CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

In the previous chapter, the formulations for efficiency measurement incorporating both, the desirable and the undesirable output variables were presented for Data Envelopment Analysis (DEA) and Directional Distance Function (DDF) approaches. In this study, DEA is employed to measure the technical efficiency. When incorporating the undesirable output, a popular approach that has been chosen to measure the eco-efficiency is the DDF technique. This approach has been considered in this analysis because it allows for desirable outputs to be expanded while undesirable outputs are contracted simultaneously. Nevertheless, this technique has a drawback in that the best efficiency measurement may not be provided when the direction vector to the production boundary is fixed arbitrarily. Hence, this study attempts to improve the drawbacks of this technique.

This chapter provides an understanding of the technical efficiency and eco-efficiency measurements in the 15 states of the Malaysian manufacturing sector. As discussed in the literature review section, little attention has been given to measure the eco-efficiency of the Malaysian manufacturing sector. Research to date has not sought to integrate carbon dioxide emissions in efficiency analysis, which is one of the main contributors to climate change. It is clear that a more comprehensive evaluation of environmental performance is needed when measuring efficiency. Efficiency measurements are biased when only desirable outputs are considered. Thus, the incorporation of undesirable outputs as well as desirable outputs becomes important in estimating efficiency levels, especially when environmental pollutants are discharged in the production process.

Before presenting all the results, it is also important to pay particular attention to the selection of variables and data source. The selection of the wrong variable and data source may result in an inaccurate efficiency measurement.

The remainder of this chapter is organized in the following manner. Section 5.2 presents performance analysis using the DEA and DDF approach. In this section, technical efficiencies of the Malaysian manufacturing sector using the standard DEA approach without taking into account undesirable outputs are discussed in section 5.2.1 while section 5.2.2 measures the eco-efficiency of each state using the DDF approach incorporating undesirable outputs. Next, in section 5.3 the discussion concerns the performance analysis using the newly developed Directional Slack-based Distance Function (DSDF) approach. In this section, a new eco-efficiency score is presented in section 5.3.1 followed by the scale direction and target for each state in section 5.3.2. Later, section 5.3.3 extends the analysis with super DSDF eco-efficiency while the following section 5.4 presents the productivity growth using the Malmquist Luenberger approach for the study period between 2001 and 2010. Section 5.5 summarizes the chapter.

5.2 Efficiency Analysis using the DEA and DDF Approaches

This section presents the empirical findings and discussions of the performance analysis using the Data Envelopment Analysis (DEA) and Directional Distance Function (DDF) approaches under the Constant Returns to Scale (CRS) assumption on technology. Two efficiency measurements are discussed in this study; these are technical efficiency using

DEA approach and eco-efficiency using DDF approach. The empirical results from these efficiency measurements help to understand the performance of the 15 states of the Malaysian manufacturing sector throughout the study period, between 2001 and 2010.

5.2.1 Technical Efficiency

This technical efficiency using the DEA model accounts for only two categories of variable which are, the input (operating expenditure and capital) and the desirable output (sales). The technical efficiency score using the DEA approach is obtained from equation (3.11) in the methodology chapter. The results of the technical efficiency scores and ranks from 2001 to 2010 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 the Non-Free Industrial Zone (N-FIZ) states consist of Kedah, Kelantan, Negeri Sembilan, Pahang, Perlis, Terengganu, Sabah, Sarawak, the Federal Territory of Kuala Lumpur and the Federal Territory of Labuan. The technical efficiency scores and ranks are calculated in every column of the year. In particular, the geometric mean for each year is also computed so that a summary of the industrial level technical efficiency can be provided. Using the DEA model with the CRS assumptions for the 15 states in Malaysia the technical efficiencies are yielded and presented in Table 5.1.

The CRS technical efficiency score in Table 5.1 indicates the presence of the inefficient use of outputs and the possible extent by which each state's outputs could be increased while maintaining existing inputs. For example, in 2001, Johor was 93.3 percent technically efficient. This finding suggests that Johor could increase its sales in manufacturing by approximately 6.7 percent while maintaining the current inputs of operating cost and capital. It should be noted that any state that has an efficiency score equal to 100 percent is defined as fully efficient, and a score of less than 100 percent is regarded as inefficient.

The outcomes, as reported in Table 5.1 show that there are quite consistent efficiency scores for each state under the FIZ category over the ten years analysis. For instance, Pulau Pinang performs almost 100 percent efficient over the ten years except for 2008 and 2010 in which there was a slight decline to 90.3 percent and 88.6 percent efficiency score, respectively. Since the score of the manufacturing sector of Pulau Pinang is almost on the production possibility frontier, it can be considered as technically efficient. The higher technical efficiency score for Pulau Pinang exhibits that most of their main industry of electronics manufacturing with more than 100 multinational technology manufacturing companies located in Pulau Pinang are good in managing their operating cost while producing output. Besides Pulau Pinang, Melaka also achieves a better technical efficiency score in the FIZ category. Melaka's main manufacturing activities are food products, clothing apparel as well as furniture products.

The higher technical efficiency scores for Johor, Pulau Pinang and Selangor signify the contribution of the electrical and electronics (E&E) industry in these three states. As a leading industry in the manufacturing sub-sector, E&E contributed 55.1 percent of the country's total exports of manufactured products for the year 2009 (Malaysia Productivity Corporation, 2009). To date, more than 300 companies operating in the E&E industry evolved in these three states which are Johor, Pulau Pinang and Selangor.

The results further suggest that, among the states in the FIZ, the poorest performer is Perak with scores between 63.8 percent and 87 percent throughout the period under study. There was a trough in the efficiency score from 2001 to 2006. But then, the score decreases again gradually in the subsequent years. Perak, which focuses on food products and the clothing manufacturing sector, manages to obtain 75.5 percent technical efficiency score on average. This result shows that Perak is the worst among the FIZ states. In fact, each year, the results of Perak indicate that this state does not utilise the input resources appropriately while producing the output.

It can be seen from Table 5.1 that the FIZ states contributed significantly (92.3 percent, 92.7 percent and 91.9 percent) to the Malaysian economy for three consecutive years between 2005 and 2007, and then their geometric mean score dropped to 85.9 percent in 2008. The impact of the economic crisis in 2008 was felt most strongly in the manufacturing sector. Referring to the 2008 annual report published by Bank Negara Malaysia, the crisis started to impact the Malaysian economy in the fourth quarter of 2008 where gross exports declined by 20 percent during the quarter while manufacturing production declined by 11.1 percent. This turn down in the manufacturing sector caused a subsequent reduction in the technical efficiency score in 2008, particularly for the FIZ states.

Table 5.1: Results of the DEA technical efficiency score and rank from 2001 to 2010

Year	2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
State	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
	%		%		%		%		%		%		%		%		%		%	
FIZ																				
1. Johor	93.3	6	86.1	8	89.7	4	84.8	7	91.6	7	93.7	7	94.1	6	86.9	7	85.6	7	85.2	9
2. Melaka	87.3	11	86.8	7	81.7	6	90.1	5	100	1	100	1	100	1	95.7	4	90.4	6	91.9	5
3. Pulau Pinang	100	1	100	1	100	1	100	1	100	1	98.3	4	99.9	4	90.3	6	99.7	4	88.6	7
4. Perak	87.0	12	78.7	14	65.2	14	63.8	15	79.8	14	82.5	12	78.2	12	76.1	12	74.0	13	69.6	14
5. Selangor	94.6	5	89.4	5	79.0	8	85.4	6	91.4	8	90.0	9	89.0	8	81.7	9	80.8	10	83.2	10
Geometric mean	*92.3*		*87.9*		*82.3*		*83.9*		*92.3*		*92.7*		*91.9*		*85.9*		*85.7*		*83.3*	
N-FIZ																				
6. Kedah	96.5	3	80.2	11	62.9	15	69.3	11	83.0	12	81.8	13	76.1	13	71.4	13	74.2	12	71.9	12
7. Kelantan	93.3	6	93.4	4	95.6	3	90.6	4	91.3	9	96.5	5	86.4	9	100	1	81.4	9	90.1	6
8. Negeri Sembilan	87.0	12	80.6	10	71.4	9	81.4	10	93.1	6	93.5	8	93.5	7	90.7	5	97.9	5	94.1	4
9. Pahang	84.9	14	80.0	12	66.2	13	65.3	14	81.0	13	85.4	11	84.8	10	82.1	8	76.2	11	78.5	11
10. Perlis	90.2	9	80.0	12	69.8	10	67.7	12	84.2	11	78.8	14	73.4	14	70.9	14	72.4	14	65.0	15
11. Terengganu	72.1	15	73.1	15	67.9	12	66.6	13	65.8	15	70.9	15	66.5	15	68.4	15	69.5	15	71.3	13
12. Sabah	91.9	8	88.8	6	89.4	5	92.6	3	94.2	5	96.3	6	95.8	5	100	1	100	1	100	1
13. Sarawak	100	1	97.1	3	79.1	7	83.1	9	98.1	4	100	1	100	1	100	1	100	1	100	1
14. Kuala Lumpur	95.5	4	85.2	9	68.1	11	83.9	8	88.0	10	88.5	10	78.9	11	77.6	10	83.6	8	87.6	8
15. Labuan	88.9	10	100	1	100	1	100	1	100	1	100	1	100	1	77.3	11	100	1	99.6	3
Geometric mean	*89.7*		*85.4*		*76.1*		*79.2*		*87.3*		*88.7*		*84.8*		*83.0*		*84.7*		*84.9*	
Total geometric mean	*90.6*		*86.3*		*78.1*		*80.7*		*88.9*		*90.0*		*87.1*		*83.9*		*85.0*		*84.3*	
Number fully efficient		2		2		2		2		3		3		3		3		3		2

Out of the five states under the FIZ category, Pulau Pinang appears to be the only state that experienced an impressive increase which is about 9.4 percent in their efficiency score after the economic crisis, from 90.3 percent in 2008 to 99.7 percent efficient in 2009. Other states, including Johor, Melaka, Perak and Selangor in the FIZ states exhibited a decreasing efficiency score from 2008 to 2009. In 2010, the geometric mean for all FIZ states shows a small drop in the technical efficiency, influenced by a large decrease for the states of Pulau Pinang and Perak. Figure 5.1 clearly depicts graphically the shift in the technical efficiency scores for the states under the FIZ category between 2001 and 2010.

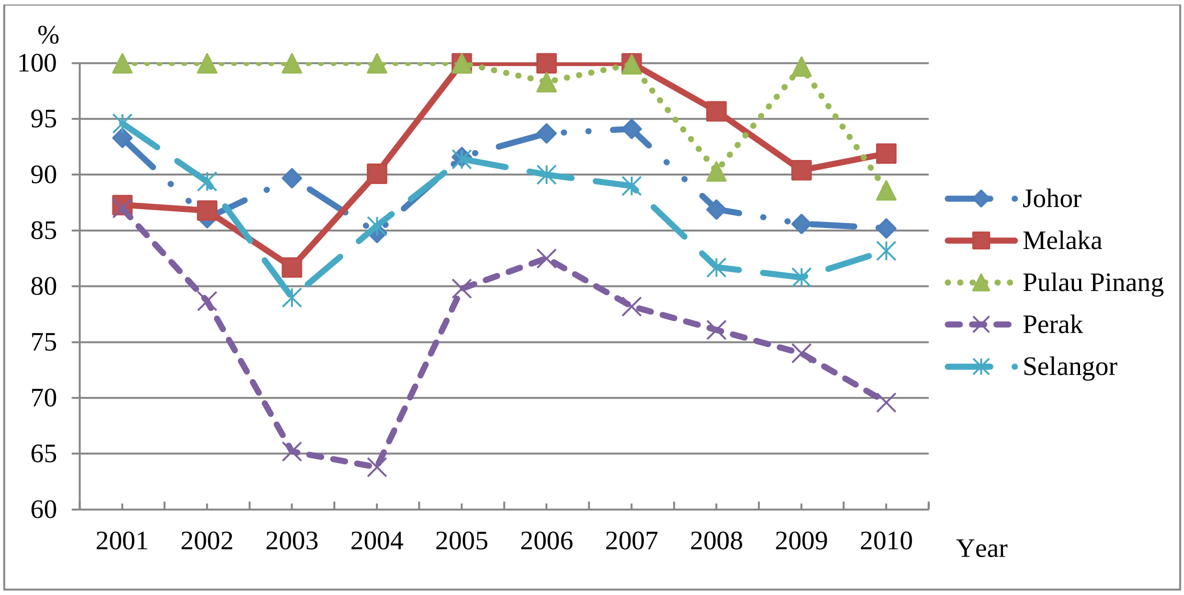

Figure 5.1: Shifts in technical efficiency scores for the states under the FIZ category

As for the N-FIZ states, Terengganu remains the least technically efficient throughout the study period with an average efficiency score of 69.2 percent. Terengganu consistently has the biggest potential to increase sales on average of up to 30.8 percent since this state is significantly below the efficient frontier. This poor performance of Terengganu could be due to this state contributing limited sales productions with a high amount of operating expenditure as well as capital. Hence, Terengganu is categorized as technically inefficient.

