CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Research Summary

Efficiency and productivity measurement of the manufacturing sector is especially crucial for continuous growth and development of the economy. However, it would be incomplete to measure the efficiency of manufacturing activities without considering the elements of pollution as these elements are regarded as undesirable outputs in efficiency measurement. 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 to avoid unfair assessment.

A comprehensive efficiency model that integrates the indicator between environmental performance and industrial activities in the Malaysian manufacturing context has been presented in this study. The issue of environmental performance seems very relevant to the element of undesirable output in production activities since the pollution factor, which is considered as undesirable output may harm the atmosphere. Furthermore, in recent times, environmental sustainability has become a major issue regarding global warming and climate change.

This study provides a better understanding of the technical efficiency as well as the eco-efficiency of the manufacturing sector in Malaysia. The manufacturing sector has been chosen as the context of the study because studies on this subject are quite limited in Malaysia. In addition, the manufacturing sector is the second largest contributor to the Gross Domestic Product (GDP) of Malaysia, and is also one of the main contributors to environmental pollution (Department of Environment, 2008). Data Envelopment

Analysis (DEA) and the Directional Distance Function (DDF) approaches have been demonstrated to gauge the technical efficiency and eco-efficiency in the 15 states of the Malaysian manufacturing sector for the study period of 2001 to 2010.

In the conventional Data Envelopment Analysis (DEA) model, technical efficiency is measured by maximizing the production (desirable) of outputs with a restricted amount of inputs. However, when there is joint production of the desirable and undesirable outputs, the efficiency measurement is best defined by increasing desirable outputs and simultaneously decreasing undesirable outputs (Färe et al., 1989). To handle this situation, the Directional Distance Function (DDF) approach was introduced by Chung et al. (1997) to measure eco-efficiency.

The DDF technique allows for desirable outputs to be expanded while undesirable outputs are simultaneously contracted. The reason why this model is considered as a more appropriate technique is because it allows one to expand the direction of desirable output while simultaneously contracting the direction of undesirable output by using a single scalar. This property is very useful in studying the input-output choices of polluting firms facing environmental regulation as firms attempting to reduce pollution will increase desirable output production.

However, there is a limitation to the DDF approach. The direction vector to the production boundary is fixed arbitrarily, which means it may not provide the best efficiency measure. This is because a different direction vector may provide a different efficiency score. Indeed, there is still no consensus on what is the best direction vector to be employed in this model.

Therefore, this study provides an alternative solution to decision makers through the extension of the previous framework of efficiency analysis by introducing a new slacks-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) technique. This new approach determines the optimal direction to the frontier for each unit of analysis and provides different expansion and contraction scales to achieve a more reasonable efficiency score. In addition, the study also demonstrates the use of the newly developed approach to establish target values for the reduction/expansion of outputs in order for the inefficient states to achieve full eco-efficiency.

Apart from the slack-based measure of eco-efficiency, a super eco-efficiency with DSDF was analysed to differentiate the extreme DSDF score of fully eco-efficient states so that a better discrimination between the states can be achieved. Using the super efficiency approach, the performance of all extreme states can be distinguished. Afterward, to complete the analysis, the Malmquist Luanberger Productivity Index (MLPI), which incorporates the element of pollutant, was used to observe the productivity performance over the period 2001 to 2010. With the MLPI, the trends of productivity change for each state, whether improved/deteriorated over time, were reported.

6.2 Discussions on Major Empirical Findings

The results of technical efficiency and eco-efficiency are presented according to the industrial grouping of the states – Free Industrial Zone (FIZ) states consist of Johor, Melaka, Pulau Pinang, Perak and Selangor; and Non-Free Industrial Zone (N-FIZ) states comprise Kedah, Kelantan, Negeri Sembilan, Pahang, Perlis, Terengganu, Sabah, Sarawak, the Federal Territory of Kuala Lumpur and the Federal Territory of Labuan.

From the empirical findings of the technical efficiency in this thesis, it can be observed that, the DEA technical efficiency score for the states under the FIZ category was slightly higher than that of the states under the N-FIZ category. This result implies that the manufacturing activities in Malaysia's free industrial zones, which are categorized as industrial areas, perform better than the states in the N-FIZ areas. This result also disclosed that the states under the FIZ category have efficiently allocated their resources while increasing the production of outputs.

