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Toward green IT: Modeling sustainable production characteristics for Chinese electronic information industry, 1980–2012

Ning Zhang, Hualin Xie *

Institute of Poyang Lake Eco-economics & Institute of Eco-civilization & Economics, Jiangxi University of Finance and Economics, Nanchang 330013, China

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ABSTRACT

With the growth of the electronic information industry across the world, China has become a world factory of information technology products. However, the technology and energy efficiency of this industry in China are lower than those in other industrialized countries. In this study, the duality theory of non-radial directional distance function is used to develop a general procedure for modeling sustainable production characteristics for this industry. Using a non-radial efficiency model, environmental technical efficiency and environmental regulatory costs are estimated. In addition, the Porter hypothesis is tested using the Granger causality test. The shadow price of carbon emissions and inter-factor substitution possibilities can be measured using the dual model. The proposed methodology is employed to conduct an empirical study on Chinese electronic information technology manufacturing industry during 1980–2012. Finally, some policy implications are suggested.

1. Introduction

China's electronic information industry has enjoyed high-speed growth for almost three decades after its liberalization under national strategic policies, and now, this industry has become a pillar of the nation's economy. In 2013, the sales of China's electronics and information industry reached 12.4 trillion China Yuan (CNY), with a growth rate of 12.7%. The revenue accounts for 21.8% of the GDP, and more than 50% of the global IT revenue worldwide. In terms of manufacture of hardware, a total of 1.46 billion cell phones, 340 million computers, and 130 million TV sets were produced in China, accounting for more than 50% of the world's total production (http://www.china-industry-research.com/News/2013-saw-an-overall-smooth-operation-of-chinese-electronic-and-it-industry.html).

The electronic information industry produces a large amount of carbon emissions, discharging more than 830 million tons of carbon dioxide (CO_2) every year, which is approximately 2.0% of the global CO_2 emissions, the same as that produced by the aviation industry (http://www.natureworldnews.com/articles/467/20130107/ict-sector-account-2-percent-global-carbon.htm). Therefore, reducing the carbon emissions of the Information and communication technology (ICT) industry is critical to mitigating climate change word widely.

The gross production of the Chinese electronic information technology manufacturing (EIM) industry, and its CO_2 emissions, are shown in Fig. 1. Although the Chinese EIM industry has achieved high growth in terms of production, its CO_2 emissions have increased rapidly as well. Some developed countries such as the United States and Japan have achieved a negative growth in CO_2 emissions in the EIM industry, accomplishing the decoupling of CO_2 emissions and production. Thus, studying the sustainable production characteristics is key to the sustainable development of the Chinese EIM industry.

The remainder of this paper is organized as follows. Section 2 presents the literature review related to environmental production characteristics. Section 3 introduces the methodology of the non-radial directional distance function

* Corresponding author. Tel.: +86 139 7912 1643; fax: +86 791 83810267.
E-mail addresses: zn928@naver.com (N. Zhang), landuse2008@126.com (H. Xie).

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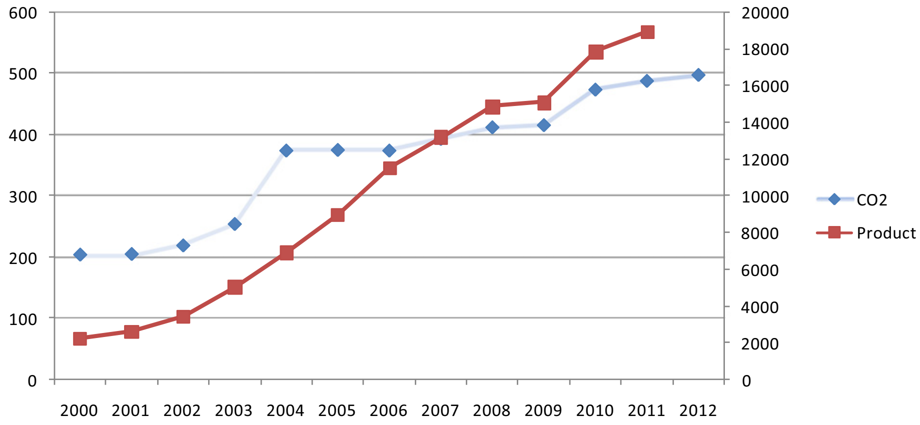

Fig. 1. CO_2 emissions and production in the EIM industry, China. Notes: CO_2 (10^4 T), Product (10^8 Yuan).
Source: Authors' calculations.