On a year-by-year basis, the trends seem to fluctuate for all the N-FIZ states except for the state of Sabah. In 2001, the efficiency score for Sabah is 91.9 percent however in the following year, the score decreases to 88.8 percent. The trend for Sabah generally rises between 2002 and 2008, climbing from 88.8 percent to 100 percent efficiency score, and there is a plateau from 2008 until 2010 at 100 percent efficiency score. This state may become a good example from the N-FIZ category in managing the input and output variables in production activities.

It can be observed that among all the states, Labuan obtains the greatest gain in efficiency, growing at an annual rate of 22.7 percent from 77.3 percent (2008) to 100 percent (2009) throughout the period of the study. Labuan also performs almost fully efficient consistently. Nevertheless, despite full efficiency throughout the years, Labuan slips in its technical efficiency during 2001 and 2008 when it only achieves a score of 88.9 percent and 77.3 percent, respectively, instead of 100 percent, as in other years. Labuan, which is not a major economic contributor to Malaysia did not take too long to boost its economic development after the economic crisis in 2008 since this state focuses more on shipping routes and offshore oil and gas fields. In fact, in the future, the manufacturing sector is expected to play a less significant role in the Malaysian economy. This scenario may allow easier handling of input resources in the state while producing fully efficient output in the manufacturing sector.

A closer examination of the technical efficiency for all states from 2001 to 2010 in Table 5.1 ranges from as low as 62.9 percent (Kedah, 2003) to as high as 100 percent. The average technical efficiency score for the FIZ category (87.9 percent) was slightly higher than the N-FIZ category (84.6 percent). The results also indicate that the majority of Malaysian states in the manufacturing sector experience high technical efficiency with an efficiency score of more than 75 percent in geometric mean during this 10 year period of study. This high technical efficiency by the manufacturing sector has enabled the Malaysian economy to achieve remarkable growth despite 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 approximately consistent with the results of the assessment on technical efficiency conducted by Nordin and Fatimah (2010). In the paper, they reported that the average technical efficiency in food manufacturing sub-sector is about 71 percent during 2002 to 2007.

With regards to total geometric mean, the efficiency score fluctuates from 90.6 percent in 2001 to 78.1 percent in 2003, lasting for 10 years before ending with an efficiency score of 84.3 percent in 2010. The FIZ and N-FIZ states both share a similar trend. Figure 5.2 clearly depicts graphically the trend of technical efficiency score over the study period for FIZ, N-FIZ and overall states.

The decline in technical efficiency from 2001 to 2003, as shown in Figure 5.2, is consistent with the trend of the manufacturing sector's growth rate, which is graphically depicted in Figure 5.3 obtained from the World Development Indicator (2010). The decline during the period 2001 to 2003 was attributed to many factors. Among others, the downturn in the global demand for manufactured goods, mainly electrical and electronic products, which are a major contributor to the manufactured exports in Malaysia. The downturn was due to the sluggish US demand for electronic equipment, in particular, automatic data office processing machines and equipment (Ministry of Finance Malaysia, 2004).

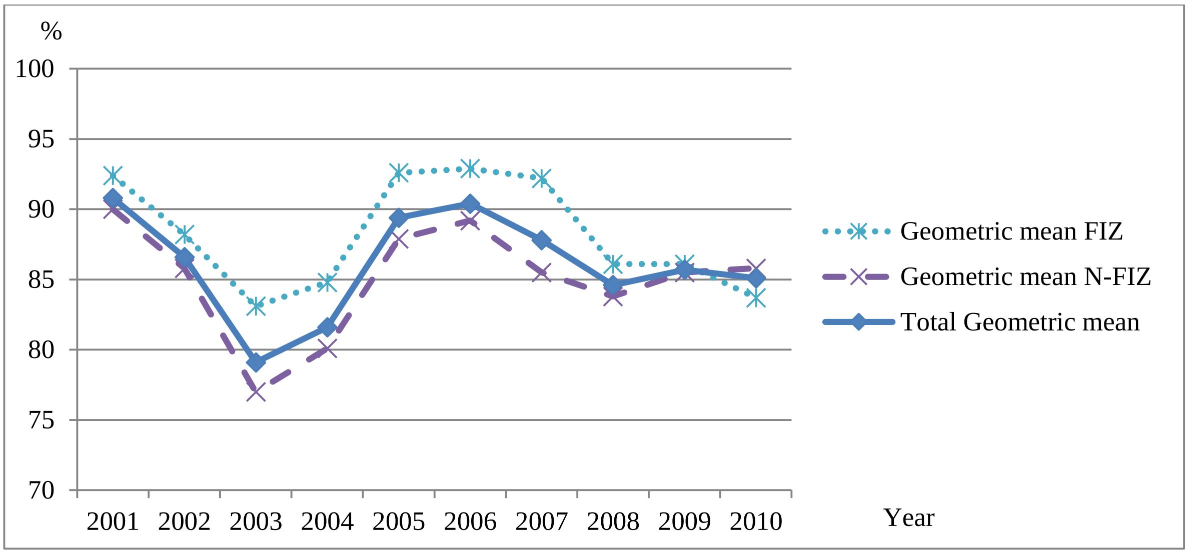

Figure 5.2: The trend of technical efficiency scores for FIZ, N-FIZ and total geometric mean

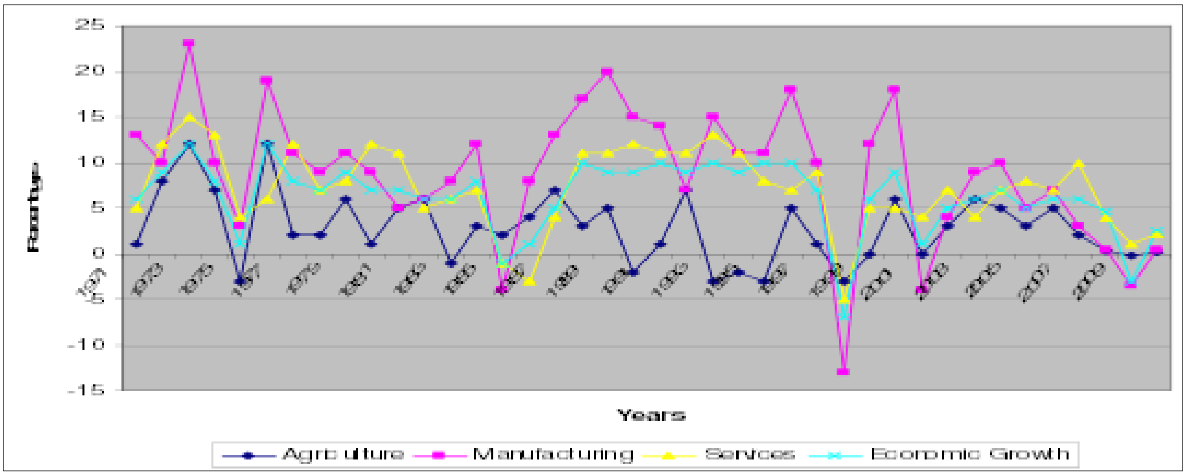

Figure 5.3: Malaysia's growth rates of key sectors from 1971 to 2010

Source: World Development Indicator (2010)

The high volume of manufacturing activities under FIZ category reflects the most important and effective approach by the Malaysian government to globalize the Malaysian economy. In addition, these manufacturing activities are the main instrument to rearticulate the economy towards international productive capital. The FIZ was basically directed towards the attraction of foreign investment to assist the Malaysian economy to take off. However, it is questionable whether the FIZ is bringing in as much foreign exchange as compared to the N-FIZ. The technical efficiency results presented in Table 5.1 indicate that the average efficiency score for the states in FIZ is higher than the N-FIZ throughout the study period. This result implies that the manufacturing activities in Malaysia's FIZ, which are categorized as industrial areas, perform better than states in the N-FIZ areas. This might be because the government has set up more industrial locations in FIZ states compared to N-FIZ states.

5.2.2 Eco-Efficiency

It is worth noting that modelling the production process without undesirable outputs can provide misleading results and unfair assessments. Therefore for the eco-efficiency measurement, both the economic efficiency as well as the ecological efficiency will be assessed in which the desirable and undesirable outputs are taken into account to avoid erroneous results. The results are presented in Table 5.2 for the period from 2001 to 2010.

The eco-efficiency scores in Table 5.2 via the Directional Distance Function (DDF) approach indicate the extent of desirable output expansion and undesirable output reduction. The eco-efficiency score using the DDF approach is obtained from equation (3.21) in the methodology chapter. For instance, in 2001, Johor was 93.7 percent efficient. This result suggests that Johor could expand its desirable output by as much as 6.3 percent while concurrently contracting its undesirable output by 6.3 percent to achieve full efficiency.

Among the states under the FIZ area, Johor, Perak and Selangor on average, are the most eco-inefficient states. According to the Department of Environment Malaysia (2009), the highest number of industrial pollution sources was in Johor (5791: 28.5 percent) followed by Selangor (4127: 20.3 percent) and Perak (2956: 14.6 percent). The highest number of industries in these three states justifies the eco-inefficiencies recorded. However, since Johor and Selangor managed higher production, the eco-efficiencies of these two states are still tolerable in comparison to Perak.

The poorest eco-efficiency score, recorded for Perak, supports the report published by the Department of Environment in 2008 in which Perak is identified as one of the states with numerous sources of industrial air pollution (Department of Environment Malaysia, 2008). In addition, the poor technical efficiency of Perak does have an effect on the poor eco-efficiency score recorded in section 5.2.1. With a lower eco-efficiency score on average, the results for Perak indicate that the input resources are not used appropriately, and the output of sales is limited with a high amount of carbon emitted. This finding might be the reason for 49 factories in the state of Perak to set up the Continuous Emission Monitoring System (CEMS) to monitor industrial air pollution. Through this system, a sample of emissions from the factories would be sent directly to the Putrajaya and Perak Envoronmental departments for further analysis. A necessary action will be taken if the emissions level violates the Environmental Quality (clean air) Regulations 1978 and Environmental Quality Act 1974. Bernama media, in July 2011, reported that this system will be introduced in stages starting from 2011.

Under the FIZ category, Melaka and Pulau Pinang achieve fully eco-efficient throughout the study period except for the years 2001 and 2010. The results may appear to be counter intuitive as these states have a lot of manufacturing activities that are likely to release air pollution. However, note that eco-efficiency measurement not only takes into account undesirable output but also desirable output in which, eco-efficiency not just measures ecological efficiency but both economic and ecological efficiencies. In addition, these counter intuitive results are also consistent with the results reported by

Watanabe and Tanaka (2007). They found that five coastal provinces/municipalities that have attracted a large amount of foreign direct investment manage to obtain a high score in efficiency when only desirable output is incorporated and also when both desirable and undesirable output are 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 highly efficient for both their industrial production as well as their environmental management.

The implementation of abatement controls within the sub-sector may also be the reason why the eco-efficiency for the FIZ category, particularly for the state of Pulau Pinang, managed to obtain fully eco-efficient. One of the leading global suppliers of technology equipment in Pulau Pinang has installed the largest photovoltaic system in Malaysia on the rooftop of its Pulau Pinang plant. This system will reduce the emissions by the Pulau Pinang plant by about 460 tons of carbon dioxide a year, which is equivalent to the emissions from 150 passenger cars. This effort of ‘going green’ by this company is a noteworthy endeavour to support the reduction of carbon footprint and trade in carbon credit.