The majority of Malaysian states in the manufacturing sector experience high technical efficiency with more than 75 percent efficiency score in geometric mean during the 10-year period of study. This high technical efficiency by the manufacturing sector has made the growth of the Malaysian economy one of the most remarkable recorded globally despite some uncertainties in the global environment arising from the September 11 incident in 2001 and crude oil price upsurge in 2004 - 2005. The finding on high technical efficiency scores is approximately consistent with the results of the assessment on technical efficiency conducted by Nordin and Fatimah (2010). In their paper, they reported that the average technical efficiency in the food manufacturing sub-sector is about 71 percent during 2002 to 2007.

However, the technical efficiency analysis above does not consider undesirable outputs such as production of pollutants from the manufacturing activities. It is worth noting that modelling the production process without undesirable outputs can provide misleading results and unfair assessments. Therefore, in this study eco-efficiency is measured using the DDF model where both the economic efficiency as well as the ecological efficiency are assessed, in which desirable and undesirable outputs are taken into account to avoid unfair assessment.

Looking at the overall picture of eco-efficiency using the DDF model, similar results to technical efficiency were obtained, in which the eco-efficiency scores for the states under the FIZ category were slightly higher than the N-FIZ category during this 10-year period of study. This high eco-efficiency by the manufacturing sector demonstrates that environmental performance in Malaysia is not adversely affected with regards to industrial development, and can be categorized as an eco-efficient country while obtaining the profits of the firms. This indicates that the states have efficiently allocated their resources not only to increase the production of desirable outputs but also to reduce production of undesirable outputs.

The technical efficiency and eco-efficiency results obtained in this study were confirmed by Watanabe and Tanaka (2007) in their study, in which they found that five coastal provinces/municipalities that have attracted a large amount of foreign direct investment managed to obtain a high score in efficiency when only desirable output was incorporated and also when both desirable and undesirable outputs were incorporated. These results exhibit that these five coastal provinces/municipalities are comparable with the states under the FIZ category in this study. Both the five coastal provinces/municipalities and the states under the FIZ category focus more on foreign direct investment activities and both manage to achieve high efficiency not only on their economic efficiency but also on their ecological efficiency.

It is worthnoting that, the drawback of measuring eco-efficiency using the DDF approach is the arbitrariness of the direction vector, which reduces the robustness of this method. A new finding on the eco-efficiency score using a newly developed Directional Slack-based Distance Function (DSDF) technique may overcome the drawback of the DDF approach. The findings indicate that the eco-efficiency results using the DSDF

technique are almost consistent with the DDF technique except for the states of Johor, Selangor and Perlis. These results are more convincing, since Johor and Selangor, with many industrial plants located in these states, appear to be having the poorest eco-efficiency score under the FIZ category. These two states have many heavy industries, which release higher levels of air pollution, thereby making them not able to attain a high eco-efficiency score. In terms of the geometric means for the two categories of states, interestingly, the DSDF approach demonstrates that the geometric mean for the N-FIZ category is higher than the FIZ category almost every year reversing the results of the DDF approach. This is largely due to the huge drop in the efficiency scores for Johor and Selangor.

The expansion and the contraction scale through the DSDF technique is more appropriate than the DDF technique because the manufacturer can expand and contract the desirable and undesirable outputs with different proportions determined by the DSDF model. For instance, through DSDF, it suggests that Pulau Pinang could expand its desirable output (sales) by 2.8 percent from actual value while concurrently contracting its undesirable output (carbon dioxide - CO_2) by 11.7 percent from the actual value to attain full eco-efficiency in 2010. The proposed method will be particularly useful when the manufacturer wants to identify the amount of undesirable output needed to be reduced in order to attain full efficiency, thus, providing a reasonable direction for the manufacturer to achieve a higher target in their productivity. In addition, supported by the fact that for almost every year, the scale direction for undesirable output is very much larger than the desirable output, it shows that Malaysian states need to prioritize the reduction of CO_2 in manufacturing activities and then followed by an increment in sales.

With regards to productivity change, the results show that eco-efficiency change is the main contributor of the productivity change during the study period. This finding is different from the results of previous studies i.e. Idris (2007) and Nordin and Fatimah (2010) which found that TFP growth was due to the contribution from technological change. It is relevant to point out here that the use of input and output variables that are taken into account in TFP reported by previous studies are not similar to this ML productivity growth. The incorporation of undesirable output in this study, makes the results from this study different from previous studies that merely rely on input and desirable output variables.

