PRODUCTIVITY GROWTH IN MALAYSIAN MANUFACTURING SECTOR: A TWO STAGE ANALYSES OF THE MALMQUIST LUENBERGER PRODUCTIVITY INDEX

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ABSTRACT

Productivity growth 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 productivity change measurement. The main purpose of this study is to calculate productivity change using the Malmquist Luenberger Productivity Index (MLPI) on the 15 states in Malaysia. 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 Directional distance function (DDF). It was found that the main source of the productivity deterioration when taking carbon dioxide (CO_2) emissions into account is eco-efficiency change.

Keywords: *undesirable outputs, eco-efficiency, Malmquist Luenberger productivity index*

INTRODUCTION

An approach that has gained popularity to analyze the productivity change, called the Malmquist Index (MI). A Malmquist index of productivity change, initially defined by Caves et al. (1982) and extended by Färe et al. (1992) by merging it with Farrell's (1957). The Malmquist productivity index is constructed from the ratios of distance functions. The formulation of this index in terms of distance functions leads to the straightforward computation by exploiting the relation between distance functions and Debrau-Farrell measures of technical inefficiency.

However, if the technology has a feature that joints the production of desirable and undesirable outputs, the Malmquist index may not be computable (Chung et al., 1997). The Malmquist Luenberger productivity index (MLPI) is formulated to measure the productivity change in which the undesirable outputs are produced together with desirable outputs. MLPI measures the environmental sensitivity of productivity growth. Malmquist Luenberger (ML) is different from the Malmquist Index since this measure is constructed from the directional technology distance functions, which simultaneously adjust desirable and undesirable outputs in a direction chosen by the decision maker (Fried et al., 2008). The ML index changes the desirable outputs and undesirable outputs proportionally because it chooses the direction to be increased the desirable outputs and decreased undesirable outputs. As a similar concept to the directional distance function approach, ML also seeks to increase the desirable outputs while simultaneously decreasing undesirable outputs.

In the MLPI, the issue of infeasibility has also been discussed by other researchers (Färe et al., 2001; Jeon & Sickles; 2004; Oh, 2010). The infeasibility solution may occur for MLPI when utilizing the DDF approach for two distance functions of mixed period, i.e. t and t+1. According to Färe et al. (2001), the production possibilities frontier constructed from observations in period t may not contain an observation from period t+1 (and vice versa). To overcome the infeasibility problem stated above, Färe et al. (2001) used multiple year windows of data as the reference technology. Jeon and Sickles (2004) on the other hand used the index number approach to determine estimates of productivity growth and its decomposition while Oh (2010) employed the concepts of the global Malmquist productivity growth index of Pastor and Lovell (2005) with the DDF of Luenberger (1992).

This study may provide an alternative solution to decision makers through the two stage analyses with multiple year windows of data to form a frontier of reference technology.

METHODOLOGY

In conventional production theory, 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 original DDF model has been modified by Ramli et al. (2013) known as scale directional distance function (SDDF) so that each output bundle can have a different direction to the production boundary. This model is based on the slacks-based measure of efficiency. The objective function of the DDF has been replaced with the summation of γ_{yj}, the expansion factor for desirable outputs, and γ_{uk}, the contraction factor for undesirable outputs in the SDDF approach in formulation (1) below.

$$\text{Max } h_m = \sum_{j=1}^{J} \gamma_{yj} + \sum_{k=1}^{K} \gamma_{uk} \tag{1}$$

Subject to

$$\sum_{n=1}^{N} z_n x_{in} \leq x_{im} \; ; \; i = 1,2,\ldots,I \; ; \; \sum_{n=1}^{N} z_n y_{jn} \geq y_{jm} + \gamma_{yj} .1 \; ; \; j = 1,2,\ldots,J \; ;$$

$$\sum_{n=1}^{N} z_n u_{kn} = u_{km} - \gamma_{uk} .1 \; ; \; k = 1,2,\ldots,K \; ; \quad z_n, \gamma_{yj}, \gamma_{uk} \geq 0 \; ; \; n = 1,2,\ldots,N$$

Where z_n is the intensity variable for the *n*th observation, x_{in} is the *i*th input of the *n*th DMU, y_{jn} is the *j*th desirable output of the *n*th DMU, u_{kn} is the *k*th undesirable output of the *n*th DMU, x_{im} is the *i*th input of the *m*th DMU, y_{jm} is the *j*th output of the *m*th DMU and u_{km} is the *k*th undesirable output of the *m*th DMU.

