CHAPTER 1

INTRODUCTION

1.1 Environmental Performance Measurement

Global warming and climate change has become a major concern of humanity nowadays. According to the United States Environmental Protection Agency (EPA), global warming refers to the recent and ongoing rise in global average temperature near Earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere. Global warming is causing climate patterns to change. Climate change refers to any major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer. Human activities that have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere are known as one of the main contributors for global warming. The majority of greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere. The greenhouse effect can change Earth's climate and result in dangerous effects to human health, welfare and eco-systems.

In 1992, The United Nations Framework Convention on Climate Change (UNFCCC) was created to provide a framework for policy making to mitigate climate change. The objective of the UNFCCC is to stabilize the greenhouse gasses at a suitably low level to prevent dangerous influence on the climate. Later, in 1997 the Kyoto Protocol was formed as a foundation document in international climate change policy. The Kyoto Protocol has been designed as an international agreement to set targets for industrialized nations to reduce greenhouse gasses (Grubb et al., 1999).

Currently, greenhouse effect receives plenty of attention from researchers which can be seen by the amount of research that has been published on the impact of human activities on the environment (Barr et al., 2011; Goudie, 2009; Laurent et al., 2012; Lieb & Lieb, 2010; McBride et al., 2011; Moldan et al., 2012; Pelletier, 2010; and many more).

The impact of greenhouse gases on environmental concern has emerged as a result of rapid economic growth and excessive consumption of natural resources (Tong, 2000). Previous researchers agreed that environmental issues escalate as economic growth increases (Hanley et al., 2012; Melville, 2010; Peng & Bao, 2006). Therefore, business organizations that generate economic growth have a very significant role to play towards reducing the greenhouse gas emissions. They need to come up with a business model and strategy that will not only be beneficial for the business but also contribute to the safety of the environment.

A few decades ago, environmental performance has been defined as the quantity of pollutants that is released from a plant (Bragdon and Marlin, 1972). A number of measures or indicators for environmental performance have been suggested, such as the ecological footprint, sustainability and other indicators and indices. However none has clearly shown the path to economic growth with less resource consumption and pollution, a key ingredient and prerequisite of sustainable development. Even the popular environmental indexes, the Environmental Sustainability Index and the Environmental Performance Index (developed by the Earth Institute, CIESEN, Columbia and Yale Universities) still focus mainly on the environment with little consideration of the relation between environment and the economy.

Nowadays, environmental performance measurement is used as a mechanism to integrate between business performance and environmental performance. Many authors dealing with environmental performance measurement have concurred with the importance and effectiveness of incorporating performance measurement to the environmental strategies of an organization (Dias-Sardinha & Reijnders, 2001; Maskell, 1991; Perotto et al., 2008; Skillius & Wennberg, 1998). Some of the important aspects that have been stressed by Perotto et al. (2008) in their studies are, supporting the organization by quantifying and reporting their environmental performance, classifying and summarizing organizational data concerning environmental aspects, providing policymakers with data on the organization circumstances with regard to its environmental situation as well as comparing the environmental performance measurement with the earlier objectives that have been acknowledged.

An approach that has been adopted for environmental performance measurement by the organizations is eco-efficiency indicator. Koskela and Vehmas (2012) provided a definition of eco-efficiency that refers to the numerous productions with limited amount of environmental impact. Economic and Social Commission for Asia and the Pacific (ESCAP) has expanded the scope of eco-efficiency beyond the production side and the business sector to the economy-wide level. The eco-efficiency indicator (EEI) is designed to capture the ecological efficiency of growth by measuring the efficiency of economic activity both in terms of consumption and production and its corresponding environmental impacts. It is composed of a set of indicators rather than being a single index of economic performance. The application of EEI in the business sectors is usually based on the ratio of product or service value to environmental impact. Most indicators focus on the consumption of energy, materials and water and the emission of greenhouse gases, wastewater and pollution emission (Economic and Social

Commission for Asia and the Pacific, 2009). Despite the popularity of the EEI, this index only presents an indicator of the score for environmental sustainability without providing further meaningful explanation.