6.3 Research Contributions of the Study

This study may provide some significant contributions to the literature of eco-efficiency and productivity growth that can be categorized in three sections. First, in terms of methodological contribution, this study has developed an enhanced method of DDF for measuring eco-efficiency. This research study extends the previous framework of efficiency analysis to introduce a new slacks-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) approach. This new approach determines the optimal direction to the frontier for each unit of analysis and provides dissimilar expansion and contraction scales to achieve a more reasonable efficiency score. Through the DSDF approach, it may also establish target values for the reduction/expansion of outputs in order for the inefficient states to achieve full eco-efficiency. In addition, the issue of infeasibility in the Malmquist Luenberger Productivity Index (MLPI) calculated by the DDF technique in the literature has been solved using a two stage solution with DSDF calculation.

Second, in terms of empirical contribution, it may present a comprehensive model that integrates the indicators between environmental and industrial elements in the Malaysian context. To the best of the author's knowledge, this study is the first attempt to measure the eco-efficiency and productivity change in the Malaysian manufacturing sector using the DDF technique among 15 states in Malaysia over the study period between 2001 and 2010. The previous studies in Malaysian manufacturing context mostly neglected the incorporation of undesirable outputs in their framework, and thus, have no bearing on eco-efficiency measurement. Therefore, this study provides 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 is especially useful in the Malaysian context, as the integration between industrial production and environmental performance is quite new. The incorporation of both desirable and undesirable outputs in the efficiency analysis is very important as the emission of environmental pollutants is of great concern to the nation. Since the eco-efficiency measurement in this study calculates both economic efficiency as well as ecological efficiency, thus it may become an alternative tool to corporate environmental management solution while improving environmental performance. Through corporate environmental management, it may provide some benefits to organizations. For instance, organizations may create more value with less ecological impact, ensure continual environmental improvement in the organization, promote staff with environmental awareness, increase financial savings resulting from resource savings and cost reductions and allow the manufacturing sector to become more environmentally responsible while focusing on production sustainability.

Third, in terms of policy implication, the findings from the study will provide some implications to the individual organization or even the government. The findings are anticipated to give some lights and directions in formulating policies, laws, regulations and strategies pertaining to any environmental performance issue particularly concerning serious environmental damage caused by industrial pollutants so that the productivity growth is in balance with environmental performance. Properly designed environmental regulations will induce or encourage firms to operate in an eco-efficient manner. The regulatory intervention will provide a signal to companies to improve and trigger innovations that will reduce pollution. The policy issues and managerial implications are broached in the next section.

6.4 Policy and Managerial Implications

As has been discussed in the previous section, the empirical evidence in this study may offer some insights in relation to policies, laws and regulations with regards to the environmental damage due to manufacturing activities. To discuss these policies, laws and regulations, the implications can be categorized into three levels which are firm level, industry level and state level.

6.4.1 Firm level in the Manufacturing Sector

It is important to incorporate the undesirable output in efficiency measurement because the economic, social as well as environmental aspects are necessary steps towards sustainable development for an individual firm. Efforts to balance up the environmental aspect as well as the profits should be inculcated among the firms in moving towards a more environmentally friendly activity. Therefore, this application may assist individual firms to be more concerned about environmental protection while gaining profit.

On the firm level, there are many approaches that can be implemented to improve eco-efficiency. Approaches that can be presented as management strategy include bringing a life cycle perspective into environmental management. The use of life a cycle perspective may help manufacturers and policy makers to identify possible improvements throughout the manufacturing process and activities. All parties need to participate with their ideas and solutions with regard to their expertise in order to improve environmental performance. According to Remmen (2007), a product life cycle perspective is equivalent to design for sustainability principles through the "6 Re philosophy", which are rethink the product and its functions so that it can be used more efficiently. Replace harmful substances with safer alternatives. Repair the product and its parts so that it can be easier to repair or change. Reduce energy intensity, material consumption and socioeconomic impact throughout a product's life cycle. Recycle the material and resources. Reuse the parts of the products for disassembly. In addition to this "6 Re philosophy", another principle that can be integrated is maximizing the use of renewable resources in manufacturing activities. This philosophy is basically consistent with the concept of Green Supply Chain Management (GSCM), which is discussed in the introduction chapter.

