ABSTRACT

Efficiency measurement must reflect the realities of production activities. In the manufacturing sector, emissions from fossil fuel combustion, which are acknowledged as being undesirable outputs, should be taken into account in efficiency measurement, since they are produced jointly with desirable outputs. This type of measurement is referred to as eco-efficiency. To analyze eco-efficiency, the Directional Distance Function (DDF) has been a popular approach. However, there is a drawback to the DDF model where the direction vector to the production boundary is fixed arbitrarily, and, hence, may not provide the best efficiency measures.

The main purpose of this study is twofold. First, to introduce a new slack-based measure of efficiency called the Directional Slack-based Distance Function (DSDF) model and deploy it to calculate productivity change using the Malmquist Luenberger Productivity Index (MLPI). Second, is to apply the DSDF model to analyze the productivity change in the Malaysian manufacturing sector over the period 2001 to 2010. The regional analysis is conducted on 15 Malaysian states which are categorized into Free Industrial Zone (FIZ) and Non-Free Industrial Zone (N-FIZ) states. Two inputs and two outputs are employed. The inputs are operating expenditure and capital while the desirable and undesirable outputs are sales and carbon dioxide (CO_2), respectively.

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. The DSDF is more appropriate than the DDF because the desirable and undesirable outputs can be expanded and contracted, respectively, in different proportions. In addition, two stage analyses with a three-year 'window' of data is employed to overcome the infeasibility problem that may occur in the MLPI calculated by DDF.

The application of the DSDF demonstrates that the eco-efficiency scores for the states under the N-FIZ category are higher than the states under the FIZ category reversing the results of the DDF model. Johor and Selangor, which have many heavy industries releasing higher levels of air pollution, appeared to have the poorest eco-efficiency scores using the DSDF model. Considering the scale direction for undesirable output is larger than the desirable output, it shows that Malaysian states need to prioritize the reduction of CO_2 in manufacturing activities followed by an increment in sales. As for the productivity change, it was found that the main source of the productivity deterioration when taking CO_2 emissions into account is eco-efficiency change.

This study offers methodological contribution by introducing the DSDF model to overcome the drawback of the DDF model and solving the infeasibility problem that may occur in MLPI when using the DDF model. In terms of empirical contribution, it presents a comprehensive model that integrates the indicators between the environmental and industrial elements to measure the eco-efficiency in the Malaysian manufacturing sector. The findings also provide important policy implications. Among others, the study suggests the introduction of a carbon tax policy for organizations so that the manufacturing sector is more environmentally responsible while focusing on production sustainability.

ABSTRAK

Ukuran kecekapan mesti mencerminkan realiti sebenar aktiviti pengeluaran. Dalam sektor pembuatan, pelepasan daripada pembakaran bahan api fosil, yang diakui sebagai output yang tidak diingini, perlu diambil kira dalam menentukan kecekapan. Ini kerana pembakaran bahan api fosil tersebut dihasilkan bersama-sama dengan output yang diingini. Ukuran ini dikenali sebagai eko-kecekapan. Untuk menganalisis eko-kecekapan, *Directional Distance Function* (DDF) telah menjadi satu pendekatan yang popular. Walau bagaimanapun, terdapat kelemahan pada model DDF dimana arah vektor ke sempadan pengeluaran ditetapkan dengan sewenang-wenangnya. Oleh itu, ukuran kecekapan yang terbaik mungkin tidak dapat dihasilkan.

Tujuan utama kajian ini terbahagi kepada dua. Tujuan pertama adalah untuk memperkenalkan ukuran baru bagi kecekapan yang berasaskan *slack*, dikenali sebagai *Directional Slack-based Distance Function* (DSDF) model dan menggunakannya untuk menentukan perubahan produktiviti melalui *Malmquist Luenberger Produktivity Index* (MLPI). Tujuan kedua adalah untuk mengaplikasikan model DSDF bagi menganalisis eko-kecekapan dan perubahan produktiviti pada sektor pembuatan di Malaysia sepanjang tempoh kajian dari 2001 hingga 2010. Analisis dijalankan pada 15 negeri di Malaysia yang dikategorikan kepada Zon Perindustrian Bebas (FIZ) dan Bukan Zon Perindustrian Bebas (N-FIZ). Dua input dan dua output digunakan. Dua input tersebut adalah perbelanjaan operasi dan aset manakala output yang diingini dan tidak diingini adalah jualan dan karbon dioksida (CO_2).

