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Changes in productivity, efficiency and technology of China's crop production under rural restructuring

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ABSTRACT

Food security is the fundamental problem of sustainable socioeconomic development in China. Since the 1990s, due to rapid socioeconomic development, the loss of cultivated land in China has become increasingly serious. In the context of inefficient assurances about the quantity of cultivated land, improving the productivity of crop production has become an important breakthrough in the new era to ensure food security in China. At present, China's agricultural development is at the stage of transition from traditional agriculture to modern agriculture. In the course of the agricultural transformation in China, what change has occurred to the total factor productivity (TFP) of crop production under rural restructuring becomes a problem worthy of in-depth study. Therefore, this study used the panel data of 31 provinces/autonomous regions in China from 1999 to 2008, and combined the traditional three-stage Malmquist productivity index (MPI) with the Bootstrap-Malmquist productivity index (Bootstrap-MPI) to measure the changes of the TFP of crop production in China. On the whole, the traditional MPI model underestimated the TFP of China's crop production and its components, the technical change (TC) index and technical efficiency change (TEC) index. After the ratification with the bootstrap method, the TFP of China's crop production had an annual average increase rate of 6.1% from 1999 to 2008, with obvious fluctuations in different time periods. Since the implementation of the protective policy for grain purchase prices in the 1990s, the TFP of crop production in China began to decrease. However, the TFP increased dramatically after the rural tax reform 2002–2003.

1. Introduction

As a large country in population and agriculture, crop production is the foundation of sustainable development in society and the economy in China. Since the implementation of the Reform and Opening-up Policy in 1978, China's economy has experienced a continuous rapid development (Li et al., 2014; Long, 2014a, 2014b). The food demand has thus irreversibly increased due to the growing economy and population. It is estimated that in 2030, the population of China will peak at 1.6 billion and the total demand for grain will be approximately 640 million tons (SCIC, 1996). To fill the gap between supply and demand, China's grain output needs to increase by more than 100 million tons in the next 10–20 years. However, this task is challenged by the problems that have emerged the background of rural restructuring in China.

Rural restructuring, which has been identified in Western Europe, North America and Israel in the Middle East, are taking place in the rural areas of China (Long et al., 2011a; 2011b). Spatial restructuring, industrial reshaping and administrative reorganization are the three main features of rural restructuring in China which have profound impacts on crop production (Long et al., 2016; Song and Liu, 2016). The problems emerged in rural restructuring such as nonagriculturalization, non-grain preference and abandonment of farmland use, inevitably decrease the grain production capacity in China (Liu et al., 2013; Long et al., 2012; van der Ploeg et al., 2014; Zhang et al., 2014). The contradiction among the food, farmland and population in China seems to have intensified under rural restructuring (Deng et al., 2015; Li et al., 2015a, 2015b; Song et al., 2009; Wu and Tan, 2007). Given that China cannot increase grain output by expanding cultivated land areas (Li et al.,

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2015b; Song and Pijanowski, 2014), it is necessary to improve the productivity of crop production in the existing cultivated land.

After the 1990s, China implemented a series of policies, such as protective grain procurement prices and agricultural tax relief. Along with the implementation of these policies, China's agricultural development has entered a new stage: it is at the stage of transition from traditional agriculture to modern agriculture. It seems that the development of modern agriculture in China has effectively offset the negative effects of rural restructuring on grain production by changing crop productivity. For example, China's total annual grain output witnessed a consecutive increase from 2003 to 2014 under the background of nonagriculturalization, non-grain preference and abandonment of farmland use. What change has occurred in the total factor productivity (TFP) of China's crop production? What contributes to the continuous increase in grain yield? What influence do the external environment variables have?

To answer these questions, this study adopted the combined method of the three-stage Malmquist productivity index (MPI) and the Bootstrap-MPI to estimate the agricultural TFP, and correct the influence of the uncontrollable external environmental factors, such as the environmental factors affecting production activities, on the changes in China's crop production. On this basis, this article revealed the change in the TFP of China's crop production and its influencing factors against the background of agricultural reform and a mode of accelerated transformation development.