The government can play an important role in assisting firms to improve eco-efficiency. Some mechanisms include providing grants or subsidies for starting a green business with the purpose of promoting eco-efficiency concerns among profit-making organizations. The green business concept is the involvement of manufacturing activities that encourage environmentally friendly and emission reduction activities among firms. All business operations in such organizations are committed to follow eco-friendly principles so that the environment is not adversely affected (Crusto, 2003).

Another mechanism that the government can introduce is a carbon tax policy for organizations. The idea is to make polluters pay for each tonne of carbon they release into the atmosphere. A carbon tax mechanism does not force but gives an incentive to firms to change their behaviour. This initiative would motivate the organizations to increase their eco-efficiency levels as well as minimize their environmental liabilities (Li & Zhang, 2012). Furthermore, this approach could be relatively easy to implement.

In addition, the installation of scrubbers is an alternative mechanism of policy implication to control pollution during production activities. The scrubbers are intended to reduce the emission of pollutants that are released into the atmosphere. For instance, the United States Environmental Protection Agency (EPA) proposed the installation of scrubbers as a regulatory action. The government can also formulate a policy for using alternative energy, which is much cleaner, or use the most cost-effective combination of energy and technology or make the emission intensive sectors, i.e. the "dirty industries" more accountable for pollution. In Korea, the National Strategy for Green Growth and the enactment of the Framework Act on Low-Carbon Green Growth in 2010 provide a comprehensive policy framework for green growth to promote eco-friendly growth engines. The above installation may assist individual firms to be more concerned with environmental protection while obtaining profit.

The environmental policy can also impose mandatory regulation and tight implementation in respect of emission control activities. For instance, small firms that are categorized under heavy polluting industry, i.e. power generation units, cement furnaces and coal mining, will be asked to stop production or even shut down following government regulation to minimize redundant production capacity (Zhang et al., 2012).

The above policy implications are relatively relevant to the firms or particular industries with regard to environmental protection and may possibly assist the Environmental Management System (EMS) in awarding a firm with the certification of ISO 14000. This is because this certification endorses the good reputation of a firm's performance, particularly concerning its perceived economic and environmental impact.

6.4.2 Industry level in the Manufacturing Sector

There is also an urgent need to look at the industry level when it comes to efforts to reduce environmental emissions. For instance, India implemented the concept of win-win opportunities in the sugar industry where environmental regulation has encouraged the firms to reduce pollution. By offering incentives for introducing innovative resource conservation measures for environmental management, this policy may ensure that pollution is reduced while increasing the productivity (Murty & Kumar, 2003).

Looking at the production and distribution of electric power and heat power industry in the manufacturing sector as an example, environmental emissions may be reduced in several ways. Enhancement in technologies relating to emissions control like technology in electricity generation and also improving the level of efficiency in the use of thermal coal, may help alleviate environmental emissions in this industry. Energy policies can also help in reducing environmental emissions. Policies like energy efficiency improvement, alternative energy development and the use of cleaner energy may result in a remarkable reduction of environmental emissions in the manufacturing activities. In addition, it is believed that industrial restructuring can also play a part in reducing these emissions.

Another alternative to improve eco-efficiency is the implementation of clean coal technologies. Technology such as Clean Coal Power Initiative (CCPI) focuses on eliminating emissions of pollutants including carbon dioxide and particulates. This technology may reduce carbon dioxide emission through Carbon Capture and Storage (CCS). Through CCS, the large amount of CO_2 that is released into the atmosphere from the fossil fuel used in manufacturing activities is captured and stored in underground geologic formations or deep in the ocean and dissolves under pressure (Zhang et al., 2012).