Table 5.2: Results of the DDF eco-efficiency score and rank from 2001 to 2010

Year	2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
State	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank	Score %	Rank
FIZ																				
1. Johor	93.7	*8*	92.7	*9*	100	*1*	96.5	*8*	94.2	*11*	93.3	*8*	98.7	*8*	93.9	*8*	89.8	*8*	89.1	*10*
2. Melaka	86.1	*13*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	96.3	*6*
3. Pulau Pinang	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	94.6	*7*
4. Perak	86.7	*12*	80.0	*12*	88.1	*14*	80.8	*14*	84.2	*14*	78.9	*14*	78.6	*13*	74.2	*13*	79.2	*13*	72.2	*13*
5. Selangor	94.9	*6*	99.2	*6*	99.7	*7*	99.6	*6*	95.2	*10*	89.4	*10*	92.3	*9*	92.7	*9*	89.7	*9*	92.3	*9*
Geometric mean	*92.1*		*94.0*		*97.4*		*95.1*		*94.5*		*91.8*		*93.5*		*91.6*		*91.4*		*88.4*	
N-FIZ																				
6. Kedah	96.5	*4*	92.6	*10*	88.3	*13*	92.9	*11*	96.8	*7*	84.9	*12*	86.4	*11*	87.0	*10*	87.6	*10*	76.6	*12*
7. Kelantan	94.3	*7*	97.5	*7*	100	*1*	96.4	*9*	90.6	*12*	100	*1*	86.5	*10*	100	*1*	86.8	*11*	92.4	*8*
8. Negeri Sembilan	86.9	*11*	86.9	*11*	90.6	*10*	92.9	*11*	96.5	*8*	93.3	*9*	100	*1*	99.7	*7*	100	*1*	100	*1*
9. Pahang	85.0	*14*	78.4	*14*	80.6	*15*	75.8	*15*	86.5	*13*	83.0	*13*	84.5	*12*	85.2	*11*	81.5	*12*	78.1	*11*
10. Perlis	91.5	*10*	78.5	*13*	89.7	*11*	81.9	*13*	83.2	*15*	73.6	*15*	71.1	*14*	73.4	*14*	73.3	*14*	56.7	*15*
11. Terengganu	61.5	*15*	67.2	*15*	89.4	*12*	100	*1*	97.0	*6*	100	*1*	59.5	*15*	61.2	*15*	59.2	*15*	67.2	*14*
12. Sabah	93.7	*8*	93.3	*8*	94.9	*8*	96.4	*9*	100	*1*	97.1	*7*	100	*1*	100	*1*	100	*1*	100	*1*
13. Sarawak	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*
14. Kuala Lumpur	96.2	*5*	100	*1*	92.5	*9*	99.4	*7*	96.0	*9*	89.3	*11*	100	*1*	81.3	*12*	99.5	*7*	100	*1*
15. Labuan	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*
Geometric mean	*89.8*		*88.7*		*92.4*		*93.2*		*94.5*		*91.7*		*87.6*		*87.7*		*87.6*		*85.6*	
Total geometric mean	*90.6*		*90.5*		*94.1*		*93.8*		*94.5*		*91.7*		*89.6*		*89.0*		*88.9*		*86.5*	
Number fully efficient		*3*		*5*		*6*		*5*		*5*		*6*		*7*		*6*		*6*		*5*

Another example of abatement control implementation is in the paper mill industry. In order to make sure that the manufacturing activities are not in conflict with the environment, several paper mills in Pulau Pinang have invested in cogeneration technology to improve on thermal efficiency and reduce the emissions of carbon dioxide. As for Melaka, the limited manufacturing sector categorizes Melaka as eco-efficient in addition to Pulau Pinang. Figure 5.4 clearly depicts graphically the shift in eco-efficiency scores for the states under the FIZ category between 2001 and 2010.

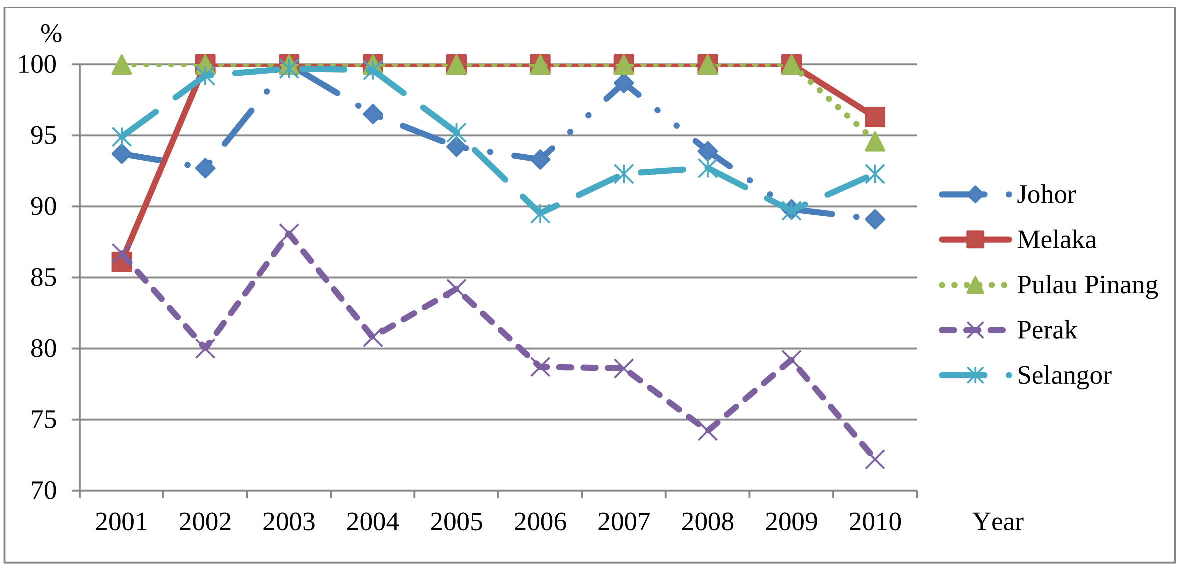

Figure 5.4: Shifts in eco-efficiency scores for the states under FIZ category

As for the N-FIZ states, it can be observed that, in 2010, Perlis with an eco-efficiency score of 56.7 percent had the greatest potential to expand its desirable output by up to 43.3 percent while concurrently contracting the undesirable outputs by about 43.3 percent, since this state was significantly below the efficient frontier. Perlis, which was among the least eco-inefficient on average, performed worse over the years. Besides Perlis, Terengganu which only managed to achieve 100 percent eco-efficient in 2004 and 2006 also performed poorly among the states in the N-FIZ category between 2001 and 2010. Overall, this result indicates that Perlis and Terengganu are the worst in managing their input and output variables in production activities.

The outcomes also revealed that Sarawak and Labuan were consistently ranked first throughout the study period. This could be attributed to the fact that these states have no heavy industries and manufacturing activities are at their minimum. Thus, the impact on air pollution is marginal. For instance, the Federal Territory of Labuan, an autonomous state located within the state of Sabah, focuses on shipping routes and offshore oil and gas fields and has limited manufacturing activities like paper industry, which contributes only 9 percent of the manufacturing sector’s carbon emissions. Sarawak, on the other hand, is the largest state in Malaysia and is also fully eco-efficient, with 80 percent of its total land area covered by forest rather than residential or industrial areas. Therefore, Sarawak is largely free from air pollution.

As for Kuala Lumpur, it is the capital of Malaysia and is the administrative and commercial centre with no heavy industry. Therefore, the impact on air pollution released by the manufacturing sector is also marginal. Thus, Kuala Lumpur can also be considered as almost fully efficient.

Looking at the overall picture in Table 5.2, Malaysia, as a whole, obtained an eco-efficiency score ranging from 56.7 percent (Perlis, 2010) to 100 percent across the states and the eco-efficiency score for FIZ was slightly higher than N-FIZ. The results also indicate that the majority of Malaysian states in the manufacturing sector experience high eco-efficiency with a score for geometric mean of more than 75 percent 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.

The trend of the eco-efficiency score for FIZ, N-FIZ and total geometric mean are incompatible with the trend of technical efficiency which starting at the 90s eco-efficiency score, the trend of eco-efficiency gradually climbed from 2001 up to 2003 but then fell slowly to less than 90 percent in 2010. If this trend is consistent, an investigation needs to be taken in order to monitor and evaluate manufacturing performance, not only in terms of economic efficiency but also ecological efficiency. Figure 5.5 clearly depicts graphically the trend of eco-efficiency scores over the study period for FIZ, N-FIZ and total geometric mean between 2001 and 2010.

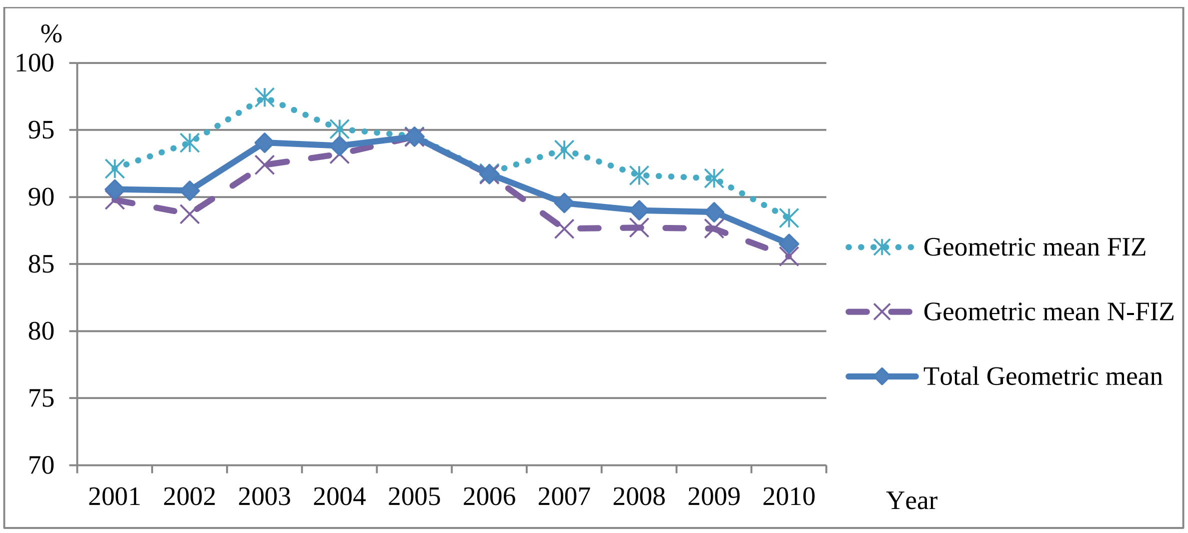

Figure 5.5: The trend of DDF eco-efficiency scores for FIZ, N-FIZ and total geometric mean

The next observation is on the yearly trend in eco-efficiency as compared to the carbon dioxide emissions over the period 2001– 2010. The yearly result is presented in Figure 5.6.

There was an inconsistent trend in CO_2 emissions released towards the eco-efficiency score from 2001 up to 2010. The highest CO_2 emissions released was in 2005 with 12.1 percent while the lowest was in 2009 with 8.5 percent. Nevertheless, the eco-efficiency score in 2005 was the highest with 94.5 percent while in 2009 the eco-efficiency score was 88.9 percent, the second lowest after 2010. This shows that the eco-efficiency score is not solely influenced by CO_2 emissions where when the CO_2 emissions released are high, the eco-efficiency will be low and vice versa. In eco-efficiency measurement, the levels of inputs and desirable outputs need to be incorporated as well besides the CO_2 emission. All these elements should be merged together in order to balance the goals of socio-economic development while retaining the environmental conditions.

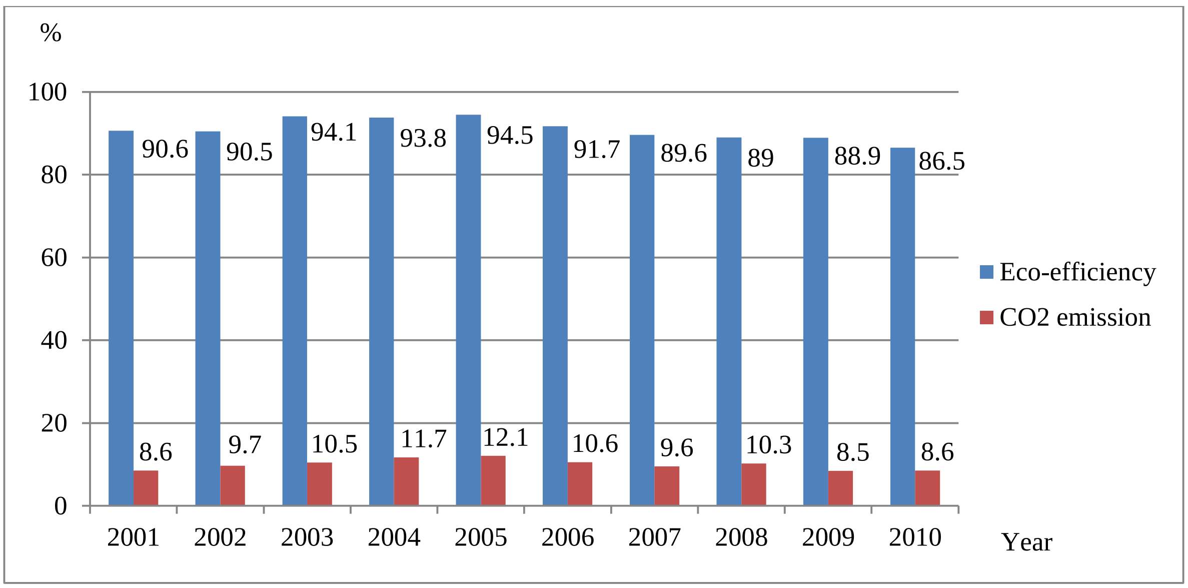

Figure 5.6: A comparison between CO_2 emissions and eco-efficiency score

In comparing technical efficiency with eco-efficiency using the CRS model, the results presented in Table 5.1 and Table 5.2 show some perturbations between both efficiency models. When the element of CO_2 is ignored in technical efficiency, only two or three states are 100 percent efficient. However, when the element of CO_2 is incorporated in eco-efficiency, there are three to seven states that are measured as 100 percent efficient. It is worth noting that as the number of variables increases (for example, with the inclusion of undesirable output in this case) the efficiency scores and the number of fully efficient states will increase.

