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The integrated efficiency of economic development and CO_2 emissions among Asia Pacific Economic Cooperation members

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ABSTRACT

In recent years, the evaluation of energy, economic and environmental efficiency, employing the data envelopment analysis models, has been a hot topic in academe. When choosing models, people always expect to improve desirable outputs, while reducing undesirable outputs at the same time (*e.g.* when using a directional distance function model). However, directional distance function models may lead to biased estimations due to different directions given to different units. To overcome this shortcoming, in this paper, we propose another non-radial efficiency evaluation model based on previous literature, which can also improve desirable outputs and reduce undesirable outputs. Then we employ this model to analyse the economic efficiency and CO_2 emissions efficiency of the Asia Pacific Economic Cooperation (APEC) members. Meanwhile, we also measure the efficiency change by using the Luenberger index, and analyse the reasons for efficiency changes from the perspectives of technical efficiency, and technical, changes. The results indicate that most countries have an extremely high economic efficiency, but relatively low CO_2 emissions efficiency and integrated efficiency except for the United States, Japan, and Singapore. According to the Luenberger index, we find an increase in integrated efficiency and CO_2 emissions efficiency for most members from 2001 to 2010; however, technical progress is the main contributor. Technical efficiency exhibits a downward trend for most members.

1. Introduction

It is well known that the global economy experienced rapid development in the past half century. Meanwhile, environmental problems caused by human activities, especially the greenhouse effect, have also been increasingly prominent. Nowadays, to relieve the greenhouse effect, many countries have set their own CO_2 emissions reduction targets and have made efforts to reduce their CO_2 emissions.

The Asia Pacific Economic Cooperation Organisation, which not only includes the most developed country in the world, the United States, but also the largest developing country, China, is one of the most important economic cooperation organisations in the world. Its economy and CO_2 emissions will have a great impact on the world economy and the global greenhouse effect. Fig. 1 shows the proportion of APEC members' total gross domestic product (GDP) and CO_2 emissions accounting for the world total in 2011,[1] respectively. From Fig. 1, both CO_2 emissions, and GDP, of APEC members account for more than 50% of the world total in 2011. In particular, the share of CO_2 emissions is nearly 60%, since it includes the two largest CO_2 emitters in the world, China and the United States. To relieve the greenhouse effect, these two largest emitters have formulated emission reduction targets. China commits to limit its greenhouse gas emissions, with a commitment to peak emissions around 2030 and to make best efforts to peak early, and to increase its share of non-fossil energy consumption to around 20 percent by 2030. Similarly, the United States Federal Government has decided to, by 2025, reduce its greenhouse gas emissions by 26–28% compared to those in 2005 (U.S.–China Joint Announcement on Climate Change[2]). Although, these policies help to alleviate the greenhouse effect, evaluation of APEC members' economic performance and CO_2 emission efficiency in past years, which

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[1] All the data are extracted from the World Bank Database. More information is available from: http://data.worldbank.org.cn/.

[2] Published 14 November 2014: in this announcement, the Presidents of the United States and China announced their respective post-2020 actions on climate change.

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0959-6526/

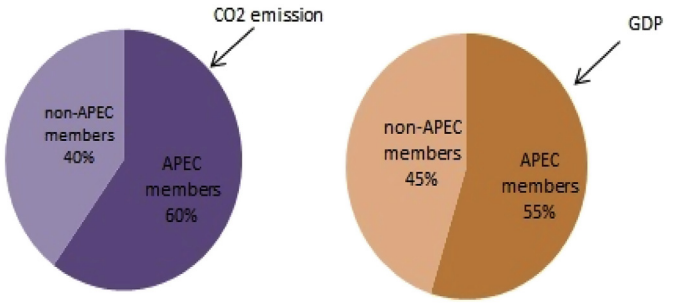

Fig. 1. Proportion of the APEC members' CO_2 emissions and GDP accounting for the world total in 2011 respectively.

informs economic development and CO_2 emission reduction policies, is also meaningful, and worthy of research.

Based on above discussion, in this paper, we mainly focus on APEC members' economic efficiency, CO_2 emissions efficiency, and their trends between 2001 and 2010. Then we analyse the determinants of efficiency change from the perspectives of technical efficiency, and technical, changes, using an index decomposition analysis approach. In addition, providing advice to relevant economic and environmental policy-makers is also a target of this study.

