Resources, Conservation & Recycling 139 (2018) 50–63

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Environmentally sensitive productivity growth of industrial sectors in the Pearl River Delta

Wei Liu[a], Jinyan Zhan[a,*], Chao Wang[a], Shuxian Li[a], Fan Zhang[b,c,d]

[a] State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China
[b] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[c] Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing 100101, China
[d] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Keywords:
Environmentally sensitive productivity growth
Total factor productivity
Malmquist–Luenberger index
Undesirable outputs
Data envelopment analysis
Pearl River Delta

ABSTRACT

Under the background of new urbanization, urban agglomeration plays an important role in boosting development in surrounding areas. However, while contributing significantly to economic growth, it was accompanied by high levels of energy consumption and emissions of waste gas and water into the surrounding ecological system. Therefore, it is worthwhile measuring the environmentally sensitive productivity changes during the development process. The Malmquist–Luenberger index based on company data for the period 2007–2012 is used to examine both desirable and undesirable outputs for total factor productivity of various industrial sectors in the Pearl River Delta. The trend in productivity growth and indexes in efficiency and technology are analyzed. We find that at the city scale, the industrial productivity levels in Dongguan, Shenzhen, and Zhongshan increased during the study period, while those in other cities decreased. Furthermore, Guangzhou, Dongguan, Foshan, Jiangmen, Shenzhen, and Zhuhai are green development cities. Technological advance was the main contributor to productivity growth. In accordance with the efficiency and technological change indexes, 225 Decision-Making Units (DMUs, refers to industrial sectors in this study) comprising specific industries from nine cities were classified into six categories. It was found that 66.9% of the DMUs developed with improved productivity and 40% developed in a green mode. Conditions and trends of industrial sectors and the key determinants affecting environmentally sensitive productivity growth was specified. Thus, it provides essential information for companies to develop in green way, as well as providing policy makers with an understanding of industrial development at both the city and sector level.

1. Introduction

Urban agglomerations play a vital role in driving national economic development. So, under the background of new urbanization, Chinese government attempts to transform traditional Chinese urbanization to sustainable new urbanization (Li and Jong, 2017). Form city clusters with mega-cities as the core so that they can boost development in surrounding areas and become new poles of economic growth (Deng et al., 2015). In China, three main economic increase poles, included Yangtze River Delta (YRD), centered on Shanghai, the Pearl River Delta (PRD) urban agglomeration, centered on Guangzhou and Shenzhen and the Jing-Jin-Ji Metropolitan Region, centered on Tianjin and Beijing (Feng et al., 2014). According to the related cities Statistical Yearbook of 2013, these three city agglomerations cover 490,019 km^2, which only comprises 5.1% of China's total land area, but account for 41% and 23.8% of China's GDP and population, respectively. Thus, they have played an essential role in China's economic growth.

Given their contribution to China's economic growth, these agglomerations are also expected to play a leading role in China's low-carbon development (Jia et al., 2018). Thus related study should measure its environmentally sensitive productivity growth and find out the key factors. According to China Statistical Yearbook of 2013, although the total GDP of YRD and Jing-Jin-Ji Metropolitan Region was larger than PRD, their GDP per capita or GDP per unit of land area was smaller than PRD's. Therefore, we can conclude that PRD metropolitan region is one of the most development potential and productive city agglomerations in China (Lin, 2001). According to the Guangdong Statistical Yearbook of 2013, the PRD covers 54,743 km^2, just 0.57% of China's land area, but accounted for 83.7% of Guangdong's GDP, or 9.3% of China's total GDP, in 2012. However, while it made a

* Corresponding author at: No. 19, Xinjiekouwai Street, Haidian District, School of Environment, Beijing Normal University, Beijing, 100875, China.
E-mail addresses: liuw@mail.bnu.edu.cn (W. Liu), zhanjy@bnu.edu.cn (J. Zhan), wangc_simlab@163.com (C. Wang), Maxine_lee_lex@163.com (S. Li), zhangf.ccap@igsnrr.ac.cn (F. Zhang).

https://doi.org/10.1016/j.resconrec.2018.07.017
Received 14 March 2018; Received in revised form 6 May 2018; Accepted 14 July 2018

significant contribution to China's economic growth, this was accompanied by high levels of energy consumption and emissions of waste gases and water into the surrounding ecological system. Therefore, we take the PRD as our study object in measuring environmentally sensitive productivity growth.