Apart from that, most of the total geometric means also exhibit lower technical efficiency scores than eco-efficiency scores. This indicates that when undesirable output is omitted in the efficiency analysis, the results can be misleading. The technical efficiency results could be a sign of erroneous modelling of the production process, which may provide false results when undesirable output is not considered. The trends in technical efficiency and eco-efficiency are displayed in Figure 5.7.

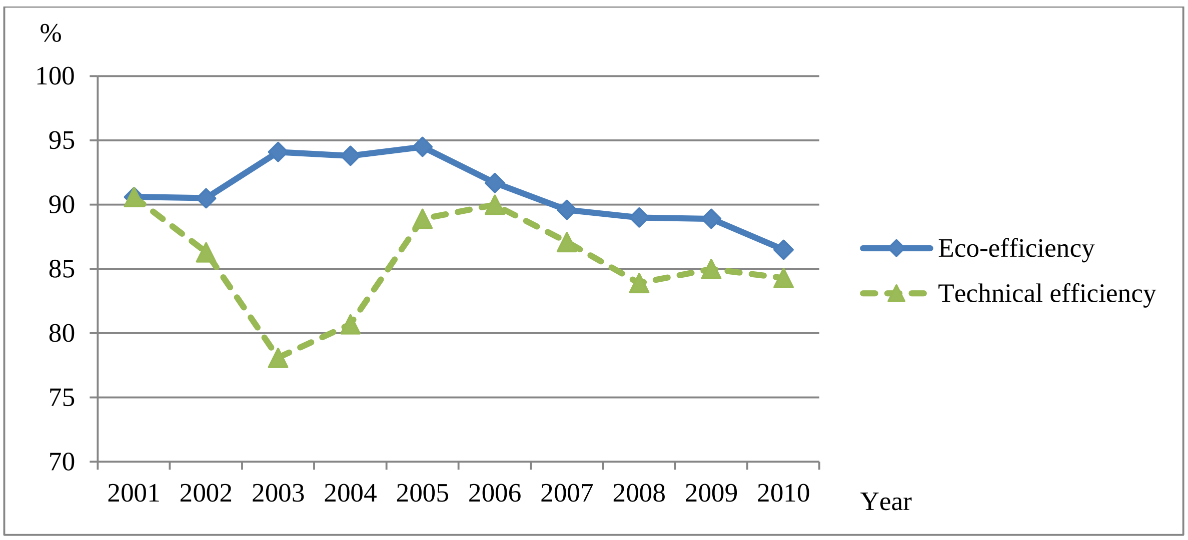

Figure 5.7: The trend between DDF eco-efficiency and DEA technical efficiency score

In further analysis, the DDF eco-efficiency results in Table 5.3 determined by the different direction vector is presented, which helps illustrate the impact of different direction vectors to the production boundary on the eco-efficiency score. To show the impact of different direction vectors, the latest data for 2010 is considered as an example. Column two and three present the DDF eco-efficiency results determined by the direction vector of g = (1, -1). Note that this result is obtained from the year 2010 in Table 5.2. Column four and five present the DDF results determined by the direction vector of g = (1,-2).

It is observed that the number of fully efficient observations drops by half (from five to two). Labuan, which is considered efficient under the direction vector of (1,-1), is inefficient under a direction vector of (1,-2). The efficiency scores are inconsistent under different direction vectors. This result shows that utilizing different direction vectors may provide different efficiency scores and may distort the ranking. Thus the DDF approach lacks robustness since the directions are arbitrarily fixed.

Table 5.3: The DDF eco-efficiency results determined by the different direction vectors

State	Eco-efficiency score DDF g = (1, -1)	Rank	Eco-efficiency score DDF g = (1, -2)	Rank
	%		%	
FIZ				
1. Johor	89.1	*10*	82.3	*8*
2. Melaka	96.3	*6*	91.3	*4*
3. Pulau Pinang	94.6	*7*	87.2	*5*
4. Perak	72.2	*13*	59.0	*13*
5. Selangor	92.3	*9*	79.6	*10*
Geometric mean	*88.4*		*79.9*	
N-FIZ				
6. Kedah	76.6	*12*	62.7	*12*
7. Kelantan	92.4	*8*	86.9	*6*
8. Negeri Sembilan	100	*1*	93.9	*3*
9. Pahang	78.1	*11*	71.9	*11*
10. Perlis	56.7	*15*	30.4	*15*
11. Terengganu	67.2	*14*	79.9	*9*
12. Sabah	100	*1*	100	*1*
13. Sarawak	100	*1*	100	*1*
14. Kuala Lumpur	100	*1*	86.5	*7*
15. Labuan	100	*1*	50.0	*14*
Geometric mean	*85.6*		*76.2*	
Total geometric mean	*86.5*		*77.4*	

5.3 Efficiency Analysis using the DSDF Approach

This section presents a new finding on the eco-efficiency score using the newly developed Directional Slack-based Distance Function (DSDF) technique, which was discussed in the previous chapter in order to overcome the drawback of the DDF approach. The new eco-efficiency score using the DSDF approach is obtained from equation (4.3) in the development of the DSDF approach chapter. The findings on the 15 states of the Malaysian manufacturing sector may provide differently on eco-efficiency scores compared to the previous approach of DDF technique. Apart from the eco-efficiency score, the expansion rate of the desirable and the contraction rate of the undesirable output is calculated further and demonstrate the target value for each state in order to obtain full eco-efficiency using the DSDF approach.

5.3.1 New Eco-Efficiency

Turning to the results using the DSDF approach in Table 5.4, it can be seen that, on average, the results are almost consistent between DDF and DSDF except for the states of Johor and Selangor for which the score for these states fell dramatically in the study period, in the year of 2009 when the economic crisis happened in the fourth quartile in 2008. These results are more convincing since Johor and Selangor, which are in the FIZ category, have many heavy industries releasing higher levels of air pollution. Therefore these states may not be able attain a high eco-efficiency score. The finding obtained through the DSDF technique exhibits that Selangor with many industrial plants located in this state, appears as having the poorest eco-efficiency score under the FIZ category. Figure 5.8 depicts in graphical form the shift in DSDF eco-efficiency scores for the states under the FIZ category.

Table 5.4: Results of the DSDF eco-efficiency score and rank from 2001 to 2010

Year	2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
State	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
	%		%		%		%		%		%		%		%		%		%	
FIZ																				
1. Johor	69.7	*14*	67.6	*14*	100	*1*	83.7	*12*	75.2	*14*	62.4	*14*	92.3	*9*	84.0	*12*	49.4	*14*	76.7	*13*
2. Melaka	94.5	*8*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	95.6	*8*
3. Pulau Pinang	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	71.1	*13*	100	*1*	100	*1*	100	*1*	94.0	*9*
4. Perak	81.9	*11*	77.0	*13*	76.4	*15*	81.8	*14*	81.3	*12*	78.0	*12*	85.6	*12*	79.3	*13*	77.1	*12*	83.5	*12*
5. Selangor	63.9	*15*	93.8	*9*	96.2	*10*	95.0	*9*	61.9	*15*	52.6	*15*	57.7	*15*	69.8	*14*	26.9	*15*	76.3	*14*
Geometric mean	*80.8*		*86.6*		*94.0*		*91.8*		*82.3*		*71.1*		*85.5*		*85.8*		*63.4*		*84.8*	
N-FIZ																				
6. Kedah	98.8	*5*	94.7	*8*	90.4	*11*	92.9	*10*	96.3	*8*	90.6	*8*	91.1	*10*	94.0	*9*	89.4	*10*	85.9	*11*
7. Kelantan	98.9	*4*	99.3	*6*	100	*1*	99.2	*7*	98.5	*5*	97.2	*6*	99.1	*8*	100	*1*	97.8	*9*	99.3	*6*
8. Negeri Sembilan	76.8	*13*	66.5	*15*	79.2	*13*	84.9	*11*	94.4	*10*	78.9	*11*	100	*1*	99.8	*5*	100	*1*	100	*1*
9. Pahang	77.2	*12*	81.6	*12*	78.2	*14*	80.1	*15*	88.4	*11*	82.4	*9*	86.2	*11*	90.7	*11*	81.1	*11*	87.8	*10*
10. Perlis	98.3	*6*	98.0	*7*	98.5	*7*	98.2	*8*	97.6	*6*	97.9	*5*	99.2	*7*	99.5	*6*	98.8	*8*	98.7	*7*
11. Terengganu	93.6	*9*	90.9	*10*	97.3	*8*	100	*1*	96.9	*7*	100	*1*	59.3	*14*	67.1	*15*	53.9	*13*	35.5	*15*
12. Sabah	86.6	*10*	85.0	*11*	87.4	*12*	82.4	*13*	75.3	*13*	80.9	*10*	84.6	*13*	95.6	*8*	100	*1*	100	*1*
13. Sarawak	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*
14. Kuala Lumpur	98.0	*7*	99.6	*5*	97.3	*8*	99.4	*6*	95.3	*9*	91.7	*7*	100	*1*	92.7	*10*	99.5	*7*	100	*1*
15. Labuan	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	100	*1*	96.6	*7*	100	*1*	100	*1*
Geometric mean	*92.4*		*90.9*		*92.5*		*93.4*		*94.0*		*91.6*		*91.0*		*93.0*		*90.7*		*87.5*	
Total geometric mean	*88.3*		*89.5*		*93.0*		*92.8*		*89.9*		*84.2*		*89.1*		*90.6*		*80.5*		*86.6*	
Number fully efficient		*3*		*4*		*6*		*5*		*4*		*4*		*6*		*4*		*6*		*5*

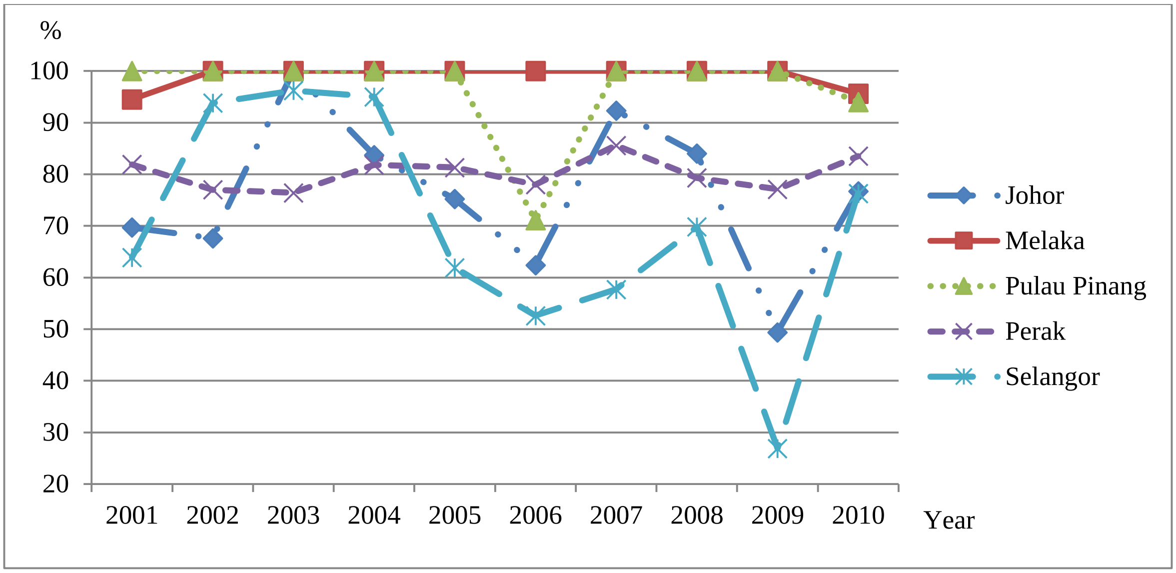

Figure 5.8: Shifts in DSDF eco-efficiency scores for the states under the FIZ category

In terms of the geometric means for the two categories of states, interestingly, the DSDF approach demonstrates that the yearly geometric means for the N-FIZ category are higher than the FIZ category reversing the results of the DDF approach. This is largely due to the huge drop in the efficiency scores for two states in the FIZ category, i.e., Johor and Selangor. Figure 5.9 clearly depicts graphically the trend of the DSDF eco-efficiency scores over the study period for FIZ, N-FIZ and total geometric mean.

Figure 5.10 depicts in graphical form the difference in eco-efficiency scores between the DDF and DSDF approach. As for eco-efficiency using the DSDF approach, it can be seen that in 2006 and 2009, the scores drop drastically. This is largely due to the huge drop in the eco-efficiency scores for Johor and Selangor in 2006, while in 2009, the huge drop might be because of the economic crisis, which occurred in the fourth quartile in 2008.