In addition to the eco-efficiency indicator above, another approach that is widely used by the researchers and practitioners to study environmental performance is eco-efficiency measurement through quantitative technique of Data Envelopment Analysis (DEA). In DEA framework, the term eco-efficiency can be described as a measurement of efficiency with the integration of undesirable outputs that contribute negatively to the environment (Dyckhoff & Allen, 2001). In eco-efficiency measurement, input and output variables are often considered in which output may consist of two categories, i.e. desirable and undesirable. Desirable output (good output) is a set of products that all the companies/organizations want to produce. Examples of desirable output are sales, production and Gross Domestic Product (GDP). On the other hand, undesirable output (bad output) can be considered as waste released during the production activities. An example of undesirable output is emission factors. In eco-efficiency measurement, both the economic efficiency as well as the ecological efficiency are assessed in which the desirable and undesirable outputs are taken into account (Koskela & Vehmas, 2012).

The topic of global warming and climate change has received increasing attention and there has been a growth in the number of studies concerning environmental performance measurement (See for example; Amirteimoori et al., 2006; Ismail et al., 2013; Riccardi et al., 2012; Song et al., 2012; Wu et al., 2012; Zaim, 2004; Zhou et al., 2008a). Therefore, this research studies environmental performance measurement through the exploration of the Directional Distance Function (DDF) model within the

Data Envelopment Analysis (DEA) framework and enhance the model to measure eco-efficiency in the Malaysian manufacturing sector.

The DEA framework is chosen in this study since it has become a popular approach in measuring efficiency. Among others, the DEA can be viewed as a benchmarking technique, as it allows decision makers to locate and understand the nature of the inefficiencies of a decision making units (DMU) by comparing it with a selected set of efficient DMUs with a similar profile. Each DMU is analysed separately to examine whether the DMU under consideration could improve its performance by increasing its desirable output and decreasing its input/undesirable output. Beyond the efficiency measure, DEA also provides other sources of managerial information relating to the performance of DMUs (Ramanathan, 2003).

While computing the eco-efficiency measurement, many research papers give greater focus on the manufacturing sector. This sector is one of the largest contributors to poor environmental performance. Emission factors, such as nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO) and sulphur dioxide (SO_2), are among the pollution factors that are produced during the combustion of fossil fuels in manufacturing activities, which may damage the environment (Oggioni et al., 2011; Wu et al., 2010). As for the Malaysian manufacturing sector, little attention has been given to the study of eco-efficiency measurement. Research to date has not sought to integrate emission factors in efficiency analysis, which is one of the main contributors to climate change. Therefore, this study will provide a new dimension concerning efficiency measurement in the Malaysian context, particularly in the manufacturing sector, wherein both desirable and undesirable outputs are considered in the analysis.

This study on eco-efficiency may benefit the researchers and policy makers. For researchers, it may fill the gap in the literature with regard to eco-efficiency measurement through the enhanced model of Directional Slack-based Distance Function (DSDF). This enhancement will be discussed further in the development of the DSDF model chapter. As for policy makers, it may provide some implications to the individual organization or even the government while formulating policies, laws, regulations and strategies pertaining to any environmental performance issue so that the productivity growth is in balance with environmental performance.

1.2 Motivation

Although there are numerous studies on the efficiency measurement with regard to the production process most of these papers solely consider the inputs or resources used by the organizations and the desirable outputs or operational products that are the results of input utilization. Other production variables, such as undesirable outputs are not taken into account in the traditional model formulation. To name a few, undesirable outputs include pollution, scrap, rework, and other qualitative outputs that can lead to dissatisfied customers. In the production process, undesirable output is produced jointly with desirable output, thus the undesirable output cannot be ignored when measuring the efficiency. Without the inclusion of these undesirable outputs, the evaluation of efficiency measurement actually ignores the real world situations and can provide misleading results and unfair assessments.

The requirement for desirable output is contradictory to the undesirable output. The desirable output needs to be extended while the undesirable output needs to be contracted. In respect of this nature, undesirable output should be treated differently to desirable output.

The Directional Distance Function (DDF) model, which is under the DEA framework, is a recognized technique for measuring efficiency with the incorporation of undesirable outputs. This approach allows desirable outputs to be expanded while undesirable outputs are contracted simultaneously. Nevertheless, it can be seen that the DDF model has its drawbacks. There are no standard techniques concerning how to determine the direction vector in the modelling. The direction to expand desirable output and reduce undesirable output is made subjectively, in other words, user specified. This arbitrary direction that is fixed by the user may be inappropriate and thus may not provide the best efficiency measures (Bian, 2008). In addition, the DDF model also omits the non-zero input and output slacks in the efficiency measurement (Jahanshahloo et al., 2012).

