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Analyzing the green efficiency of arable land use in China

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ABSTRACT

In this study, a non-radial directional distance function (NDDF) approach is used to evaluate and analyze the green efficiency of arable land use of China's 30 provinces and cities during the period 1995–2013. The study finds that the green efficiency of arable land use in China shows a trend that is first declining and then increasing. Northeast China is the most efficient, followed by the southwestern region, the eastern region, and the northwestern region; the central region has the lowest efficiency. At the provincial level, the green efficiency of arable land use in Guangdong is the highest, followed by Guangxi and Jilin. The green efficiency of arable land use in Heilongjiang, Beijing, and Tibet is relatively low. All the environmentally green production technology leaders come from the northeastern, northwestern, and southwestern regions. The results of an analysis of dynamic efficiency change show that the technology change for arable land use was significantly higher than the efficiency change. This reflects that the country's attempts to improve production technology as well as its policies for the improvement of environmental conditions had played a significant role. Even though these practices are at the expense of short-term efficiency, they are conducive to long-term technological progress.

1. Introduction

Land is an indispensable natural resource for human survival and development, carrying the productive activities of all human society (Lambin, 2012; Sun, 2013). Arable land is the essence of land resources, and an important material basis for human survival and development. Agriculture is the foundation of the national economy, and arable land resources are the most important part of agricultural land. As the most basic element of agricultural production inputs, the effective use of arable land is directly related to the guarantee of grain production capacity and the realization of sustainable socio-economic development. Since China's reform and opening up, its grain output has been increasing in most of the years, from 304.7 million tons in 1978 to 601.9 million tons in 2013, with an average annual growth rate of 3.16%. However, with the pressure of population, China's food security concerns cannot be ignored. In recent years, China's urbanization and industrialization continued to develop in depth; the cities have been expanding, and construction land and other demands for land use have been increasing. In order to meet the needs of urban construction, the arable land resources in different regions are to varying degrees subject to occupation; the area of arable land has decreased year by year (Wang and Qu, 2005). Statistically, only in the period 1996 to 2004, the total amount of arable land in China decreased by nearly 8×10^6 ha. The 2016 China National Land Resources Bulletin issued a net reduction of 43.5 thousand hectares of arable land.

On the other hand, due to the slow progress of agricultural production technology in most parts of China, it is far from being able to realize large-scale mechanized production. The utilization of arable land resources is extensive rather than intensive, which has led to the low efficiency of arable land resources (Xie et al., 1998). In addition, due to the improper use of chemical fertilizers and pesticides, the ecological environment around arable land is more serious, greatly reducing the production capacity of arable land and the quality of agricultural products (Skevas et al., 2014). The 2014 National Survey of Soil Pollution showed that the over-standard rate in cultivated soil in China was as high as 19.4%. The irrational use of agricultural inputs such as sewage irrigation, chemical fertilizers, pesticides and agricultural films, and livestock and poultry breeding are the main causes of soil pollution in arable land. With regard of cadmium contamination, the over standard rate of grain becomes serious in recent years, and it is closely related to the change in application structure of chemical fertilizers and pesticides. For decades, the application of chemical fertilizers, especially nitrogen fertilizer, has been increasing, resulting in the acidification of soil. At the same time, acid rain caused by burning coal as the main energy aggravates soil acidification (Guo et al., 2010). The above two factors lead to the high effect of heavy metal in soil on grain crops (Chen et al., 2017a).The development of any country must follow the old saying of “people to food for the day”—arable land is a country's

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economic development base, but also the important guarantee of food security, ecological security, and social stability (Liu, 2015). The effective use of arable land resources is essential to maintain social stability and promote economic development (Yao and Zhang, 2009). Asian Development Bank estimated that, the direct economic loss caused by the destruction of China's agricultural resources accounted for 0.5% to 1% of the national GDP. Due to excessive application of chemical fertilizers and pesticides, there were 7.4 billion dollars of export commodities, including agricultural products are blocked by green barriers each year (Rao et al., 2011). In addition, the impact of pesticides and fertilizers on the surrounding ecological environment is significantly negative. If this negative effect is not taken into account, it will inevitably lead to an imperfect land use efficiency index system and a skewed reflection of the actual situation (Feng et al., 2015). Hence, the optimal green efficiency of arable land use can be defined as the largest economic and ecological effects that are produced with the lowest cost in the process of arable land use. In other words, the green efficiency of arable land use not only takes into account the economic outputs, but also the positive and negative externality effects. Taking into account the actual problems of our country and the deterioration of environment, it is of great significance to analyze the green utilization of arable land resources from the economic, environmental, and social perspectives in China.