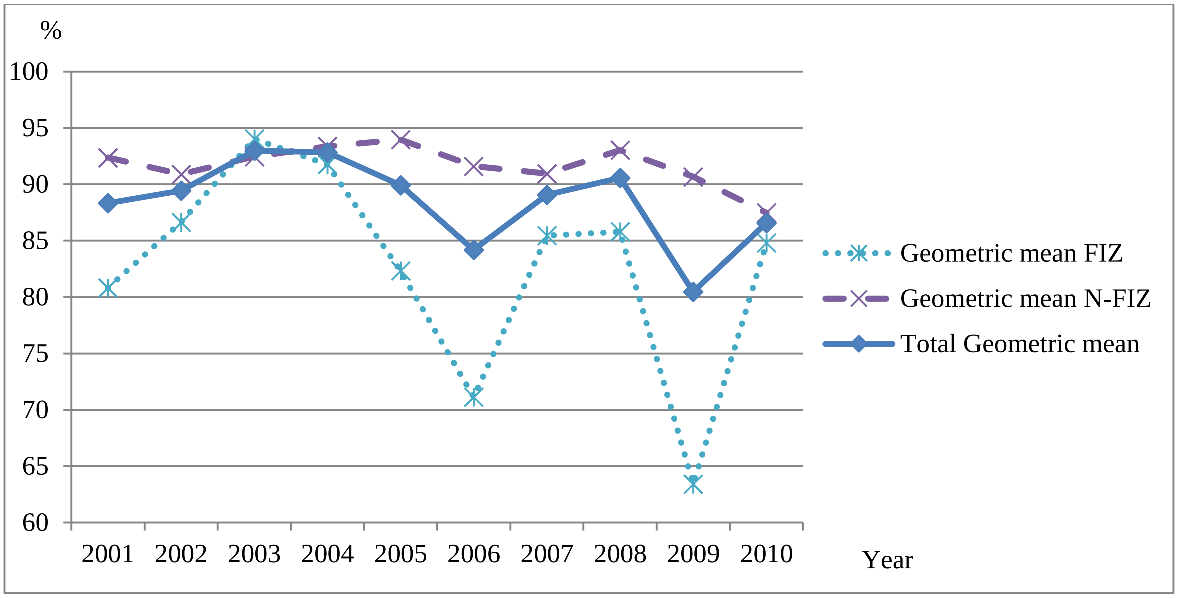

Figure 5.9: The trend of DSDF eco-efficiency scores for FIZ, N-FIZ and total geometric mean

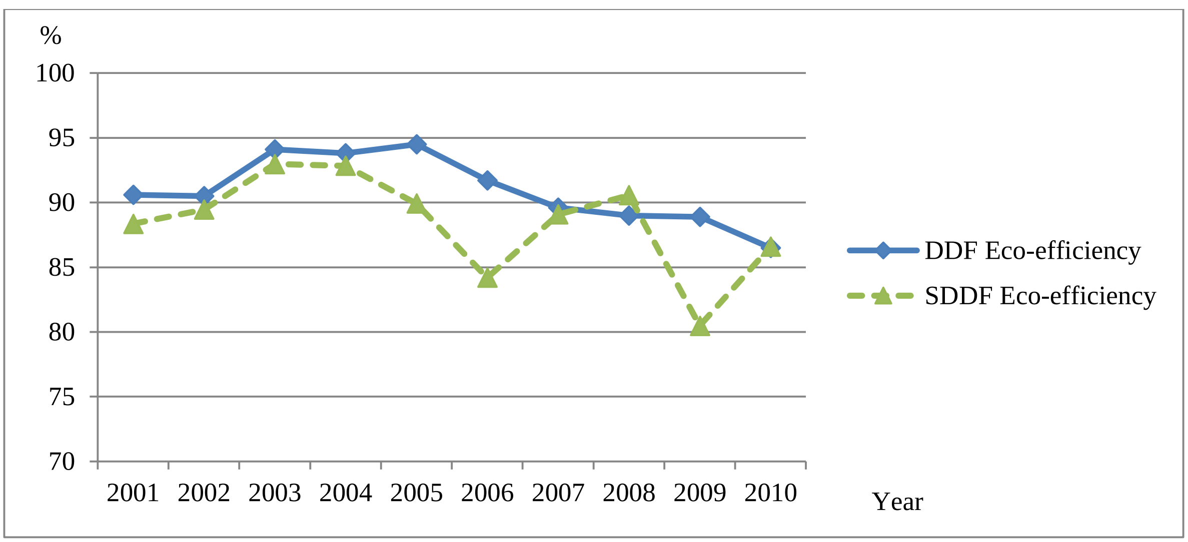

Figure 5.10: The difference in eco-efficiency scores between the DDF and DSDF approach

5.3.2 Scale Direction and Target Value

Based on the eco-efficiency scores presented in Table 5.4, the expansion rate of the desirable and the contraction rate of the undesirable output is calculated further and demonstrates the target value for each state in order to obtain full eco-efficiency using the DSDF approach. The expansion and the contraction rate through the DSDF technique is more appropriate because the manufacturer can expand and contract the desirable and undesirable outputs by different proportions given by the assumption. 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 and provides a reasonable direction for the manufacturer to achieve a higher target in their production activities.

The scale directions of the desirable and undesirable outputs are obtained from equation (4.3) while the target value for each state is measured from equation (4.4) in the development of the DSDF approach chapter. The results are presented in Table 5.5 and Table 5.6 using the earlier and latest data for the year 2001 and 2010. (The results between 2002 and 2009 can be referred to in Appendix C). The scale direction vector for sales and CO_2 are calculated in columns two and three. Columns four and five represent the target value for sales and CO_2 while the ‘change (%)’ is listed in columns six and seven. Using the Directional Slack-based Distance Function (DSDF) approach, the ‘scale direction’ column indicates the extent of desirable output (sales) expansion and undesirable output (CO_2) reduction. The ‘target value’ column suggests the levels of sales and CO_2 that each state should produce in order to achieve full eco-efficiency, while the ‘change (%)’ column shows in percentage terms how much the target value of sales and CO_2 need to be increased or decreased respectively.

Referring to the earlier analysis, the original DDF approach could suggest that the states should expand and contract both desirable and undesirable outputs by a single scalar without increasing the input. Nevertheless, in this analysis, through the DSDF approach, the states can expand and contract the desirable and undesirable outputs by different proportions. For instance, in Table 5.5 which is based on 2001 data, Johor could expand its desirable output (sales) by a scale direction of 0.149 while concurrently contracting its undesirable output (CO_2) by a scale direction of 0.851 to attain full eco-efficiency.

Table 5.5: Results of scale direction, target value and change for the inefficient state for 2001

States	Scale direction		Target value		Change (%)	
	Sales	CO_2	Sales (RM '000)	CO_2('000 tonne)	Sales	CO_2
FIZ						
1. Johor	0.149	-0.851	74942004	1147	7.1	36.3
2. Melaka	0.545	-0.455	26243625	397	14.6	13.5
3. Pulau Pinang	0	0	69255141	1085	0	0
4. Perak	0.110	-0.890	17702215	257	14.6	61.3
5. Selangor	0.158	-0.842	116470174	1768	5.7	30.4
N-FIZ						
6. Kedah	0.417	-0.583	16351955	251	3.4	6.5
7. Kelantan	0.084	-0.916	1545307	23	9.1	50.7
8. Negeri Sembilan	0.134	-0.866	26181433	389	14.8	56.7
9. Pahang	0.057	-0.943	9744788	142	17.9	79.3
10. Perlis	0.059	-0.941	905923	13	12.6	75.0
11. Terengganu	0.344	-0.656	8324693	121	38.8	47.4
12. Sabah	0.067	-0.933	12594707	190	8.6	62.5
13. Sarawak	0	0	24484392	356	0	0
14. Kuala Lumpur	0.105	-0.895	4346307	66	6.1	39.9
15. Labuan	0	0	737774	186	0	0

From Table 5.5, the scale direction with a value of zero for both sales and CO_2 exhibits that no change to the actual value of outputs is required as the expansion of desirable and contraction of undesirable output becomes zero. This is because this observation is already located on the frontier. For instance, Pulau Pinang, Sarawak and Labuan are not required to increase or decrease their value of sales and CO_2 since these states have been assigned an eco-efficiency score of 100 percent. The rest of the observations need to simultaneously increase their sales as well as decrease their CO_2 emissions in order to achieve full eco-efficiency scores. The results for Terengganu portray the highest change percentage (38.8 percent) for sales where this state needs to increase the amount of sales from the actual value of RM 5997143 to target value of RM 8324693 and reduce the amount of CO_2 from the actual value of 685 metric tonnes to the target value of 142 metric tonnes. Figure 5.11 clearly depicts graphically the changes from actual to target value for sales and CO_2 for the year 2001.

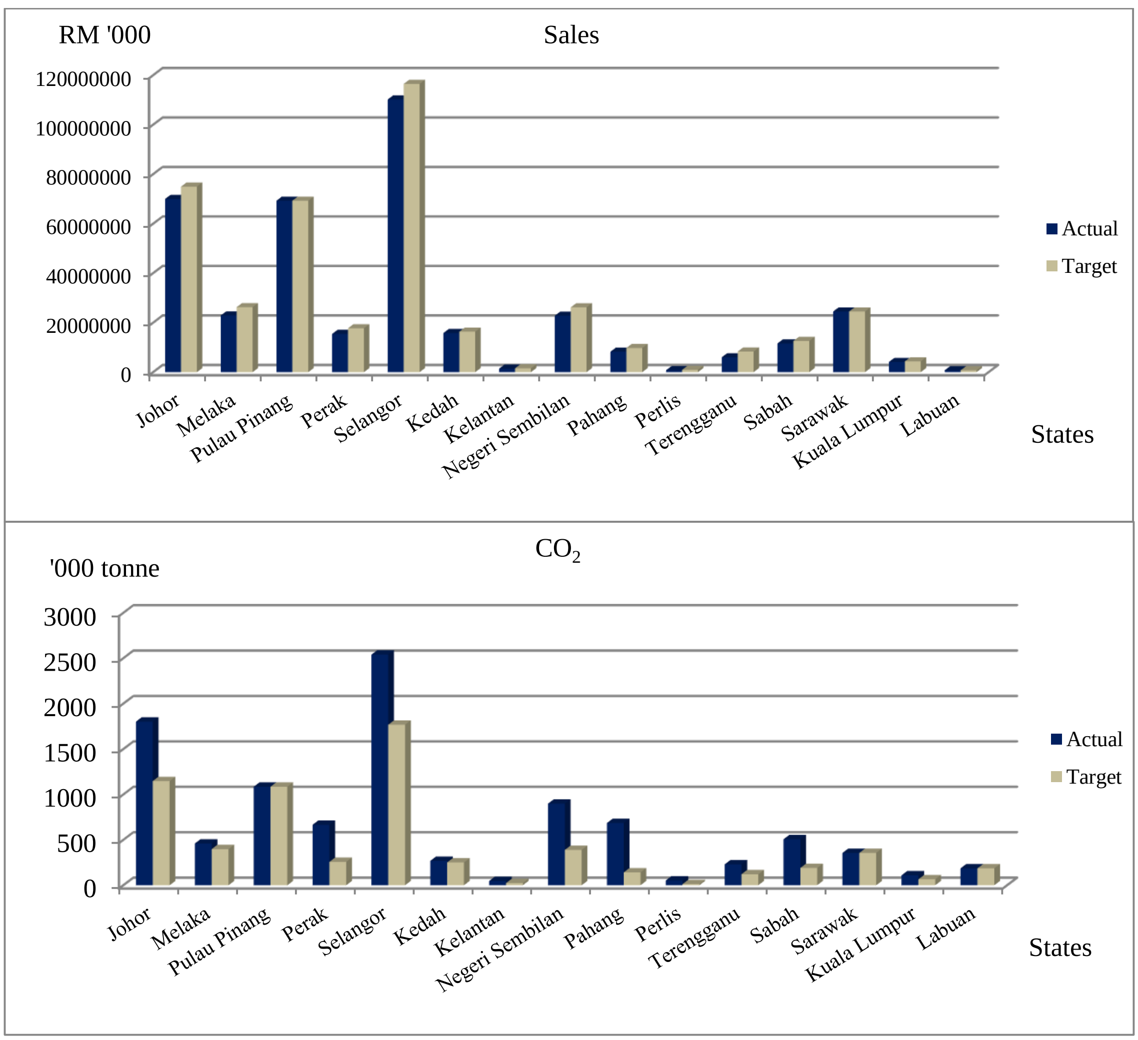

Figure 5.11: Actual and target value for sales and CO_2 for 2001

The results presented for the year 2010 are inconsistent with the results presented for the year 2001 wherein most of the states need to reduce their CO_2 emissions. Since all observations, except for the fully efficient ones have to reduce their CO_2 emissions, this finding shows that Malaysian states need to prioritize the reduction of CO_2 in manufacturing activities and later followed by the increment in sales. This is also supported by the fact that the scale direction for undesirable output is very much larger than the desirable output.

