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Theoretical and Empirical Studies of Productivity Growth in the Agricultural Economics —— Cases of China and the United States

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Abstract

This article investigates agricultural productivity growth over several decades, emphasizing to a great extent the agricultural economic development condition for the nine agricultural divisions of the United States, and China's 27 provinces in terms of Malmquist productivity growth index. The paper sets up a technique to make use of two-stage linear programming method, based on sequential production technology, to estimate the most fitted and reliable distance functions in relevant agricultural sectors, and thus to compute the Malmquist productivity indexes. Especially, it proposes to decompose the productivity growth index into two major components, technical progress and efficiency improvement, and their sub-components, to study the sources of growth in productivity.

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*Keywords:*World economy; Malmquist productivity index; Linear programming optimization; Distance function

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1. Introduction

For several decades, the global agriculture experiences a persistent and rapid decline, to the most obvious contrary to the performances of other economic sectors that exhibits continuously fast development in recent years, the productivity growth of the agricultural sector, however, speeds relatively slow. Among them, the possible main reasons include increasingly resource scarcity, limited technological innovation, environmental degradation, and insufficient agricultural policy support. This article uses the linear programming technique to calculate the Malmquist productivity indexes based on the built-up technical frontiers, in order to investigate the total factor productivity growth of the two main greatest agricultural countries, China and the US, through several decades of years, and especially the function of their

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sub-components, technical efficiency and technological innovation, that increase the productivity, which in turn serves a reference basis as to raise the agricultural productivity and efficiency in the future.

Traditional agricultural productivity researches rely heavily on productivity index approaches, such as those of Fisher, Tornqvist, that are incapable of disaggregating the total effect of agricultural productivity into changes in performance and changes in technology. Because these approaches mask some important factors that determine the measurement of productivity change over time. Besides, traditional techniques usually presume that production is always efficient. However, different from the traditional indexing procedures, Malmquist index with distance functions requires neither of the use of input prices nor that of output prices in its construction.

This study examines the agricultural Malmquist productivity index using distance functions in estimating the total factor productivity. This approach allows for the decomposition of productivity growth into changes in technical efficiency over time (or catching-up) and shifts in technology over time (or technical change). Besides, it does not require presumption that production is always efficient. Furthermore, a non-parametric linear programming introduces in the second stage admits inefficient performances in technology.

2. Methodology

2.1. Distance Function and Malmquist Index

The Malmquist index was introduced by Caves et al. (1982) who adopted the output-based Malmquist productivity index after Sten Malmquist, who earlier proposed constructing quantity indexes as ratios of distance functions (Malmquist, 1953; Fare et al, 1994). Distance functions are basic components that define the Malmquist index. Distance functions are function representations of multiple-output and multiple-input technology which require data only on input and output quantities. In measuring total factor productivity growth, output-based Malmquist index of productivity change is assumed in this study.

To define the Malmquist index, two different time periods, t and $t+1$, must be specified. In order to avoid choosing an arbitrary benchmark time period, the geometric mean of two output-based Malmquist indexes with equivalent two consecutive time periods based on different time periods is defined as follows:

$$M_o^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \right) \left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}}.$$

Equivalently, an alternative form of the above index can be written as follows:

$$M_o^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}}.$$

With the second expression, Malmquist productivity index can be decomposed into two components: change in efficiency (EFFCH) and shift in technology (TECHCH). A ratio outside the bracket is efficiency change component, which describes relatively efficiency catch-up between two periods, t and $t+1$, or sometimes called the effect of catching-up. A geometric mean of two ratios inside the bracket captures the shifting effect of frontiers representing the change of technology, on some years' observations for each of two periods, or sometimes called the effect of technological innovation. In sum, Malmquist productivity index can also be expressed in word as following form:

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