ln x_{il} + \varepsilon_i;\ \varepsilon_i = v_i - u_i \tag{2}$$

where the term v_i is set to capture noise, $v_i \sim$ i.i.d. $N(0, \sigma_v^2)$ and the term u_i is set to be the technical inefficiency term, $u_i \sim N(\mu_i, \sigma_u^2)^+, i = 1, 2, \ldots, N$. The mean μ_i is defined as the technical inefficiency model:

$$\mu_i = \tau_0 + z_i \times \tau_i \tag{3}$$

where z_i is a vector of explanatory variables (including input variables) associated with the technical inefficiency, τ_0 is a constant term in the technical inefficiency model, and τ_i is a vector of unknown parameter to be estimated (Coelli and Battese, 1996; Huang, 2015). We used Maximum Likelihood Estimation (MLE) to estimate the parameters. The unit isoquant of the fully efficient producer (represented in Fig. 2) permits the measurement of TE. Suppose the grain producer uses TLPP and other inputs to produce corn, operating at point P, the TE of a grain producer can be expressed by the ratio:

$$\mathrm{TE} = \frac{\mathrm{OQ}}{\mathrm{OP}} \tag{4}$$

where TE takes a value between zero and one, and the technical inefficiency value equals one minus the TE value. A technical efficiency value of one implies the grain producer is fully technically efficient. For example, the point Q (Fig. 2) is technically efficient because it lies on the efficient isoquant.

The LPI, which is termed the efficiency of TLPP, is defined as the ratio of the minimum feasible TLPP needed for corn planting with the same output to the observed TLPP, conditional on observed levels of input labor and capital, and corn output (Reinhard et al., 2002; Huang et al., 2016):

$$LPI_i = \frac{Min.\ \ total\ land\ productivity\ potential}{Observed\ total\ land\ productivity\ potential} \tag{5}$$

3. Study area and data

3.1. Study area

We selected Shandong Province and Heilongjiang Province as case study areas, because both are regarded as key 'breadbaskets' for China. Heilongjiang Province is one of the nation's commercial corn planting bases and has high potential for agricultural development as a result of its high level of mechanization and huge available cultivated land area. Shandong Province has good conditions for corn planting, including