Table 5.6: Results of scale direction, target value and change for the inefficient states for 2010

State	Scale direction		Target value		Change (%)	
	Sales	CO_2	Sales (RM '000)	CO_2 ('000 tonne)	Sales	CO_2
FIZ						
1. Johor	0	-1	128677447	927	0	33.9
2. Melaka	0	-1	66483734	487	0	15.6
3. Pulau Pinang	0.217	-0.783	100732801	704	2.8	11.7
4. Perak	0	-1	29373553	213	0	61.3
5. Selangor	0	-1	215955588	1550	0	23.7
FIZ						
6. Kedah	0	-1	30415329	228	0	55.8
7. Kelantan	0	-1	3691470	26	0	36.3
8. Negeri Sembilan	0	0	41048411	287	0	0
9. Pahang	0	-1	28244678	216	0	53.5
10. Perlis	0.077	-0.923	1272501	9	11.4	72.2
11. Terengganu	0	-1	26757354	200	0	86.8
12. Sabah	0	0	33141275	425	0	0
13. Sarawak	0	0	72520117	866	0	0
14. Kuala Lumpur	0	0	20916149	162	0	0
15. Labuan	0	0	2078622	174	0	0

The results presented for scale direction are almost consistent with the change percentage for sales and CO_2. Terengganu portrays the highest change percentage (86.8 percent) for CO_2 and needs to reduce the amount of CO_2 from the actual value of 1511 metric tonnes to the target value of 200 metric tonnes.

Figure 5.12 clearly depicts graphically the changes from the actual to the target value for sales and CO_2 for the year 2010. It can be seen from this figure that there are drastic decreases to the amount of CO_2. This histogram provides a closer fit and perhaps more strategies can be identified for the states to obtain full eco-efficiency. The achievement of this goal in the short-term appears daunting. Some policy implications will be discussed in the conclusion section so that the amount of CO_2 can be reduced gradually in order to achieve the targeted CO_2 reduction by the Malaysian government.

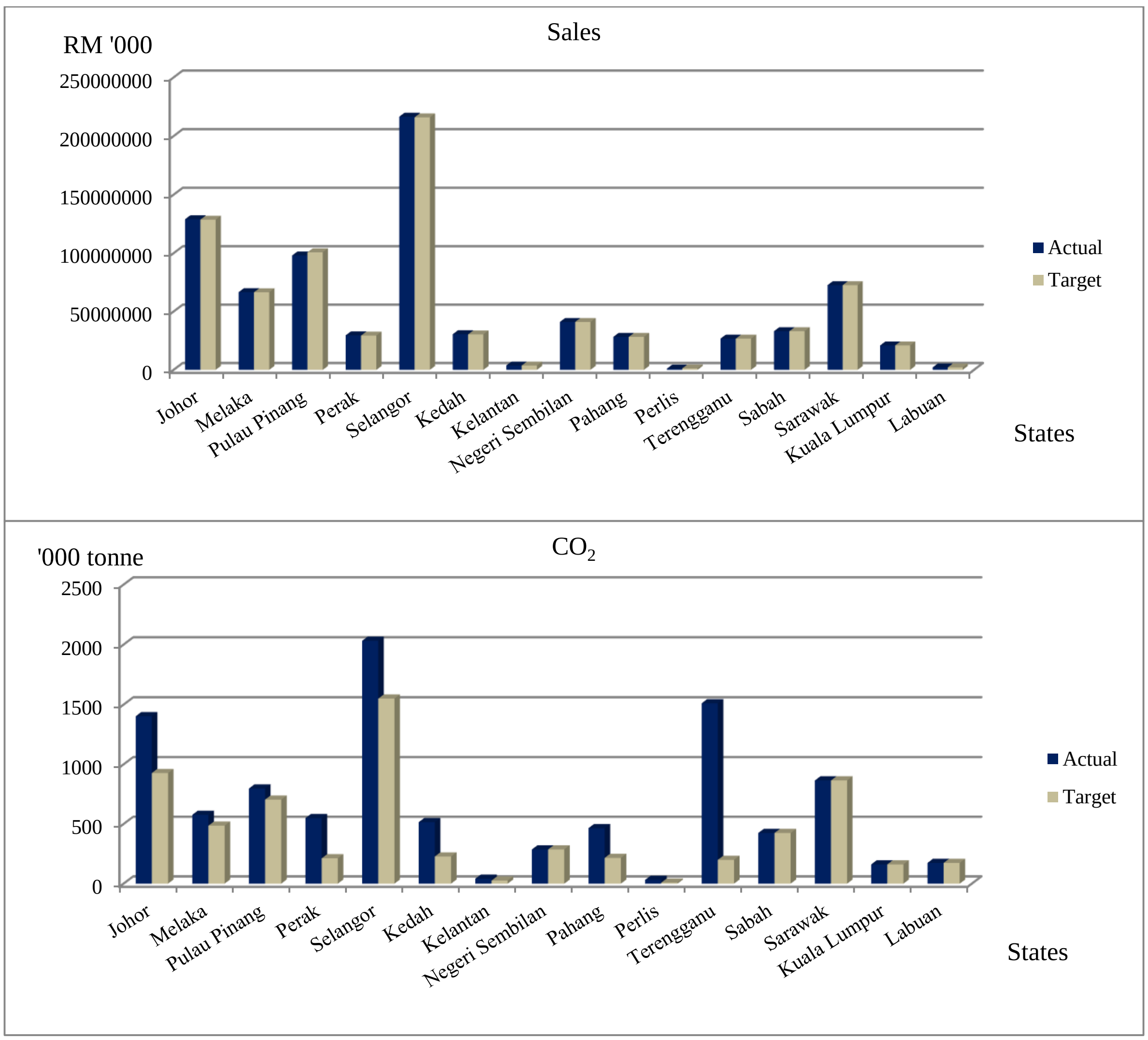

Figure 5.12: Actual and target value for sales and CO_2 for 2010

5.3.3 Super DSDF Eco-Efficiency (SDEE)

The results of the eco-efficiency of DSDF approach presented in Table 5.4 show that several states achieved a score of 100 percent score. Thus, there seems to be a lack of discriminatory power within the model. This is partly due to the low number of DMUs relative to the input-output used. To improve discrimination and to differentiate the fully efficient states, a Super DSDF Eco-efficiency (SDEE) was developed. The results presented in Table 5.7 are obtained from equation (4.7) in the development of the DSDF approach chapter.

Based on the results in Table 5.7, on average, Sarawak is ranked between first and third consistently throughout the study period. On the other hand, Labuan exhibits the last rank among the states under super efficient which is between rank third and rank sixth. In 2001, Pulau Pinang experiences the highest super efficient yielding a score of 133.9 percent while the rest of super efficiency scores are marginal. Even though the differences in super efficiency scores obtained are marginal, the technique is still applicable to rank the states.

In addition, it is worth noting that among the fifteen states, the average result for Sarawak which is ranked first, is consistent among the three models of DDF, DSDF as well as super DSDF eco-efficiency. This finding implies that the manufacturing activities in Sarawak were performing the most efficient among the other states throughout the study period. Thus, Sarawak may become a good example in managing their input resource while producing their output in manufacturing activities without neglecting the emission factor of pollution.

Table 5.7: Results of super DSDF eco-efficiency score and rank from 2001 to 2010

Year	2001		2002		2003		2004		2005		2006		2007		2008		2009		2010	
State	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
FIZ																				
1. Johor	69.7	*14*	67.6	*14*	100.2	*5*	83.7	*12*	75.2	*14*	62.4	*14*	92.3	*9*	84.0	*12*	49.4	*14*	76.7	*13*
2. Melaka	94.5	*8*	106.8	*2*	108.2	*1*	110.7	*2*	108.6	*1*	120.1	*1*	100.8	*4*	101.9	*3*	107.7	*1*	95.6	*8*
3. Pulau Pinang	133.8	*1*	117.8	*1*	106.9	*2*	112.7	*1*	100.3	*3*	71.1	*13*	107.3	*1*	107.9	*2*	100.6	*4*	94.0	*9*
4. Perak	81.9	*11*	77.0	*13*	76.4	*15*	81.8	*14*	81.3	*12*	78.0	*12*	85.6	*12*	79.3	*13*	77.1	*12*	83.5	*12*
5. Selangor	63.9	*15*	93.8	*9*	96.2	*10*	95.0	*9*	61.9	*15*	52.6	*15*	57.7	*15*	69.8	*14*	26.9	*15*	76.3	*14*
Geometric mean	*85.7*		*90.7*		*97.0*		*95.9*		*83.8*		*73.8*		*86.8*		*87.4*		*64.4*		*84.8*	
N-FIZ																				
6. Kedah	98.8	*5*	94.7	*8*	90.4	*11*	92.9	*10*	96.3	*8*	90.6	*8*	91.1	*10*	94.0	*9*	89.4	*10*	85.9	*11*
7. Kelantan	98.9	*4*	99.3	*6*	100.1	*6*	99.2	*7*	98.5	*5*	97.2	*6*	99.1	*8*	100.2	*4*	97.8	*9*	99.3	*6*
8. Negeri Sembilan	76.8	*13*	66.5	*15*	79.2	*13*	84.9	*11*	94.4	*10*	78.9	*11*	104.7	*3*	99.8	*5*	101.1	*3*	103.3	*2*
9. Pahang	77.2	*12*	81.6	*12*	78.2	*14*	80.1	*15*	88.4	*11*	82.4	*9*	86.2	*11*	90.7	*11*	81.1	*11*	87.8	*10*
10. Perlis	98.3	*6*	98.0	*7*	98.5	*7*	98.2	*8*	97.6	*6*	97.9	*5*	99.2	*7*	99.5	*6*	98.8	*8*	98.7	*7*
11. Terengganu	93.6	*9*	90.9	*10*	97.3	*8*	100.4	*4*	96.9	*7*	100.4	*3*	59.3	*14*	67.1	*15*	53.9	*13*	35.5	*15*
12. Sabah	86.6	*10*	85.0	*11*	87.4	*12*	82.4	*13*	75.3	*13*	80.9	*10*	84.6	*13*	95.6	*8*	100.3	*5*	101.3	*3*
13. Sarawak	103.3	*2*	103.8	*3*	104.4	*3*	104.8	*3*	103.3	*2*	105.4	*2*	107.2	*2*	110.6	*1*	107.1	*2*	108.1	*1*
14. Kuala Lumpur	98.0	*7*	99.6	*5*	97.3	*8*	99.4	*6*	95.3	*9*	91.7	*7*	100.2	*5*	92.7	*10*	99.5	*7*	100.2	*4*
15. Labuan	100.1	*3*	100.1	*4*	100.3	*4*	100.2	*5*	100.1	*4*	100.2	*4*	100.1	*6*	96.6	*7*	100.1	*6*	100.1	*5*
Geometric mean	*92.7*		*91.2*		*92.9*		*93.9*		*94.3*		*92.1*		*92.0*		*94.0*		*91.4*		*88.6*	
Total geometric mean	*90.3*		*91.1*		*94.2*		*94.5*		*90.6*		*85.6*		*90.3*		*91.8*		*81.4*		*87.3*	

With this super DSDF eco-efficiency model, we are able to distinguish the performance of all efficient states. The higher the super efficiency score the better the states presenting their performance.

5.4 Productivity Change using the Malmquist Luenberger Productivity Index (MLPI)

To further analyse the changes in productivity over time, the Malmquist Luenberger (ML) productivity index has been applied. Table 5.8 reports the results of productivity change calculated by the Directional Distance Function (DDF) model. The changes are reported for the nine pairs of years over the period 2001/2002 to 2009/2010. In addition, the productivity changes between the two endpoint years 2001 and 2010 are also calculated to provide an overall picture of the changes. The geometric means of the 15 states are calculated to obtain sample average results. The following tables also present the amount of regress (less than 1), progress (greater than 1) and no change (equal to 1) for each particular period. Since output oriented is computed to measure the productivity change, the value of the Malmquist Luenberger index or any of its components that is greater (less) than one denotes an improvement (deterioration) in the relevant performance and vice versa. Values of one exhibit no change in performance.

As has been discussed in Chapter 3, there is a possibility of an infeasible solution when calculating the ML productivity index using DDF approach. The infeasible solution can be seen in Table 5.8. Since some of the values appear as infeasible, no results are presented for eco-efficiency change and technological change.