Environmentally sensitive productivity growth is helpful in understanding the degree of competitiveness and the level of economic development. Productivity is an indicator of the amount of economic output (desirable outputs) that is derived from each unit of resources consumed. Environmentally sensitive productivity growth refers to measuring the productivity change taking the undesirable outputs into consideration. The big difference between productivity and environmentally sensitive productivity is whether take the undesirable outputs into consideration. With increasing international concerns about climate change and sustainable economic growth (Liu and Deng, 2011), measuring environmentally sensitive productivity has become an essential direction in research (Wang and Zhao, 2016; Deng et al., 2017; Deng and Gibson, 2018). Further, undesirable outputs such as CO_2 and SO_2 are often produced in conjunction with desirable outputs (Chen, 2015; Zhan et al., 2017). However, many studies only focus on desirable outputs, and do not account for undesirable outputs such as CO_2, which may affect the productivity evaluation (Hu and Wang, 2006; Mukherjee, 2008). Some studies have taken undesirable outputs into consideration when calculating productivity (Song et al., 2017) mainly using one of two methods: either the undesirable outputs were treated as inputs for processing (Reinhard and Thijssen, 1999) or data transformation has been applied to undesirable outputs, and environmental efficiency has been evaluated by applying the traditional efficiency model based on the transformed data (Atkinson and Dorfman, 2005; Song et al., 2012). However, these methods are not consistent with the materials balance approach (Murty et al., 2012), physical laws, and the standard axioms of production theory (Färe and Grosskopf, 2003). The various methods of measuring productivity efficiency mainly include the growth accounting method (Lankauskienė, 2016), the production function method (Petrin et al., 2004), stochastic frontier analysis (SFA) (Cullinane and Khanna, 2000), and data envelopment analysis (DEA) (Banker et al., 1984). Among these methods, SFA, which is parametric, and DEA, which is nonparametric, are widely used (Chen and Golley, 2014). The main weakness of SFA is that it requires a specific parametric functional form (Kamrul et al., 2012), while DEA does not require any information other than the input and output quantities. Thus, DEA is widely used to measure environmentally sensitive productivity growth.

We use a directional distance function to analyze the productivity growth, efficiency change, and technological change in 29 industrial sectors at the city level in the PRD during the period 2007–2012. Efficiency change denotes the effectiveness of the available knowledge and technology translated into productivity growth, while technological change represents the level of innovativeness (Lall et al., 2002). Industries in different regions experience different development opportunities (O'Donnell et al., 2008), and thus productivity analysis helps us to understand the level of economic prosperity and the competitiveness of a country. Therefore, it is important to identify the factors that determine productivity growth allied with a reduction in undesirable outputs, and which industrial sectors are able to develop in a green manner. This provides basic information for decision-makers in relation to the effectiveness of economic policies.

The remainder of this paper is structured as follows. Section 2 describes the data that were used and the study area. Section 3 discusses the methodology used in this study. Section 4 presents the results. Section 5 concludes.

2. Data and study area

2.1. Study area

The PRD metropolitan region is the low-lying area surrounding the Pearl River estuary. It is one of the most densely urbanized regions in the world, and an economic hub of China. The term PRD refers to the dense network of cities that covers nine prefectures in the province of Guangdong, namely Guangzhou, Shenzhen, Zhuhai, Dongguan, Zhongshan, Foshan, Huizhou, Jiangmen, and Zhaoqing (Fig. 1). The PRD covers 54,754 km^2, has a southern subtropical monsoon climate, the mean annual temperature is 22 °C, and the mean annual rainfall is 1600–1900 mm. According to the Guangdong Statistical Yearbook of 2013, the PRD's permanent population was 56.9 million. In 2012, GDP in the region totaled 7.57 billion US dollars, and the annual GDP growth rate was 9.2%, which was 2% higher than the provincial growth rates. Investment in fixed assets was 2.21 billion US dollars.

2.2. Data

The data used in this study were obtained via a survey of 8523 and 9777 companies in 2007 and 2012, respectively. We selected the companies that had been surveyed in both 2007 and 2012, which resulted in a sample of 2810 companies that were able to be included in this study. The data included company name, administrative code, amount of every form of energy consumed, annual hours of production,

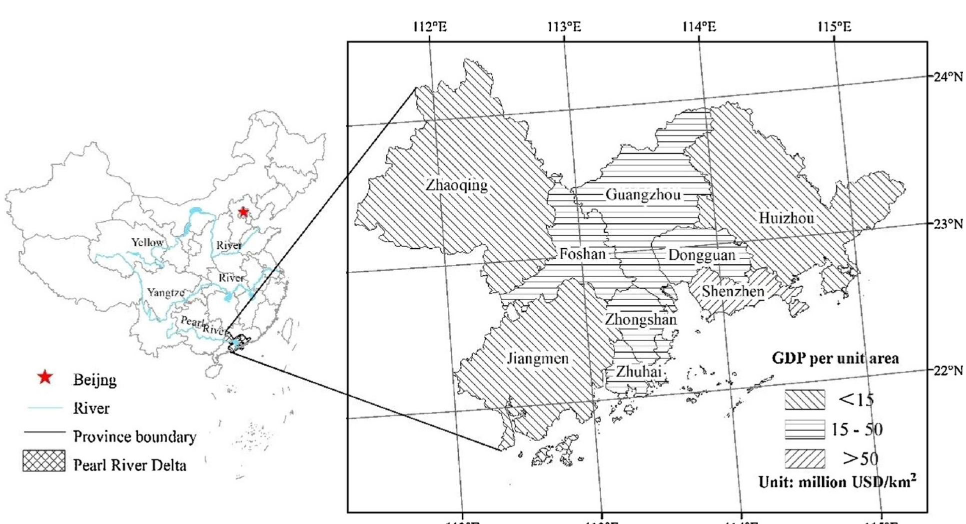

Fig. 1. Location of study area and GDP per unit area of nine cities in the Pearl River Delta.