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Measuring the inefficiency of Chinese research universities based on a two-stage network DEA model

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ABSTRACT

This paper investigates the inefficiency and productivity of 64 Chinese research universities and their evolution over the recent period of 2010–2013, where the production process of each research university is described as a general two-stage network process. We first develop a general two-stage network directional distance framework with carry-over variables to gauge the universities' inefficiencies. Second, to study the evolution of the universities, we develop a Luenberger productivity indicator to measure the productivity changes over time, as well as decompositions. The empirical results show that the Luenberger productivity indicator increased significantly over the examined period. The productivity gains were primarily driven by improvements in efficiency. In other words, the efficiency increased on average over the period of 2010–2013. However, technical changes for many universities were below zero, which led to technology deterioration on average. Finally, based on the estimates, we propose several policy suggestions for improving efficiency and productivity.

1. Introduction

In modern society, universities and colleges are social organizations and cultural institutions and play an important role in human society, economy, culture and international communication through the realization of various functions. Jaspers (1965) stated ÏA] *University is composed of scholars and students of the truth-seeking community.*Ät the beginning of their establishment, the function of colleges and universities was more singular, primarily imparting knowledge and training specialized personnel. With the development of society, the functions of colleges and universities have been expanded and standardized, i.e., talent cultivation, scientific research and serving society have become the three main functions of modern colleges and universities. Currently, these three functions have become the consensus of the higher education system worldwide.

As in almost every country in the world, universities are also important institutions for scientific and technological achievements, particularly in China. Since the reform and open-door policy implementation in 1978 and with the country's emphasis on education and technological innovation, China has made significant efforts to improve the performance of its scientific system to reach the forefront of world research over the past several decades given the country's continuously growing financial expenditures on university education. Consequently, increasingly numerous talent is becoming involved

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in scientific research activities, and increasingly numerous scientific and technological achievements have been reached. In August 2015, the National Science Library (LAS) of the Chinese Academy of Sciences (CAS) released an official report entitled "Blue Book on China's Competitiveness in Basic Research 2015", which states that the number of SCI papers published in China amounted to more than 216,000 in 2013, approximately 62.2% as many as the United States (US) in the same year. In addition, the number of citations of papers written by researchers at Chinese universities and research institutions increased significantly. For example, the number of citations in 2012 accounted for approximately 12.4% of those of American papers, whereas the corresponding percentage was only 6.6% in 2008. In certain disciplines, such as environmental biotechnology and chemical engineering, China has surpassed the US in terms of the number of SCI publications. This success was primarily due to China's huge investment in its higher education system in recent years. OECD (2014) shows that R&D (research and development) expenditure in China has doubled from 2008 to 2012. In 2012, China's Gross Domestic Expenditure on R&D (GERD) was 257 billion US dollars.[1] In the same year, the GERDs in the US, EU-28 countries and Japan were 397 billion dollars, 28 billion dollars and 134 billion dollars, respectively. Currently, China is reorganizing its scientific system to become more competitive, and funds should be used more efficiently given the limited resources.

Johnes et al. (2017) argued that it is important for education to be provided as efficiently as possible with competing demands for government funding, and efficiency occurs when outputs from education are produced at the lowest level in terms of resources. Arguments in the same direction can be found also in, for example, Abbott and Doucouliagos (2003), Avkiran (2001), and Casu and Thanassoulis (2006). Therefore, it is of great importance to address the need for an efficiency analysis and performance evaluation of Chinese universities.

As a mathematical tool for evaluating the efficiency of multiple decision-making units (DMUs), the DEA (data envelopment analysis) approach (e.g., Banker, Charnes, & Cooper, 1984; Charnes, Cooper, & Rhodes, 1978;) is widely used in performance evaluation or analysis. The DEA avoids the influence of subjective factors on the evaluation results; therefore, it is widely used in the evaluation of scientific research efficiency worldwide. For example, the DEA has been applied in education efficiency analyses (Johnes, Portela, & Thanassoulis, 2017). While most conventional DEA models treat the operation of a DMU as a "black box" (Färe & Grosskopf 2000; Kao & Hwang, 2008), some recent research intends to go inside the "black box" and the internal structure of the DMUs (Tone & Tsutsui, 2009). For example, network DEA models have been developed in recent years to consider the process within a DMU, which can include several sub-processes or stages. Every stage is characterized by its own inputs and outputs and is related to other stages through intermediate flows (Färe & Grosskopf, 2000).

A university's scientific research activity is a complex process of multiple inputs, internal processes, and multiple outputs. There are several Input-Process-Output (IPO) models that have been extensively used to describe the influences of team effectiveness of production units (see, e.g., West Borrill, & Unswort, 1998). Brandt and Schubert (1997) augmented the IPO model, taking into account the production technology determining the process by which inputs are transformed into outputs. Their IPO model depicts inputs, processes and outputs as three interrelated variable complexes. However, our literature survey shows that most of the studies conducted through a DEA are at the static level and not at the dynamic level of multi-stage scientific research productivity; see the literature review in detail in Section 2. This point can be twofold. First, there are few studies on university efficiency that have focused on a two-stage network DEA model with carryover variables. Second, according to the IPO model, it is important to open the process between inputs and outputs by treating universities as a two-stage network process instead of merely a "black box" to portray the internal activities inside universities.

While we believe that DEA is a desirable approach for university efficiency evaluation, the traditional or black box DEA has not been incorporated into the internal structure that exists at a DMU. Motivated by the coping strategies for this limitation, this paper aims to investigate the inefficiency and productivity of 64 Chinese research universities and their evolution over the recent period of 2010–2013, where the production process of each research university is described as a general two-stage network process with feedback between two stages, where the feedback variable produced at the second stage of a previous year (a portion of total income (TI) in our study. See Section 4.1) goes into the first stage of the current year. To this end, we develop a general two-stage network directional distance framework with carryover variables to measure the universities' inefficiencies and a Luenberger productivity indicator to measure the productivity changes over time, as well as decompositions of the indicator for the examined universities. It should be noted that in this study, we assume that the technology transfer revenue is used to support research and development (R&D) outputs and technology services; hence, these are the input of the first stage of university production.

The remainder of the paper is organized as follows: Section 2 briefly summarizes the existing literature on university performance measurements and describes the two-stage process of a university. Section 3 sets up the mathematical basis for the analysis and defines a two-stage network directional distance (NDD) measure for gauging the efficiency of representative Chinese research universities, as well as a Luenberger productivity indicator for productivity changes over time. In Section 4, we show the details of the input and output variables used in this paper and their data source as well as the corresponding descriptive statistics. A case study on 64 Chinese research universities over the period 2009–2013, along with policy implications and suggestions, follows in Section 5. Finally, Section 6 offers a discussion and presents the study's conclusions.

[1] Hereafter, monetary figures refer to dollars at purchasing power parity in 2005.