Table 5.8: Productivity change using the MLPI calculated by DDF from 2001 to 2010

State	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	01/10
FIZ										
1. Johor	0.900	1.343	0.967	1.027	1.025	1.032	0.955	0.971	0.989	0.959
2. Melaka	1.038	0.996	0.997	Inf	Inf	0.936	0.998	Inf	0.704	1.015
3. Pulau Pinang	0.928	1.002	Inf	Inf	1.030	0.978	0.985	0.997	0.924	0.869
4. Perak	0.940	1.003	0.959	1.040	1.022	1.010	1.000	1.011	0.995	0.981
5. Selangor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
N-FIZ										
6. Kedah	0.947	0.972	1.009	1.064	0.961	0.999	0.996	1.013	0.937	0.978
7. Kelantan	1.000	1.006	0.991	0.979	1.072	0.973	0.967	0.748	1.067	1.023
8. Negeri Sembilan	0.903	1.119	1.021	1.010	1.000	1.061	0.958	0.982	0.905	1.002
9. Pahang	1.023	0.978	0.999	1.098	1.042	1.037	1.027	0.950	1.026	0.971
10.Perlis	0.996	1.005	0.975	1.039	0.963	1.164	1.028	0.891	0.878	0.989
11.Terengganu	0.966	1.068	1.020	0.985	Inf	Inf	0.945	0.938	1.098	1.021
12.Sabah	0.970	1.031	1.005	1.002	0.978	1.030	Inf	0.873	Inf	Inf
13.Sarawak	Inf	1.001	Inf	1.028	Inf	Inf	Inf	0.916	Inf	Inf
14.Kuala Lumpur	1.006	0.978	1.028	1.005	1.001	1.096	0.839	0.955	0.968	0.958
15.Labuan	Inf	1.062	0.976	1.014	Inf	1.302	1.045	Inf	Inf	Inf

Inf = Infeasible

To overcome the infeasibility results in Table 5.8, the DSDF model with two stage solutions has been calculated for the MLPI (the discussion on the two stage solutions has been explained in previous chapter). Tables 5.9, 5.10 and 5.11 report the results obtained by using the MLPI for productivity change, eco-efficiency change and technological change. Note that, the three-year "windows" of data is employed to form a frontier of reference technology for the mixed period in the DSDF approach. Therefore, the changes are reported for the seven pairs of years over the period 2003/2004 to 2009/2010. In addition, the productivity changes between the two endpoint years 2003 and 2010 are also calculated to provide an overall picture of the changes.

Looking at Table 5.9, given that the total geometric means of productivity change for all periods was always less than 1, by taking undesirable output into account, all the states experienced deterioration in the productivity performance over the study period except in 2006/2007 and 2007/2008 which showed an improvement in productivity (greater than 1). The results also show that the states under FIZ category experienced a higher rate in productivity regression compared to the states under N-FIZ category.

Table 5.9: Productivity change using the MLPI calculated by DSDF from 2003 to 2010

State	03/04	04/05	05/06	06/07	07/08	08/09	09/10	03/10
FIZ								
1. Johor	0.859	1.033	0.924	1.240	0.929	0.890	1.095	0.758
2. Melaka	0.982	0.970	0.944	0.927	1.041	0.939	0.904	0.904
3. Pulau Pinang	0.953	1.019	0.867	1.189	1.054	0.966	0.919	0.867
4. Perak	1.037	1.009	0.980	1.065	0.940	1.020	1.028	1.037
5. Selangor	0.989	0.897	0.984	1.018	1.045	0.940	1.183	0.808
Geometric mean	0.962	0.984	0.939	1.082	1.000	0.950	1.020	0.870
N-FIZ								
6. Kedah	1.007	1.052	0.959	1.002	1.021	0.990	0.948	0.941
7. Kelantan	0.991	0.998	0.989	1.019	1.009	0.981	1.010	0.992
8. Negeri Sembilan	1.035	1.141	0.878	1.211	0.982	1.028	0.972	1.177
9. Pahang	1.006	1.069	0.962	1.029	1.035	0.952	1.042	1.070
10.Perlis	0.997	0.995	1.003	1.013	1.003	0.994	0.998	1.001
11.Terengganu	1.011	0.982	1.041	0.710	1.051	0.939	0.875	0.619
12.Sabah	0.943	0.985	1.052	1.023	1.075	0.980	1.014	1.081
13.Sarawak	0.993	0.860	0.976	0.984	0.963	0.937	0.992	0.980
14.Kuala Lumpur	1.011	0.965	0.986	1.082	0.928	1.081	1.000	1.015
15.Labuan	0.969	1.024	0.998	0.990	0.984	0.999	1.000	1.001
Geometric mean	0.996	1.005	0.983	0.999	1.004	0.987	0.984	0.976
Total geometric mean	0.985	0.998	0.968	1.026	1.003	0.975	0.997	0.939
Progress (> 1)	6	7	3	11	9	3	8	7
Regress (< 1)	9	8	12	4	6	12	7	8
No change (= 1)	0	0	0	0	0	0	0	0

From the results obtained, we may find insignificant variation across states ranging from a low rate of 29 percent decrease in productivity change for Terengganu in 2006/2007 to a high rate of progress of 24 percent for Johor in 2006/2007 as well. Overall, the results suggest that productivity regressed. This regress is shown in the rightmost column in Table 5.9, which compares the two endpoint years of the period under evaluation. This shows that there has been a regression in productivity of as much as 6.1 percent over the entire period for manufacturing as a whole.

Figure 5.13 illustrates the trend of productivity change from 2003 to 2010 for FIZ, N-FIZ and the total geometric mean. The trend for productivity change appeared to undulate from the beginning of the year until 2009/2010. The economic crisis in 2008 seems to be reflected in the gradual decrease between 2007 and 2009. However, the erratic yearly trend for the total geometric mean is just a moderate variation between the low for productivity regress of 3.2 percent (2005/2006) and the high for productivity progress of 2.6 percent (2006/2007).

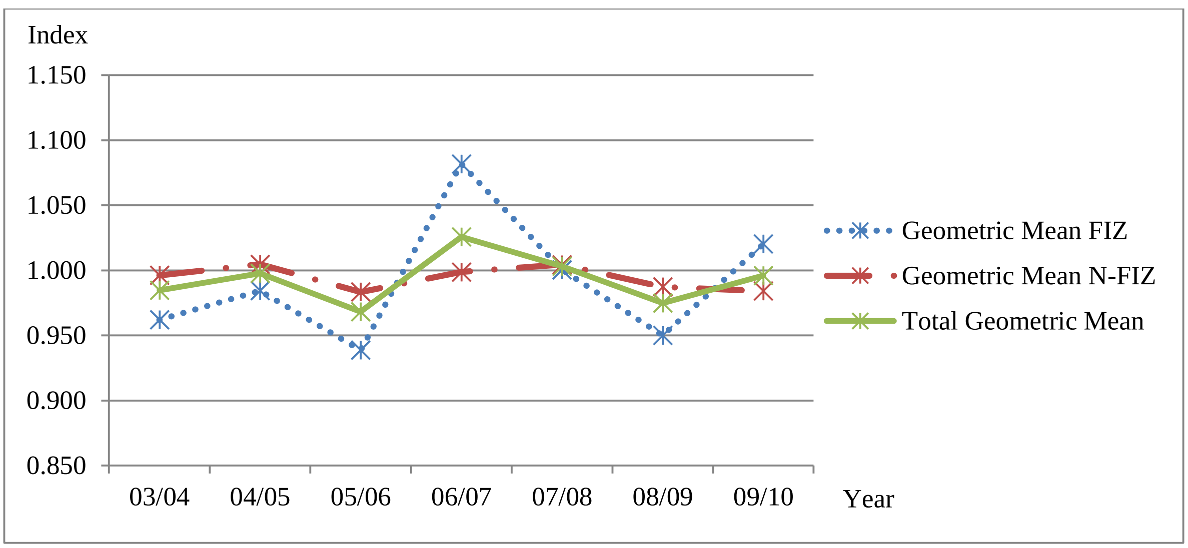

Figure 5.13: The trend for productivity change from 2003 to 2010

Further decomposition of productivity change for the manufacturing sector in Malaysia include the eco-efficiency change (catching up) component and a technological change (innovation) component. Tables 5.10 and 5.11 display the decomposition of productivity change into its component measures, eco-efficiency change and technological change, respectively. Before discussing each component further, remember that the productivity change is obtained by the product of eco-efficiency change and technological change. For instance, the geometric mean for productivity regress of 0.3 percent in the recent year 2009/2010 in Table 5.9 when CO_2 was weakly disposable was the product of an eco-efficiency change improvement of 2.8 percent and a technological change deterioration of 3 percent, industry wide.

Table 5.10: Eco-efficiency change using the MLPI calculated by DSDF from 2003 to 2010

State	03/04	04/05	05/06	06/07	07/08	08/09	09/10	03/10
FIZ								
1. Johor	0.860	0.932	0.907	1.278	0.928	0.772	1.219	0.811
2. Melaka	1.000	1.000	1.000	1.000	1.000	1.000	0.958	0.958
3. Pulau Pinang	1.000	1.000	0.776	1.289	1.000	1.000	0.943	0.943
4. Perak	1.046	0.996	0.973	1.066	0.948	0.982	1.055	1.061
5. Selangor	0.989	0.760	0.937	1.036	1.093	0.752	1.400	0.839
Geometric mean	0.977	0.933	0.915	1.127	0.992	0.894	1.102	0.918
N-FIZ								
6. Kedah	1.023	1.033	0.948	1.005	1.027	0.958	0.969	0.961
7. Kelantan	0.992	0.993	0.987	1.019	1.009	0.978	1.015	0.993
8. Negeri Sembilan	1.050	1.090	0.872	1.211	0.998	1.002	1.000	1.208
9. Pahang	1.016	1.074	0.949	1.033	1.041	0.919	1.060	1.086
10.Perlis	0.997	0.994	1.003	1.013	1.003	0.993	0.999	1.002
11.Terengganu	1.027	0.970	1.031	0.711	1.059	0.909	0.889	0.624
12.Sabah	0.957	0.943	1.047	1.032	1.105	1.044	1.000	1.126
13.Sarawak	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14.Kuala Lumpur	1.021	0.961	0.967	1.083	0.932	1.068	1.005	1.027
15.Labuan	1.000	1.000	1.000	1.000	0.967	1.034	1.000	1.000
Geometric mean	1.008	1.005	0.979	1.003	1.013	0.989	0.993	0.990
Total geometric mean	0.997	0.980	0.957	1.043	1.006	0.956	1.028	0.965

Progress (> 1)	6	3	3	11	7	4	6	6
Regress (< 1)	5	8	9	1	5	8	5	7
No change (= 1)	4	4	3	3	3	3	4	2

A glance at Table 5.10 indicates that the results for individual states for each period appeared slightly heterogeneous as it shows the eco-efficiency change exhibits regress and progress over the study period. As for Sarawak, it has been reported in Table 5.4 as being efficient for each year. Hence the eco-efficiency change index is also equal to 1 from 2003 until 2010. This does not necessarily imply, however, that the absolute performance of this state has remained stagnant over the study period. It can be found that the change in eco-efficiency ranged from an increase for Selangor of 40 percent in 2009/2010 to a decrease for Terengganu of 28.9 percent in 2006/2007. For the total geometric mean, the eco-efficiency changes portrayed some deterioration except in 2006/2007, 2007/2008 and 2009/2010 when they exhibited improvement. Figure 5.14 illustrates the trend for eco-efficiency change from 2003 to 2010 for FIZ, N-FIZ and total geometric mean.

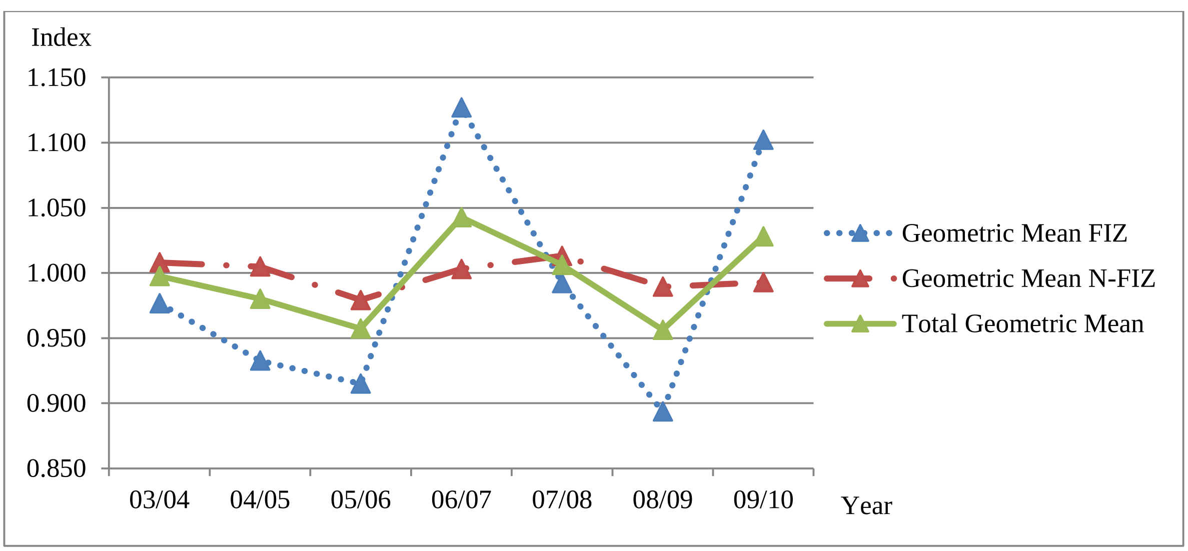

Figure 5.14: The trend for eco-efficiency change from 2003 to 2010

The technological change shows the extent to which the boundary of efficient production shifts over time. This component reflects changes in the performance of best states as opposed to the performance of those states that operate at the interior of the production boundary. Table 5.11 shows the results of the technological change component for all the states. Out of the 105 entries, about 53 demonstrated a negative shift in technology. This means that, about 50 percent of the entries only demonstrated a positive shift in technology. In addition, only one period of time, i.e. 2005/2006 saw technological progress for almost all the states.