Therefore, this study extends the previous framework of efficiency measurement to introduce a new slacks-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) model. This new model determines the optimal direction to the frontier for each unit of analysis and provides dissimilar expansion and contraction factors to achieve a more reasonable efficiency score. The detailed explanation on the development of the DSDF model to gauge the eco-efficiency will be addressed in detail in Chapter 4.

In respect of the efficiency measurement in the Malaysian manufacturing sector, the studies on this subject are quite limited. Most of the studies that have been done in Malaysia do not incorporate undesirable output in their efficiency measurement. In light of the above reasons, an appropriate technique should be employed to measure the efficiency with the incorporation of undesirable output in Malaysia, particularly in the manufacturing sector so that the association between environmental performance and industrial activities can be observed.

1.3 Aims and Objectives of the Study

The main purpose of this study is to introduce a new slack-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) model and to apply the DSDF model in eco-efficiency measurement and productivity change in the Malaysian manufacturing sector for the period between 2001 and 2010. The specific objectives of this study are as follows:

1. To measure the technical efficiency and eco-efficiency of the manufacturing sector in Malaysia using the Data Envelopment Analysis (DEA) and Directional Distance Function (DDF) approaches.
2. To introduce a new slacks-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) model for eco-efficiency measurement.
3. To calculate the productivity change of the Malaysian manufacturing sector by utilizing the Malmquist Luenberger Productivity Index (MLPI).

1.4 Research Questions

This study is guided by the following research questions:

1. What are the differences between technical efficiency and eco-efficiency?
2. What techniques can be utilized to measure the technical efficiency and eco-efficiency of the Malaysian manufacturing sector?
3. What are the strengths and weaknesses between the Data Envelopment Analysis (DEA) and Directional Distance Function (DDF) approaches?
4. How can the drawbacks of the DDF approach be overcome?
5. How can the productivity change over the years be examined?

1.5 Thesis Structure

This chapter provides the introduction to this study. It begins with an overview of the global warming and climate change that have become a major concern of humanity nowadays. Responding to climate change leads to another dimension for measuring environmental performance through the exploration of the eco-efficiency measurement. Then, it briefly discusses the focus of this study, which is on eco-efficiency measurement in the Malaysian manufacturing sector. Later, this chapter explains the problems that provide the motivation for the study. All of these elements outline the main purpose and objectives that this study targets to achieve.

In chapter 2, an explanation on efficiency measurement is provided for both the theoretical and empirical orientations. The initial part of the discussion is on the non-parametric DEA framework. It reviews the various approaches that can handle undesirable output according to the direct or indirect approaches. Turning to the empirical part, the discussion introduces the relevant empirical studies based on earlier literature. The empirical orientation discusses technical efficiency as well as eco-efficiency studies with various approaches besides productivity growth in the manufacturing sector. In addition, the effect of environmental regulations on the eco-efficiency as well as potential variables and sources of pollution by different industries are discussed.

Chapter 3 presents the methodology that is preferred in this study. The DEA model without incorporating the undesirable output is formulated for the technical efficiency measurement while the Directional Distance Function (DDF) technique is formulated for the eco-efficiency measurement. The Malmquist Luenberger Index calculated by the DDF technique is also provided in this section.

Chapter 4 mainly discusses the development of the Directional Slack-based Distance Function (DSDF) approach to measure eco-efficiency. In addition to eco-efficiency measurement, this chapter presents how the new DSDF model determines the optimal direction to the frontier for each unit of analysis and provides dissimilar expansion and contraction factors to achieve a more reasonable eco-efficiency score. Furthermore, a super eco-efficiency model and Malmquist Luenberger Productivity Index (MLPI) are formulated to complete the whole picture of eco-efficiency in this study. In addition, a brief overview of the data that is used to illustrate the application of these formulations is discussed further.

Chapter 5 provides a discussion on the empirical results of technical efficiency, eco-efficiency and productivity change based on the DEA, DDF, DSDF as well as MLPI approaches, which were formulated in the previous chapters.

As a final point, chapter 6 presents the conclusion and recommendation for further exploration from this research effort. This section summarizes the implications of the findings in relation to policy making, and finally, provides some recommendations for future research.