In academe, non-parametric data envelopment analysis (DEA), proposed by Charnes et al. (1978), has been widely applied to the evaluation of energy and environmental efficiency as it provides an appropriate method to deal with multiple inputs and outputs in examining relative efficiency. In its early stage, DEA is mainly applied to evaluating public sectors' relative operating efficiency, for example, banks, hospitals, and schools Liu et al. (2013). However, since energy and environmental problems have become more prominent, DEA has also been applied to estimating the energy efficiency, economic efficiency, and environmental efficiency more widely. In early literature, which focuses on efficiency evaluation of energy and environmental issues, the authors do not take the actual pollutants into consideration (Hu and Wang, 2006). Undoubtedly, it leads to a biased efficiency evaluation. In the literature, which incorporates the pollutants into evaluation models, there also are two main ways to deal with the pollutants. One way is to treat the pollutants as inputs (Lansink and Reinhard, 2004; Shi et al., 2010; Dyckhoff and Allen, 2001). Even though this assumption looks reasonable, many scholars criticise this method. On one hand, it is not consistent with practical production. On the other hand, it violates the material balance equation and common sense (Førsund, 2009). Another way is to employ an environmental reference technology, which is proposed by Färe and Grossopf (2004) who suppose that the undesirable outputs meet weak disposability criteria, while inputs and desirable outputs still meet strong disposability criteria. The weak disposability of undesirable outputs indicates that the desirable outputs will also reduce by the same proportion, when we are devoted to reducing pollutant emissions. The pollutants cannot vanish completely, until we stop production process. Because of its rationality, the weakly disposable reference technology is widely accepted and used to evaluate efficiency in energy and environmental fields by most scholars, such as Wang et al. (2013a,b), Sueyoshi and Wang (2014), Leleu (2013), Zhou et al. (2008a,b), Zhang and Choi (2013), Färe et al. (2004), and Ramanathan (2005).

In the context of environmental reference technology, Tyteca (1996, 1997) proposes a radial measure method, which only optimises the pollutant, to estimate pollutant emissions efficiency. A flaw of this method is that only one kind of undesirable outputs is considered. Taking various undesirable outputs into consideration, Zhou et al. (2007) use a non-radial efficiency measurement method to measure the environmental performance of 26 OECD members from 1995 to 1997. In this paper, the authors can choose different weights on undesirable outputs to reflect their preferences. This kind of non-radial method is widely applied to evaluating pollutant emissions efficiency (Wang et al., 2013a,b; Hernández-Sancho et al., 2011; Sueyoshi and Wang, 2014; Meng et al., 2013). However, these radial and non-radial efficiency measures simply ignore the slack in each variable which leads to biased estimates (Fukuyama and Weber, 2009). To remedy this limitation, Färe and Grossopf (2010) develop a more generalised non-radial and non-oriented directional distance function based on a slack-based measure (SBM). Compared to radial and non-radial measures, the SBM method estimates the relative efficiency more accurately. Nevertheless, people also expect to increase desirable outputs while reducing undesirable outputs at the same time. Therefore, Chung et al. (1997) propose a directional distance function model, which has been widely used to evaluate relative efficiency in the energy and environmental fields (Sueyoshi and Goto, 2011; Zhang and Choi, 2013; Wang et al., 2013a,b; Leleu, 2013; Wang and Wei, 2014).

Although the directional distance function could maximise desirable outputs and minimise undesirable outputs at the same time, it has the disadvantage that the direction must be given in advance and directions vary with decision-making units, which may lead to a one-sided relative efficiency. Therefore, to avoid this shortcoming of the directional distance functions, we propose another model which could also maximise desirable outputs, and minimise undesirable outputs, at the same time on the basis of Zhou et al. (2008a,b). In that paper, the authors propose environmental performance evaluation models under different reference technologies. However, its defect is that those models proposed by Zhou et al. (2008a,b) cannot maximise desirable outputs, and minimise undesirable outputs at the same time.

To increase desirable outputs, and reduce undesirable outputs at the same time, we add some additional constraints to the model in Zhou et al. (2008a,b), to guarantee the increase in desirable outputs and reduction in undesirable outputs at the same time. In comparison to the directional distance function, the advantage of this model is that, all decision-making units' relative efficiency only depends on its own input–output, and there is no need to specify a direction vector. Undoubtedly, the model can estimate the relative efficiency more accurately. We employ this model to estimate APEC member economic efficiency and CO_2 emissions, as well as the integrated the efficiency of the economy and CO_2 emissions over the period 2001–2010. Then we measure the change in integrated efficiency, and analyse the reason for their changes from the perspective of technical efficiency, and technical, changes at the same time. In addition, we also propose relevant policy suggestions towards economic development and CO_2 emissions for some of the countries discussed.

The rest of this paper is organised as follows: the second part mainly focuses on the research methods and introduces the relevant models; the third part discusses the input–output variables and the statistical description of the data; the fourth part presents the results, and the last part summarises the results of this study and proposes some relevant policy recommendations for some countries.

2. Methodology

2.1. The environmental reference technology

Suppose there are Q decision making units (DMU), and each unit has N inputs, M desirable outputs, and L undesirable outputs. The inputs, desirable outputs, and undesirable outputs of unit q at period t are denoted by

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