Table 5.11: Technological change using the MLPI calculated by DSDF from 2003 to 2010

State	03/04	04/05	05/06	06/07	07/08	08/09	09/10	03/10
FIZ								
1. Johor	0.998	1.109	1.019	0.970	1.001	1.154	0.898	0.935
2. Melaka	0.982	0.952	1.044	0.927	1.041	0.992	0.943	0.943
3. Pulau Pinang	1.023	0.883	1.117	0.922	1.054	0.966	0.974	0.919
4. Perak	0.992	1.013	1.007	0.999	0.992	1.038	0.974	0.977
5. Selangor	1.000	1.180	1.050	0.983	0.957	1.250	0.845	0.963
Geometric mean	0.999	1.022	1.047	0.960	1.008	1.075	0.926	0.947
N-FIZ								
6. Kedah	0.984	1.018	1.011	0.998	0.994	1.033	0.977	0.979
7. Kelantan	0.999	1.005	1.001	1.000	1.000	1.003	0.995	0.999
8. Negeri Sembilan	0.987	1.047	1.007	1.000	0.984	1.026	0.972	0.974
9. Pahang	0.991	0.995	1.014	0.996	0.994	1.036	0.984	0.986
10.Perlis	1.000	1.001	1.000	1.000	1.000	1.001	0.999	0.999
11.Terengganu	0.985	1.013	1.010	0.999	0.993	1.033	0.985	0.991
12.Sabah	0.985	1.044	1.005	0.992	0.973	0.939	1.014	0.960
13.Sarawak	0.996	0.860	0.996	1.001	0.994	0.937	1.005	1.018
14.Kuala Lumpur	0.990	1.005	1.020	0.999	0.996	1.012	0.995	0.988
15.Labuan	0.969	1.024	1.000	0.990	1.018	1.000	1.000	0.999
Geometric mean	0.988	1.000	1.006	0.997	0.994	1.001	0.993	0.989
Total geometric mean	0.992	1.007	1.020	0.985	0.999	1.025	0.970	0.975
Progress (> 1)	1	11	12	1	4	10	2	14
Regress (< 1)	12	4	1	11	9	4	12	1
No change (= 1)	2	0	2	3	2	1	1	0

For the overall result, technological change ranged from an increase for Selangor of 25 percent in 2008/2009 to a decrease for Selangor also of 15.5 percent in 2009/2010. The technological change component saw a total of five periods of technological deterioration. Especially during 2006 – 2008 and at each endpoint year of 2003/2004 and 2009/2010 regression for the technology are recorded. As noted by Shestalova (2003), it is quite common to observe technological regress in some industrial branches eventhough the technology should at least remain unchanged or progress. Figure 5.15 illustrates the trend for technological change from 2003 to 2010 for FIZ, N-FIZ and the total geometric mean.

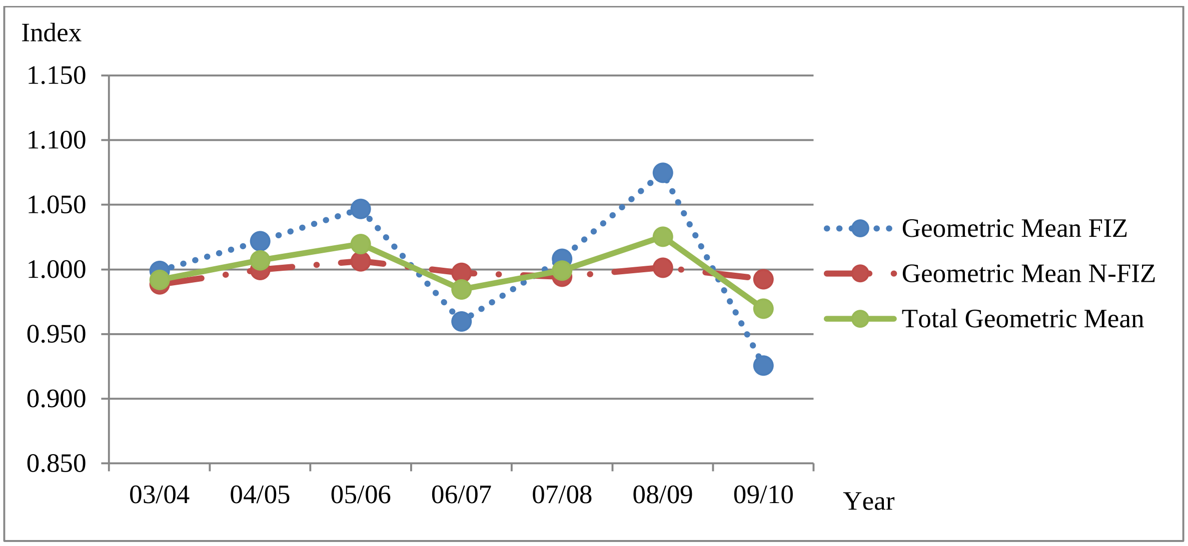

Figure 5.15: The trend for technological change from 2001 to 2010

The results of the total geometric mean in Tables 5.9, 5.10 and 5.11 are plotted into a trend map. Figure 5.16 shows the annual trend of the Malmquist Luenberger indices. The Malmquist Luenberger productivity index appears to fluctuate over the study period. Overall, it can be seen that eco-efficiency change is the main contributor to the productivity change during the study period. As for the initial period, i.e. from 2003 until 2005, it can be seen that technological change is the main contributor of the productivity growth. This trend is consistent with the productivity report (2005/2006) wherein total factor productivity (TFP) grew by 3.3 percent between 2001 and 2005 due to technological change, which improved manufacturing productivity and competitiveness. Examples of technology-driven processes and equipment include computer-aided design, computer-aided engineering systems, robotics, nanotechnology and advanced processing and packaging systems. However, 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 the technological change.

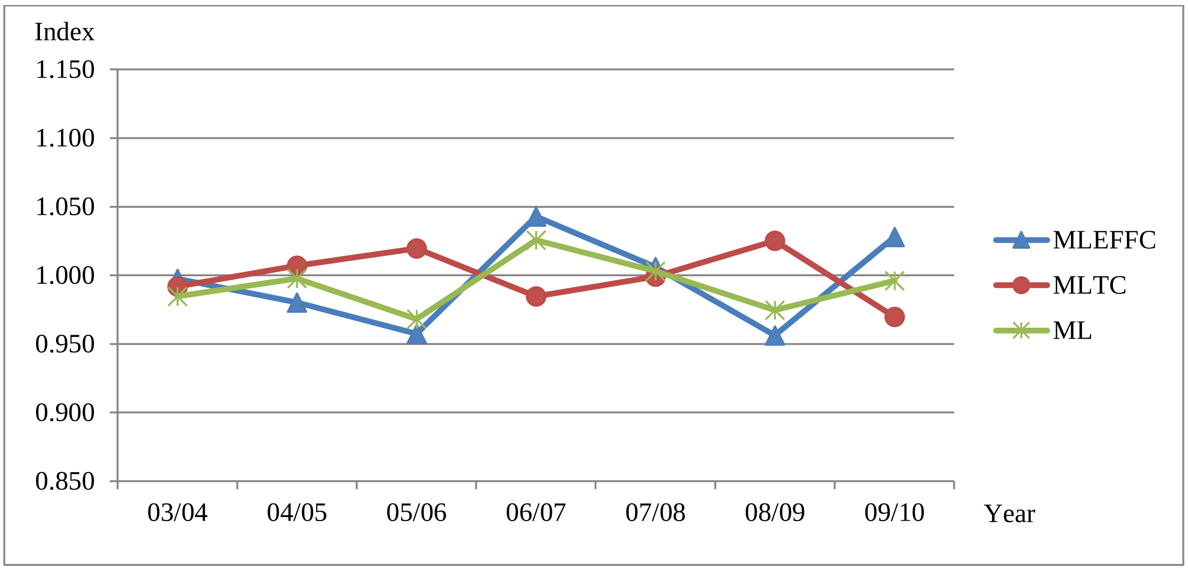

Figure 5.16: The trend for the MLPI and its component from 2003 to 2010

It is relevant to point out here that some of the factors taken into account in TFP reported by previous studies on TFP in Malaysia are not similar to this ML productivity growth. The factors include the use of input-output variables. The incorporation of undesirable output in this study, makes the result from this study different from the productivity report and previous studies that only rely on input and desirable output variables. In addition, different periods of data and methods of computing definitely yield different results for TFP measures.

Nevertheless, despite the contrasting results from the two studies above, the results of Elsadig (2006b) who employed the non-frontier Divisia Translog Index corroborate these findings. He found that the total factor productivity growth regressed about 0.12% during the study period between 1987 and 2001 when pollutant emissions variables were added to the model. According to Elsadig (2006b), the period of 1987 – 2001 was indeed the golden era of the Malaysian industrial development, and consequently, it generated high levels of pollutions. In relation to Elsadig's study, it can be concluded that industrial development increased until the year of 2010 and produced high level of pollution continuously. This high level of pollution led to a productivity regress in this study. Halimahton and Elsadig (2012) also found that Malaysian economic growth has an impact on air and water pollution. The continued rapid industrial development in Malaysia in the last decade has spawned increasing levels of pollution, particularly in the free industrial zones of Johor and Selangor, as observed in this study.

5.5 Conclusion

The empirical analysis results for the Malaysian manufacturing sector have been presented in this chapter using two different approaches while incorporating the undesirable output in efficiency measurement (the DDF and the DSDF models), covering the period from 2001 to 2010. Using the newly developed DSDF model presents appropriate scale direction results while obtaining the best eco-efficiency score. The results presented will be particularly useful when the manufacturer or decision maker wants to identify the amount of desirable output that needs to be increased and the amount of undesirable output that needs to be reduced to attain fully efficient and provides a reasonable direction to achieve higher target in their productivity.

The outcomes presented show some perturbations in the eco-efficiency scores as well as the ranking numbers across the two different models of DDF and DSDF due to some methodological reasons. The original concept of the direction vector in the DDF approach is determined by the method of ratio, which was discussed in the previous chapter. By giving the expansion of desirable output and reduction of undesirable output simultaneously with an arbitrary direction ($g = (y, -u)$) may provide an inappropriate direction for each output variable. This is the drawback of using this approach in as much as there are no standard techniques concerning how to determine the direction vector.

The direction vector results in the DSDF approach being different from the original concept of the DDF approach whereby it is determined by the additive slack of the desirable and undesirable output. The direction results are more appropriate because the DMUs can expand and contract the desirable and undesirable outputs by different proportions given by the assumption. The results obtained are especially applicable in the Malaysian context as the integration between industrial production and environmental performance is quite new. In addition, the incorporation of both industrial production and environmental performance is very important in estimating efficiency levels since the emission of environmental pollutants is of great concern to the nation.

The ability to rank or differentiate the efficient units is theoretically important. Thus, the super efficiency DSDF has been applied in this study. This super eco-efficiency result is useful to differentiate efficient states and motivate appropriate behaviour. The results of the super efficiency DSDF presented in Section 5.3.3 may overcome the discriminatory power of the DSDF score presented in Section 5.3.1. All the super efficiency scores are applicable in the sense that the measure exists, i.e. the defining programs have a feasible solution. Even though the differences in super efficiency scores obtained are marginal, the technique is still applicable to rank the states, hence the performance of the states can be differentiated.

The Malmquist Luenberger Productivity Index calculated using the DSDF model also provides additional insight into productivity growth of the eco-efficiency over time. It was found that the main source of the productivity deterioration when taking CO_2 emissions into account throughout the states is eco-efficiency change i.e. the catching up effect rather than technological change i.e. the innovation effect.