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Eco-efficiency in greenhouse emissions among manufacturing industries: A range adjusted measure

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ABSTRACT

Air pollution as a result of production processes has a great impact on the environment and contributes directly to global warming, which is linked to climate change. This paper evaluates the eco-efficiency of the manufacturing sector in Malaysia by taking into account both economic and ecological factors (i.e. air pollution). Manufacturing activities produce pollutants that can contribute to poor environmental performance and are regarded as undesirable outputs. Thus, it would be incomplete to measure the efficiency of manufacturing activities without considering the undesirable outputs. This study employs the Range Adjusted Measure (RAM) model which accounts for both desirable and undesirable outputs in the production process. The results show that the Malaysian manufacturing industry as a whole has an average unified eco-efficiency score of 94% (category 1) in 2010 which indicates scope for reduction of inputs and pollutants as much as 6%. The results also reveal that, on average, the eco-efficiency score of the free industrial or free trade zone states are higher than non-free industrial zone states. This may be due to two reasons, first, manufacturers in the free industrial zones are export orientated and learning effects are gained from export participation which help firms improve their efficiency over time. Second, the firms enjoy duty free imports of raw materials as well as are exempt from various taxes and duties that help reduce production costs. The empirical evidence in this study may provide some directions in formulating policies, laws, regulations and strategies pertaining to any environmental performance issue particularly concerning environmental damage caused by industrial pollutants so that the productivity growth is in balance with environmental performance.

1. Introduction

Global warming and climate change have become major concerns of humanity these days. Human activities that release large amount of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere are known as part of the main contributors of global warming (Zhang et al., 2012). Currently, the greenhouse effect receives plenty of attention from researchers, which can be seen by the increasing amount of research that has been published on the impact of human activities towards the environment (Pelletier, 2010; McBride et al., 2011; Laurent et al., 2012; and many more). For instance, the impact of greenhouse gases on the environmental concern has emerged as a result of rapid economic growth and excessive consumption of natural resources (Tong, 2000). Furthermore, previous researchers concur that environmental issues keep escalating as the economic growth increases (Peng and Bao, 2006; Melville, 2010; Kasman and Duman, 2015). Therefore, business organizations that generate the economic growth have a very significant role towards reducing the greenhouse gas emissions. Due to this, they need to come up with a business model and strategy that will not only be beneficial to the business but also contribute to the safety of the environment.

Nowadays, environmental performance measurement is used as a mechanism to integrate business performance and environmental performance. An approach that is widely used by the researchers and practitioners to study environmental performance is the measurement of eco-efficiency. Eco-efficiency refers to the ability to create more goods and services while using fewer resources and creating less environmental impact. The measurement of eco-efficiency is essentially on measuring efficiency with the integration of undesirable outputs that contribute negatively to the environment (Dyckhoff and Allen, 2001). In the eco-efficiency measurement, input and output variables are often considered, in which output may consist of two categories, i.e. desirable and undesirable. Desirable outputs (good outputs) are a set of products that all the companies/organizations want to produce while undesirable outputs (bad outputs) can be considered as waste released during the production activities. In eco-efficiency measurement, both the economic and ecological efficiencies are assessed, where the desirable and undesirable outputs are taken into account simultaneously (Koskela and Vehmas, 2012).

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The aim of this paper is to measure the eco-efficiency in the greenhouse emissions of the manufacturing sector in Malaysia employing the Range Adjusted Measure (RAM) model. The RAM model proposed by Sueyoshi and Goto (2011) accounts for both desirable and undesirable outputs in the production process. The manufacturing sector has been chosen as the context of the study since this sector is not only the major contributor of Malaysia's economy but also one of the main contributors to air pollution (Department of Environment, 2008), as fuel combustion in production activities is the largest contributor to air pollutant emission. In this study, we consider CO_2 emission, since it is the main by-product of industrial activities from the combustion of fossil fuels (Wu et al., 2010; Oggioni et al., 2011).

This study presents a comprehensive eco-efficiency model that integrates the indicators between environmental and industrial elements for the first time in the Malaysian manufacturing sector. The previous studies in the Malaysian manufacturing context neglects the incorporation of undesirable outputs in their framework, and thus, has no bearing on the eco-efficiency measurement. Therefore, this study provides a new dimension concerning efficiency measurement in the Malaysian manufacturing context accounting for both desirable and undesirable outputs in the analysis. This study also is one of the first applications of the RAM model in the manufacturing sector. Additionally, this study looks at the variations in eco-efficiency at the Malaysian state level as some regions/states have free industrial zones or free trade zones while others do not. A free industrial zone is a designated, secured area in which commercial and industrial activities are carried out mainly for the manufacture of export goods and where customs control is at the minimum.