The Chinese government's concern about the issue of arable land has led it to strengthen the protection of arable land from the 1990s. If policymakers place a greater emphasis on the protection work of relative natural resources, they would develop and implement protection measures strictly, and bear greater policy pressure. Then, the relative natural resource would be better protected, and the improvement of expected goals would require a higher efficiency of current protection measures (Chen et al., 2017b). The Ministry of Land and Resources of China announced that the country would begin to implement a strict “double protection project” including “economic development” and “green land” from the beginning of 2010, which committed it to implementing the most stringent arable land protection system and adhere to 18 million mu of arable land red line. At the same time, local governments would be required to scientifically plan land use and avoid irrational occupation of arable land resources (Zhang et al., 2009). The Chinese government has been working to improve the farmland transfer system and establish a mature agricultural land market, trying to promote agricultural industrialization development and the use of agricultural machinery, and improve the efficiency of arable land use (Che, 2004). It is evident that the Chinese government has been protecting the arable land resources and improving the efficiency of arable land use through the improvement of agriculture and land policies in recent years; however, the effect of these policies is still unknown. Given China's vast territory, regional differences are obvious. It is necessary to understand the actual situation of arable land use in various regions in detail, as an important reference for policy formulation.

This paper makes four main contributions to the literature. First, it evaluates the evolutionary characteristics and interregional differences of green efficiency of arable land use in China from 1995 to 2013 based on the non-radial distance function (NDDF), taking into account the undesirable output of agricultural production innovatively, and it enables a more accurate assessment on arable land green use efficiency. Second, combined with the Luenberg productivity index to construct the total-factor non-radial green productivity index of arable land (see Section 2), measures the status of green productivity and its development trend of arable land at the national, regional, and provincial levels. Third, determine environmentally friendly production technology innovators in arable land use to set an example in arable land use technology for the relatively backward provinces. Fourth, conduct an in-depth comparison and analysis on the inverse trends between EC and TC and explore the reasons, so as to provide a basis for targeted policy formulation on the improvement of arable land green use efficiency.

The remainder of this paper is organized as follows: Section 2 gives reviews the literature of approaches to land use productivity, Section 3 introduces the methods and data; Section 4 presents the results of the empirical analysis; and Section 5 concludes the paper.

2. Literature review: measuring land use efficiency

In recent years, China's arable land use efficiency evaluation has aroused widespread concern at home and abroad. Some scholars use the single factor index analysis method to evaluate the regional land use efficiency. However, this method is essentially a measure of the economic output per unit area of arable land resources, which is in fact biased. As arable land use is a complex process, arable land as one of the input elements of agricultural production must be combined with labor, agricultural machinery, fertilizer, pesticides, and other input elements to facilitate production (Lin and Hülsbergen, 2017). Therefore, it is necessary to evaluate the efficiency of arable land use through the establishment of a total-factor index analysis framework.

Data Envelopment Analysis (DEA) is a holistic factor analysis model with multiple indicators. It is favored because it can objectively determine the weight of the parameters and evaluate the efficiency of the system. Liang et al. (2008) used DEA to evaluate the efficiency of arable land use in China from 1997 to 2004. It was found that China's arable land resources had not been effectively utilized, and that the efficiency of arable land use fluctuated somewhat. Pure technical efficiency was the main factor that influenced arable land use efficiency. Yang et al. (2011a, 2011b) also used this model to evaluate the efficiency of arable land use in the Shaanxi Province from 1990 to 2008, and explored the impact of some socio-economic variables related to agricultural production on the efficiency of arable land use based on the Tobit model. The results show that the arable land in the Shaanxi Province was far from being effectively utilized during the study period, and that the total power and effective irrigation rate of agricultural machinery had the greatest effect on arable land use efficiency. Xie et al. (2016a) used DEA and GIS technology to measure the efficiency of arable land use in 25 counties (cities) of the Poyang Lake Ecological Economic Zone from 1999 to 2010. The Tobit regression model was used to reveal the influencing factors of arable land use efficiency, and the results show that the comprehensive technical efficiency of arable land use in Poyang Lake Ecological Economic Area from 1999 to 2010 is 0.844. This indicates that the overall level of arable land use needs to be improved; integrated technical efficiency is affected by changes in pure technical efficiency and scale efficiency, but scale efficiency has a greater impact. The factors affecting the efficiency of arable land use have different effects on the efficiency of arable land use in different directions and to different degrees. Effects can be ordered as follows: multiple cropping index > agriculture policy > percentage of rural population > total power of farm machinery per arable area > per capita net income of farmers. Pan and Ren (2010), and Li et al. (2013) also studied the efficiency of arable land use in Sichuan and Shandong based on this model. However, their efficiency evaluation ignores the fact that agricultural production also produces large amounts of pollutants that cause significant damage to the ecological environment surrounding the arable land. Several attempts using data envelopment analysis (DEA) methods have been made in the literature to measure efficiency in the presence of undesirable outputs (Ball et al., 1994; Färe et al., 1989; Oude Lansink and Silva, 2003; Reinhard et al., 2000; Yang and Pollitt, 2009; Skevas et al., 2014; Xie et al., 2016a, 2016b; Wang et al., 2017). Building two different cross efficiency models based on the maximization and minimization of other DMUs, Song et al. (2017) calculate the efficiency values of 15 thermoelectric enterprises in China by means of Shannon entropy weighting, increasing the accuracy of the results. In China, Feng et al. (2015) used the SBM-DEA model to measure the agricultural non-point source pollution and land carbon emissions and other undesirable output of arable land use efficiency on the provincial level in China. However, this model is based on assumptions that the production technology in different years is the same,