Model DSDF ini menentukan arah optimum kepada sempadan pengeluaran bagi setiap unit analisis dan menyediakan faktor penambahan dan pengurangan yang berbeza untuk mencapai skor eko-kecekapan yang lebih munasabah. Model DSDF adalah lebih sesuai daripada model DDF kerana output yang diingini dan tidak diingini boleh ditambah dan dikurangkan mengikut perkadaran yang berbeza. Sebagai tambahan, dua peringkat analisis dengan tiga tahun data digunakan untuk mengatasi masalah penyelesaian *infeasible* yang boleh berlaku di dalam MLPI melalui pengiraan DDF.

Pendekatan DSDF menunjukkan bahawa skor eko-kecekapan bagi negeri-negeri di bawah kategori N-FIZ adalah lebih tinggi daripada negeri-negeri di bawah kategori FIZ berbeza dengan keputusan pendekatan DDF. Negeri Johor dan Selangor, yang mempunyai lebih banyak industri berat dan menghasilkan tahap pencemaran udara yang tinggi mendapat eko-kecekapan terendah melalui teknik DSDF. Memandangkan arah skala untuk output yang tidak diingini adalah lebih besar daripada output yang diingini, maka, ini menunjukkan bahawa negeri-negeri di Malaysia perlu memberi keutamaan kepada pengurangan CO_2 dalam aktiviti pembuatan seterusnya diikuti dengan peningkatan jualan. Bagi perubahan produktiviti, didapati eko-kecekapan adalah faktor utama yang mempengaruhi penurunan produktiviti apabila mengambil kira elemen CO_2.

Kajian ini memberi sumbangan metodologi dengan memperkenalkan model DSDF untuk mengatasi kelemahan model DDF dan seterusnya mengatasi masalah *infeasibility* apabila menggunakan model DDF semasa menentukan MLPI. Untuk sumbangan empirikal, ia mencadangkan model yang komprehensif dimana, faktor alam sekitar dan faktor industri diintegrasikan bagi mengukur eko-kecekapan dalam sektor pembuatan di Malaysia. Dapatan kajian ini juga menyumbang kepada implikasi dasar yang penting. Antara lain, kajian ini mencadangkan pengenalan dasar cukai karbon kepada organisasi supaya sektor pembuatan menganbil berat berkenaan alam sekitar disamping memberi tumpuan kepada kemampanan pengeluaran.

ACKNOWLEDGEMENTS

I sincerely thank Allah, the Most Gracious, the Most Merciful, for blessing me with good health, inspiration and patience to undertake this academic work.

In completing my Ph.D thesis, I owe a great debt to many people who contributed to its successful completion.

First and foremost, I would like to express my sincere thanks, gratitude and deep appreciation to my supervisor, Associate Professor Dr Susila Munisamy for her sincere efforts, interest and time in guiding my research. I am extremely grateful and indebted to Dr Susila for her excellent supervision, intellectual guidance and invaluable comments, without which it would have been impossible to complete my thesis. I had the good fortune and honour to train with and work under her supervision. I am very grateful to her for the time she spent to teach me, and sincerely thank her for her interest and wisdom, as well as her extraordinary cooperation and amazing patience in correcting my mistakes and restructuring my inconsistent writing. I have learned a lot from her and without her support this dissertation would not have been successfully completed. Many thanks for her supervision not only in this thesis but also in guiding me on how to become a good academician as well as her encouragement in seeking publication.

I would like to convey my gratitude to the University of Technology MARA, for providing me with the scholarship to carry out my doctoral study at the University of Malaya and also the Government of Malaysia, especially the Department of Statistics, for providing me with their invaluable data, which has contributed greatly to the completion of this thesis.

I want to thank my beloved parents, my parents-in-law and members of my family for their prayers, moral support and encouragement during my study. I owe my loving gratitude to my husband, Hakimi Md. Din and my sons Muhammad Ihsan, Muhammad Arif and Muhammad Yusuf for their tolerance, patience and understanding. Without their presence it would have been impossible for me to finish this thesis.

My gratitude is also extended to all my friends who always support me whenever I am down. Thank you for being persistent and encouraging, for believing in me, and for the many precious memories along the way.

Finally, I offer my regards and blessing to all who kindly supported me in any respect during the completion of this thesis.