Thus, this study provides a more accurate measurement of efficiency in the Malaysian manufacturing sector and contributes to the literature of eco-efficiency and productivity growth measurement especially in the Malaysian context, as the integration between industrial production and environmental performance is quite new. The study also contributes to the limited empirical evidence on the relationship between export activities and efficiency as the free industrial zones manufacturers are export oriented while the non-free industrial zone manufacturers are domestically orientated.

It is expected that the findings in this study aid researchers and policymakers. For researchers, it presents an interesting insight into the current literature on the joint assessment of the environmental and industrial elements to measure the eco-efficiency. It also provides policymakers with useful information to design more effective policies towards environmental protection so that the economic growth is in balance with environmental performance.

The remainder of the paper is organized as per the following sequence. Section 2 reviews previous studies while Section 3 discusses the RAM model that is employed in this paper. Next, Section 4 describes the variables selection and data set for the empirical application followed by Section 5 with a presentation of the results. Section 6 provides some discussion on the unified efficiency category I and II then Section 7 concludes the study.

2. Literature review

The underpinnings of the efficiency measurement begin with the work of Debreu (1951) and Koopmans (1957). Debreu provided the first measure of efficiency, which is the 'coefficient of resource utilization' while Koopmans is the first who defined the concept of technical efficiency. Technical efficiency focuses on the ability to increase the outputs while keeping the inputs constant or the ability to reduce the inputs while keeping the outputs constant. Technical efficiency involves either a single or multiple input and output in the analysis. Many studies can be found in the literature that analyse the technical efficiency. For instance, Karadağ et al. (2005) measured the technical efficiency of Turkish manufacturing sector and evaluated the total factor productivity (TFP) change of the selected provinces in Turkey over the 1990–1998 period. In their paper, they utilized the output-oriented DEA model to observe the ability to maximize output production, subject to a given resource level.

When incorporating undesirable outputs such as pollutants, the measurement is essentially on eco-efficiency. The concept of eco-efficiency can be classified as a measurement of efficiency with the integration of environmental pollution that are regarded as undesirable outputs together with desirable outputs (Arocena and Waddams Price, 2002).

Since the last decade, eco-efficiency measurement has received more attention and there has been a growth in the number of studies concerning this topic (See for example; Zaim, 2004; Amirteimoori et al., 2006; Riccardi et al., 2012; Ramli et al., 2013 and many more). Tyteca (1996) reviewed almost 100 previous studies on environmental performance and at the same time conducted an empirical study on employing the index number approach to assess environmental performance of firms. Tyteca (1996) measured resources used, desirable outputs produced and air and water pollutants (BOD and SO_2) using the index number approach while recommending the use of DEA technique when estimating environmental performance. In 2008, Zhou et al. (2008) conducted a survey of studies using DEA in energy and environmental studies, encompassing about 100 studies on eco-efficiency measurement by using the DEA framework. The studies employ various techniques within the DEA framework to measure the environmental performance of industries in their application area.

2.1. Techniques used

In measuring eco-efficiency, a popular approach amongst researchers is the Directional Distance Function (DDF) technique (See for example, Boyd et al., 2002; Färe et al., 2006; Watanabe and Tanaka, 2007; Zhang, 2009; Mandal and Madheswaran, 2010; Zhang et al., 2014). The DDF model gains popularity because it allows the consideration of non-proportional changes in outputs and makes it possible to expand desirable outputs while contracting the undesirable outputs. The DDF model is measured based on distance function, which is determined by the method of ratio. However, there is also a major drawback of using this model as there is no standard technique on how to determine the direction vector. The direction vector to the production boundary is fixed arbitrarily, and thus, may not provide the best efficiency measure. In addition, according to Jahanshahloo et al. (2012) "the radial measures omit the non-zero input and output slacks in the efficiency measurement, and thus, fail to account for the non-radial excesses and shortfall". Recently, Ramli et al. (2013) extended the previous DDF framework of efficiency analysis to introduce a new slacks-based measure of efficiency. Using the new approach, it may provide dissimilar expansion and contraction factors to achieve a more reasonable efficiency score. Besides that, another enhancement of DDF is the sequential generalized DDF (SGDDF) model, developed by Zhang et al. (2014). This model gauges sustainability performance by taking into consideration various dimentions including environmental, economic as well as social domains.

An alternative approach for eco-efficiency measurement is the Range Adjusted Measure (RAM). Sueyoshi et al. (2010) extended the basic model of RAM with the incorporation of undesirable outputs. This model measures the efficiency by maximizing the distance from the efficient frontier whereby outputs are maximized and inputs are minimized simultaneously. This method overcomes the drawback of the DDF approach and provides a more accurate efficiency measure. Due to this situation, this method is adopted in this paper for evaluating the efficiency of the Malaysian manufacturing sector. A discussion of the RAM model is provided in the methodological section.

2.2. Importance of incorporating undesirable outputs

The measurement of eco-efficiency, in contrast to its counterpart efficiency, is deemed important in production processes that produce