6.4.3 State level in the Manufacturing Sector

Regarding the third category, which is the state level, environment management is seen to be more complex where integration between the industrial development policies at state level and environmental policies on emission structure is very much needed to achieve maximum efficiency level. Several mechanisms can be taken into consideration. The first mechanism is to give particular attention to high emission states, i.e. the FIZ states. Limiting the amount of emissions according to the different types of emission can gradually reduce industrial environment emissions in this zone. In addition, introducing an emission trading mechanism or cap-and-trade can help decrease industrial environmental emissions particularly from the intensive pollution sectors, such as the power sector in several zones under the FIZ states (Zhang et al., 2012). This is a market-based approach where economic incentives act as a strong driver to reduce the emission of pollutants in the manufacturing sector. For instance, in 2003, cap and trade was applied in the eastern region of the United States through a NOx Budget trading Programme (NBP) to reduce the regional transport of NO_x emissions from power plants and other large combustion sources contributing to ozone nonattainment. This programme is an effective mechanism in reducing emissions from

multiple sources, while achieving emission reductions (US Environmental Protection Agency, 2003).

Another possible mechanism is through collaboration between undeveloped and developed states. The industrial raw material inputs in some FIZ states are supplied by the N-FIZ states which may lead to less environmental emissions and lower electricity consumption in the FIZ states. Meanwhile, at the same time, the central and local government should monitor the transfer of the pollution intensive industries from FIZ states to N-FIZ states and improve production capacities in N-FIZ states.

The Department of Environment (DOE) under the Ministry of Science, Technology and Environment in Malaysia should also revise the carbon pollution standard in the Environmental Quality Act, which has been implemented since 1974 (Amendment 1996). As time moves on and more pollutants are released, the regulation should be revised concurrently to improve eco-efficiency behaviour. The revision should reflect on the amount of carbon pollution that future development, such as manufacturers, will be allowed to emit since they are currently among the largest sources of carbon pollution. A comprehensive design of environmental regulation will induce or encourage manufacturers in Malaysia to operate in an eco-efficient manner.

6.5 Limitations

Despite the relevance and importance of this study and its theoretical and empirical merits, like any other study, it has limitations. However, it opens up opportunities for further research to deepen the understanding of Malaysian eco-efficiency and productivity change. Data availability is limited in this study, thus the scope of this study covers eco-efficiency only in air pollution. It was not possible to incorporate all

environmental pollutions, which consist of air, water and land pollutions. It might be useful to take into consideration all pollution factors in production activities so that the results can be used to make generalization on many other aspects of environmental performance that are not analysed in this study.

Another shortcoming related to data limitation is that the data gathered by the Department of Statistics, Malaysia (DOSM) can only be differentiated according to the states but not to the manufacturing sub-sectors. It would be more informative and analytical if the data collected by the DOSM can be presented by sub-sector since different sub-sectors may produce different pollution, and thus, offer interesting variations in the empirical literature.

Another limitation relates to the DDF approach itself in which, there is no statistical verification for the significance of the estimated eco-efficiency score. Most researchers use descriptive statistics to make assumptions concerning how the eco-efficiency scores are calculated. These descriptive statistics, however, are not sufficient to prove the confidence interval in the calculation of eco-efficiency score. Thus, this limitation may lead to another topic in future research.

6.6 Recommendations and Future Research Direction

The findings and limitations of this study suggest that this study can be extended and further investigated in several areas relating to the issues of efficiency and productivity. One of the most significant findings that has been identified, particularly in the literature review section, is that the body of knowledge is lacking theoretical based studies compared to empirical based studies. Although empirical studies are important, it is hoped that this study can initiate future research to introduce a new outstanding

technique while filling the weaknesses of previous models with regards to efficiency measurement with undesirable output in DEA. For instance, the combination model technique using the direct approach can be seen as a new paradigm in comprehensive efficiency measurement and would be a very significant contribution for future research in the DEA framework.

Another possibility for future studies with regards to empirical research is that the studies should also take into account other wastes beside carbon dioxide. This is because industrial activities contribute significantly to the wide range of complex pollutants that are disposed off in the air, water or on land i.e. sewage and landfill for water pollution and solid waste, respectively.

In addition to empirical research, the studies should consider a cross sectional study with the longitudinal data of eco-efficiency measurement. A combined cross sectional and longitudinal study of the Malaysian manufacturing subsector is more interesting since different subsectors will present different outcomes for different periods.

Further, as has been noted in the limitations section, there is a lack of statistical inference in efficiency analysis, particularly in the DDF approach while taking into consideration both desirable and undesirable outputs. Therefore, statistical inference like the bootstrapping approach can be considered as a better approach to ensure consistency and an unbiased eco-efficiency score. It is hoped that this further extension will be a significant contribution to the DEA research framework.