(DDF) approach, including measuring environmental technical efficiency, environmental regulatory cost, the shadow prices of emissions, and the Morishima elasticity of substitution among the factors therein. In Section 4, an empirical study of the Chinese EIM industry during 1980–2012 is conducted using the proposed methodology. Section 5 concludes and suggests some policy implications.

2. Literature review

Recognizing the importance of evaluating sustainable production, a number of studies have attempted to address the environmental and carbon efficiency issues in China. For instance, there have been studies conducted at a provincial-level (Hu and Wang, 2006; Choi et al., 2012; Zhang and Choi, 2013a), for industrial sectors (Shi et al., 2010; Wang et al., 2012; Wu et al., 2012), the iron and steel industry (Wei et al., 2007; Smyth et al., 2011; He et al., 2013), the manufacturing industry (Lee and Zhang, 2012), the power generation industry (Xie et al., 2012; Zhang and Choi, 2013b,c), and the transportation industry (Chang et al., 2013; Zhou et al., 2013). Although sustainable production efficiency in many sectors has been widely analyzed, no studies have focused on the EIM industry for China. Therefore, this study aims to fill this gap by investigating the sustainable production characteristics for EIM industry in China.

Among the various sustainable production modeling methods, the distance function approach has gained much popularity, possibly because it can model joint-production technology with good and environmental bad outputs simultaneously. Another possible reason is that unlike the cost function, the distance function does not require price-specific data that is relatively difficult to obtain. Given only the quantity data of inputs and outputs, which are easier to obtain, various critical environmental production characteristics can be formally studied, such as environmental technical efficiency, environmental productivity growth, the shadow prices of pollutants, and inter-factor substitution possibilities (Zhang and Choi, 2014).

Regarding using distance function for environmental studies, there are generally two kinds of distance functions that are widely used in the literature: The Shephard distance function (Shephard, 1970) and the directional distance function (DDF) (Chambers et al., 1996). The Shephard distance function expands the good and bad outputs proportionally, as much as possible. Thus, this method does not credit reduction of bad outputs, since all outputs are expanded at the same rate. On the other hand, the DDF, a relatively new approach for environmental production modeling, has attracted much attention recently. A major advantage of the DDF is that it is capable of expanding desirable outputs and contracting bad outputs simultaneously. Therefore, the DDF is a generalized form of the Shephard distance function and is more powerful and flexible.

Regarding to the specification, the DDF can be specified in at least two different ways: the parametric and the non-parametric approach. The parametric approach is based on a specific functional form that requires the adoption of a functional form, such as a translog or a quadratic function, for the distance function. It has the advantage of providing an estimated parametric representation of the sustainable production technology, which is differentiable and easy to manipulate algebraically. Therefore, the parametric method can be used to estimate the shadow prices of emissions (Färe et al., 1993) and the curvature or substitutability along the frontier (Lee and Zhang, 2012). On the other hand, the non-parametric approach, also called data envelopment analysis (DEA), is based on the construction of a piecewise linear combination of all observed outputs and inputs, and relies on mathematical programming. A major advantage of the DEA approach is that it does not require the imposition of a specific functional form on the underlying environmental technology. Therefore, non-parametric DDF provides an easier and more flexible means of estimation.

As the basic DDF (Chambers et al., 1996) aims to reduce inputs and expand outputs at the same rate, it can be regarded as a radial efficiency measure. However, the radial measure has several limitations, one of which is that a radial measure may lead to overestimate efficiency when the slacks exist (Fukuyama and Weber, 2009) and it has relatively weak discriminating power in ranking the entities to be evaluated (Zhou et al., 2007). To this end, recent studies sought to develop alternative non-radial DDF models (Zhang and Choi, 2013b,c; Fukuyama and Weber, 2009; Zhou et al., 2007; Färe and Grosskopf, 2010; Zhou