2. Literature review

2.1. Development of TFP and its application in agriculture

Total factor productivity is often interpreted as the "surplus" in total output that cannot be explained by the factor input. Early TFP estimations mainly used traditional econometric models, such as the Cobb–Douglas production function, the Solow model, the Tornqvist index, the growth accounting method, and the average function method (Carter et al., 1999; Fan and Zhang, 2002; Lin, 1992; McMillan et al., 1989; Wen, 1993). Since the 1990s, frontier analysis has gradually been introduced into the calculation of TFP, with technical efficiency taken into consideration. Based on whether a specific production function is assumed, the frontier analysis is divided into parametric methods (e.g., deterministic frontier analysis [DFA], stochastic frontier analysis [SFA]) (Aigner et al., 1976, 1977; Battese and Coelli, 1992; Headey et al., 2010) and non-parametric methods (e.g., data envelopment analysis [DEA], MPI) (Alene, 2010; Charnes et al., 1978; Coelli et al., 2005; Esposti, 2011; Headey et al., 2010). Compared with the parametric method, the non-parametric method has the advantages of simultaneously studying the multi-input and multi-output TFP issues, of having no need for a specific production function, and not being affected by subjective factors, so most scholars tend to use non-parametric frontier analysis. However, the measurement of actual technical efficiency is influenced by management efficiency, the external environment of production activities, the manager's luck and other uncontrollable variables. Therefore, some methods have been proposed, such as the one-stage model (Banker and Morey, 1986), the two-stage model (Bhattacharyya et al., 1997; Fried et al., 1993; Timmer, 1971), the three-stage model (Fried et al., 2002), and the four-stage model (Fried et al., 1999). These models effectively eliminate the interference of environmental factors and manager's luck on the measurement of technical efficiency but cannot correct the estimation error caused by a limited sample size. Therefore, some scholars (Simar, 1992; Simar and Wilson, 1998, 1999; 2007) proposed the bootstrap method to correct such estimation errors and applied this method in the correction of TFP estimations (Grosskopf, 1996; Odeck, 2009; Tortosa-Ausina et al., 2008; Zhang and Bartels, 1998).

Since the 1970s, TFP has gradually been applied to the research on estimation and evaluation of agricultural productivity. The researches on TFP mainly include the estimation of agricultural TFP, evaluation and analysis of regional TFP differences, and analysis of the growth factor of TFP. Hayami (1969) analyzed the output elasticity of different input factors and the resultant international differences in agricultural productivity using transnational data (38 countries, including the United States, India and Japan) from 1957 to 1962. Coelli and Rao (2005) adopted the MPI to estimate the agricultural TFP of 93 countries from 1980 to 2000. The average annual TFP of China's agriculture was found to reach 6.0%, which was far higher than the average growth rate of TFP (2.1%) in other countries.

Since 1978, the TFP of agriculture in China has experienced significant changes. Fan (1997) estimated the TFP of agriculture of China using a Tornqvist-Thile index. It was found that the productivity increased by 1.51% annually from 1952 to 1995. Nin-Pratt et al. (2010) reported that TFP growth in China was high, with an average annual growth rate of 2.11% from 1961 to 2006. Nevertheless, the growth rate increased to 3.40% after the reforms of the late 1970s and early 1980s. Hong et al. (2010) found that China's agricultural TFP developed by 3% per year from 1978 to 2008 using the DEA method, and technical change was the main source of China's agricultural TFP growth. Many researchers reported that the planned economy, economic environment, and R&D (research and development) could affect agricultural activities. However, when these uncontrollable factors, such as off-farm employment, farmers' incomes and natural disasters, were added into the assessment of TFP, it was not possible to present an accurate picture of productivity. When aiming to obtain an accurate estimate of TFP, it is necessary to find a method to "filter" the external environment and random factors.

2.2. The evolution of agricultural policy in China since 1978

Since 1978, China has gradually deregulated the prices and allowed prices to reflect basic market conditions (Nin-Pratt et al., 2010). The double-track price system was a transitional policy from a planned economy to a market economy from the mid-1980s to the mid-1990s. The transitional policy generated obvious effects on the crop production decisions of households. However, such an intervention policy could enlarge market price fluctuations (Aigner et al., 1977; Li and Zhang, 2012). In this context, the State Council of China introduced the protection price system for grain purchase in 1993. With this, the basic system of grain circulation was formed. During this period, the household responsibility system (HRS) – a basic economics system – evolved from the people's commune. The HRS equally allocated collectively owned (or village-controlled) land to individual households in each village (Deng et al., 2010; Song and Liu, 2014). As the most important land system innovation, HRS had become the primary motivator for increasing agricultural productivity in the early reform period (Huang et al., 2012).

In the second stage (from the mid-1990s to 2002), aiming to stabilize market grain prices at a reasonable level and reduce the financial burden of the grain support program (Brummer et al., 2006), the Chinese government gradually implemented policies to protect market grain prices. However, the price of agricultural products was still restricted by policies, hindering the farmers' enthusiasm for agricultural investment and application of new technology (Ren et al., 2009). During this period, the pace of agricultural economics development slowed, and grain production decreased from 508 million tons in 1999 to 431 million tons in 2003 (NBSC, 2000a; 2004a). Furthermore, in 1998, China started the second round of rural land contracts. In 1999, the policy stating that