In this study, two stage analyses with multiple year “window” of data, as has been suggested by Färe et al. (2001), is employed to form a frontier of reference technology to solve the infeasibility problem for a mixed period in the MLPI approach. In the first stage, four distance functions are calculated using the model of SDDF. For mixed period calculation, three-year data are used to construct the reference technology. According to Färe et al. (2001), all of the production frontiers that are calculated are derived using observations from that year and the previous two years. In other words, the reference technology for time period t would be constructed from data in t, t – 1 and t – 2 and period t + 1 would be constructed from data in t, t + 1 and t – 1. For instance, the reference technology for time period 2003 would be constructed from data between 2001 and 2003 and period 2004 would be constructed from data between 2002 and 2004.

Using the SDDF approach in model (1), the solution for mixed period can be solved as follows:

$$\overrightarrow{DS}_o^{t+1}(x^t, y^t, u^t; y^t, -u^t) = \text{Max} \sum_{j=1}^{J} \gamma_{yj}^{\mathrm{t}} + \sum_{k=1}^{K} \gamma_{uk}^{\mathrm{t}} \tag{2}$$

Subject to

$$\sum\nolimits_{n=1}^{N} z_n^{\mathrm{t+1}} x_{in}^{\mathrm{t+1}} \le x_{im}^{\mathrm{t}}\ ;\ \ i = 1,2,\dots,I\ \ ;\quad \sum_{n=1}^{N} z_n^{\mathrm{t+1}} y_{jn}^{\mathrm{t+1}} \ge y_{jm}^{\mathrm{t}} + \gamma_{yj}^{\mathrm{t}}.1\ \ ;\ \ j = 1,2,\dots,J\ \ ;$$

$$\sum_{n=1}^{N} z_n^{\mathrm{t+1}} u_{kn}^{\mathrm{t+1}} = u_{km}^{\mathrm{t}} - \gamma_{uk}^{\mathrm{t}}.1\ ;\ \ k = 1,2,\dots,K\ \ ;\quad z_n^{\mathrm{t+1}}, \gamma_{yj}^{\mathrm{t}}, \gamma_{uk}^{\mathrm{t}} \ge 0\ ;\ \ n = 1,2,\dots,N$$

The ML index defined by Chung, et al. (1997) using SDDF model can be formulated as below

$$ML_t^{t+1} = \left[\frac{(1+\overrightarrow{DS}_o^{t+1}(x^t,y^t,u^t;y^t,-u^t))}{(1+\overrightarrow{DS}_o^{t+1}(x^{t+1},y^{t+1},u^{t+1};y^{t+1},-u^{t+1}))}\ \frac{(1+\overrightarrow{DS}_o^{t}(x^t,y^t,u^t;y^t,-u^t))}{(1+\overrightarrow{DS}_o^{t}(x^{t+1},y^{t+1},u^{t+1};y^{t+1},-u^{t+1}))}\right]^{\frac{1}{2}} \tag{3}$$

Equation (3) can be further decomposed into two measured components of productivity change, which are eco-efficiency change (MLEFFC) and technological change (MLTC). MLEFFC represents a movement towards the best practice frontier while MLTC represents a shift in technology between t and $t+1$.

$$MLEFFC_t^{t+1} = \left[\frac{(1+\overrightarrow{DS}_o^{t}(x^t,y^t,u^t;y^t,-u^t))}{(1+\overrightarrow{DS}_o^{t+1}(x^{t+1},y^{t+1},u^{t+1};y^{t+1},-u^{t+1}))}\right] \tag{4}$$

$$MLTC_t^{t+1} = \left[\frac{(1+\overrightarrow{DS}_o^{t+1}(x^t,y^t,u^t;y^t,-u^t))}{(1+\overrightarrow{DS}_o^{t}(x^t,y^t,u^t;y^t,-u^t))}\ \frac{(1+\overrightarrow{DS}_o^{t+1}(x^{t+1},y^{t+1},u^{t+1};y^{t+1},-u^{t+1}))}{(1+\overrightarrow{SD}_o^{t}(x^{t+1},y^{t+1},u^{t+1};y^{t+1},-u^{t+1}))}\right]^{\frac{1}{2}} \tag{5}$$

For each observation, four distance functions must be calculated in order to measure the ML productivity index. Two distance functions use observation and technology for time period t and $t+1$ i.e. $\overrightarrow{DS}_o^{t}(x^t, y^t, u^t; y^t, -u^t)$ and $\overrightarrow{DS}_o^{t+1}(x^{t+1}, y^{t+1}, u^{t+1}; y^{t+1}, -u^{t+1})$, while another two use the mixed period of t and $t+1$, i.e. $\overrightarrow{DS}_o^{t}(x^{t+1}, y^{t+1}, u^{t+1}; y^{t+1}, -u^{t+1})$ and $\overrightarrow{DS}_o^{t+1}(x^t, y^t, u^t; y^t, -u^t)$.

The infeasibility solution may also occur for MLPI when calculated by the SDDF model for two distance functions of mixed period. The solution using a multiple year "window" of data as the reference technology simply reduces the number of infeasible solutions. There are some circumstances where the infeasible solution still exists, especially when the DMU observed is beyond the reference technology i.e. $\overrightarrow{DS}_o^{t}(x^{t+1}, y^{t+1}, u^{t+1}; y^{t+1}, -u^{t+1})$. To solve the infeasible problem, second stage analysis will be calculated using the concept of super-efficiency measurement. Using super-efficiency frontier, the infeasible DMU will increase the undesirable output and decrease the desirable output to reach the production frontier. This second stage analysis is only applied to the infeasible solution that occurs during the first stage analysis. Four distance functions are re-calculated as follows:

$$\overrightarrow{DS}_o^{t+1}(x^t, y^t, u^t; y^t, -u^t) = \text{Min}\sum_{j=1}^{J}\gamma_{yj}^{\text{t}} + \sum_{k=1}^{K}\gamma_{uk}^{\text{t}} \tag{6}$$

Subject to

$$\sum\nolimits_{n=1}^{N} z_n^{\text{t+1}} x_{in}^{\text{t+1}} \leq x_{im}^{\text{t}}\ ;\ \ i = 1,2,\ldots,I\ \ ; \sum_{n=1}^{N} z_n^{\text{t+1}} y_{jn}^{\text{t+1}} \geq y_{jm}^{\text{t}} - \gamma_{yj}^{\text{t}}\,.\,1\ \ ;\ \ j = 1,2,\ldots,J\ \ ;$$

$$\sum_{n=1}^{N} z_n^{\text{t+1}} u_{kn}^{\text{t+1}} \leq u_{km}^{\text{t}} + \gamma_{uk}^{\text{t}}.1\ ;\ \ k = 1,2,\ldots,K\ \ ;\quad z_n^{\text{t+1}}, \gamma_{yj}^{\text{t}}, \gamma_{uk}^{\text{t}} \geq 0\ ;\ \ n = 1,2,\ldots,N$$

RESULTS AND DISCUSSIONS

This study considers the manufacturing sector in 15 states throughout Malaysia. The state level data for the observed period between 2001 and 2010 was obtained from the Department of Statistics, Malaysia. In this analysis, two inputs and two outputs are employed. The inputs are operating expenditure (opex) and capital. The desirable output is sales in the manufacturing industry while the carbon dioxide (CO2) emission factor has been included as an undesirable output

Tables 1, 2 and 3 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 SDDF 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 1, given that the total geometric means of productivity change for all periods was always less than 1, 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). 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 1, 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.

Table 1: Productivity change using the MLPI calculated by SDDF 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

Further decomposition of productivity change for the manufacturing sector in Malaysia include the eco-efficiency change (catching up) component (Table 2) and a technological change (innovation) component (Table 3). For instance, the geometric mean for productivity regress of 0.3 percent in the recent year 2009/2010 in Table 1 when CO2 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 2: Eco-efficiency change using the MLPI calculated by SDDF 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

A glance at Table 2 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, 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.

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 3 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. In addition, only one period of time, i.e. 2005/2006 saw technological progress for almost all the states.

Table 3: Technological change using the MLPI calculated by SDDF 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

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.

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. Examples of technology-driven processes and equipment include computer-aided design, computer-aided engineering systems, robotics and nanotechnology.

CONCLUSION

This study may present a comprehensive model that integrates the indicators between environmental and industrial elements in the Malaysian context. 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. 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 productivity change 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.

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