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Is There a Real TFP Growth Measure for Malaysia's Manufacturing Industries?

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The existence of a "real" or accurate total factor productivity (TFP) growth measure is discussed and questioned by comparing TFP growth measures from a parametric and nonparametric frontier model using a panel data of twenty-eight manufacturing industries from 1981 to 1996. The discussion is then enhanced by the decomposition of TFP growth from the two frontier models into technical change and change in technical efficiency. In this way, the identification of the sources of TFP growth allows for more accurate policy implications for sustainable growth. The results are also compared with previous studies for robustness.

I. Introduction

Total factor productivity (TFP) growth is an important measure of potential output growth given the nature of the diminishing returns to input use in the long run. Thus, Malaysia in her drive to enjoy sustainable growth to raise its living standards is set on focusing on TFP growth as stated in Malaysia's Second Industrial Master Plan 1996–2005. In fact, the manufacturing sector which has increased its contribution to gross domestic product (GDP) output from 19.3 per cent in 1979 to 34.2 per cent in 1996 has been identified as a key growth engine in this transformation process. Hence, it is imperative and timely for an analysis on the productivity growth performance of this sector to be undertaken.

This study adds to the existing empirical literature in three ways. First, previous studies on Malaysian manufacturing have only considered the nonfrontier measure using the divisia translog index approach. To date, using the nonfrontier approach, Tham (1996, 1997) and the *Productivity Report 1999* provide evidence of declining TFP growth for the Malaysian manufacturing sector in the 1990s (see Table 3).[1] How would this result compare with the use of the frontier approach? Will the frontier models also provide low TFP growth measures? This is one of the issues addressed in this article.

As for the earlier studies, the nonparametric technique adopted computes TFP growth as a residual since it measures "anything and everything" of output growth that is not accounted by input growth. More importantly, the translog index TFP growth measure ignores the concept of technical inefficiency (by unrealistically assuming that all industries are technically efficient) and inaccurately interprets technical change as TFP growth. Thus in this study, frontier measures are used to overcome these major drawbacks. In the productivity literature, TFP growth is shown to be composed of both technical change (frontier shift) and technical efficiency (catching up effect). While the frontier effect indicates how far the efficient frontier itself has shifted over time due to the use of better technology and equipment, the catching up effect reflects how far the industry has moved towards the efficient frontier due to the better use of technology and equipment.

The second difference in this study is that empirical robustness is ensured by the use of both the parametric and nonparametric frontier approaches to calculate TFP growth. Under the parametric approach, a stochastic production frontier model incorporating non-parallel shifts is estimated. With the nonparametric approach, the data envelope analysis (DEA) technique is used. Using a panel data set of twenty-eight manufacturing industries (see Appendix 1 for a list) from 1981 to 1996, a measure of TFP growth is first obtained and then decomposed to technical change and change in technical efficiency for both models. The results are then compared to previous studies with a focus on the Malaysian manufacturing sector as TFP growth studies on the aggregate economy may have broad implications that are not necessarily reflective of the TFP growth performance of specific sectors in the economy.

The third contribution of this article is that the comparative performance of the results from alternative methodologies would add to similar work by Bjurek and Hjalmarsson (1990), Coelli and Perelman (1999), and Kumbhakar, Heshmati, and Hjalmarsson (1999) which provide mixed evidence of similarities in the results from the use of various models. Often, the choice of the method is said to depend on a range of factors. For instance, if the researcher simply wants to know if output growth is TFP or input-driven growth, then either approach would suffice. However, to answer questions on maximum productive or best practice output levels, the stochastic frontier can be used to understand the industries' catching up behaviour with respect to its own maximum potential, while DEA allows for the study of the performance of each industry relative to efficient industries in the sample. Another consideration for the model choice is the sector that is being investigated. With the manufacturing sector, as there is reason to believe that measurement error is related to inaccuracy in data due to poor quality of data or the way data are generated, it would be grossly inaccurate to assume that all deviations from the frontier constitute technical inefficiency. In this case, the use of the stochastic frontier method is appropriate. However, Wan (1995) explains that the idea of technical change being reflected only in varying values of the estimates from the parametric frontiers is rather restrictive, and when our knowledge of underlying technologies is weak, it is best to use DEA which does not impose unwarranted structure on the frontier. In the empirical literature, both the parametric and nonparametric methods of the frontier approach have been widely used to analyse the manufacturing sector. Thus, this study attempts to compare these methods' productivity growth and efficiency measures as obtained from a decompositional framework. In this regard, it is also important to identify and compare the sources of TFP growth which would lead to different policy implications if the models gave different results.

The article is organized as follows. The next section gives an overview of the manufacturing sector in Malaysia. Section III briefly sets out the theoretical framework underlying the two models. Section IV discusses data issues and variables used in the models. Section V presents the empirical results and Section VI concludes.

II. The Malaysian Manufacturing Sector

The composition of the Malaysian manufacturing sector has changed considerably. The food, beverage, and tobacco as well as the textiles, clothing, and footwear industries have experienced falling value-added shares. Meanwhile, machinery, metal products, electrical machinery, and transport equipment have increased their value-added

TABLE 1
Summary Statistics on the Manufacturing Industries
(Mean Value Over 1981–96)

Industries	*Value Added (RM '000)*	*Capital (RM '000)*	*Labour (No. of Workers)*
Food	1568808.3	2452629.7	75026
Beverage	228698.2	295005.4	5168
Tobacco	281521.4	298072.1	5070
Textiles	513740.3	291536.3	5423
Wearing Apparel	367105.6	285289.8	5804
Leather	14206.5	277919.4	5773
Footwear	13195.3	274569.5	5650
Wood	979142.7	269383.0	5590
Furniture and Fixtures	173898.7	218368.1	19280
Paper	254842.3	265175.3	5532
Printing, Publishing	473599.4	260431.3	5492
Industrial Chemicals	1302360.7	253062.4	5422
Other Chemicals	404209.4	245839.9	5512
Petroleum Refineries	373251.7	235040.4	5538
Miscellaneous Products of Petroleum and Coal	56215.6	223074.4	5573
Rubber	838472.6	211217.6	5657
Plastic	498355.5	200400.5	5688
Pottery, China and Earthenware	52441.4	182298.5	5706
Glass	121824.9	167767.4	6446
Non-Metallic Mineral	761137.3	173701.5	6898
Iron and Steel	415155.4	175672.8	6580
Non-Ferrous Metal	129492.7	171727.6	6245
Fabricated Metal	615366.3	194384.5	8357
Machinery	681538.1	210722.6	10308
Electrical Machinery	3929556.7	4275996.5	200405
Transport Equipment	785669.8	1122952.2	28036
Professional, Scientific, and Measuring Controlling Equipment	168015.4	216641.7	12260
Other Manufacturing	158145.8	254686.2	15127

SOURCE: *Annual Survey of Manufacturing Industries* (Department of Statistics, Malaysia).

shares. Other manufactured products with a moderate increase in value added share include optical and scientific equipment, toys and sporting goods, and other manufactures over the 1981–96 period. Table 1 provides summary statistics on the manufacturing industries.

It can be seen that in terms of value added, the large industries are the electrical machinery, industrial chemicals, and food industries. However, industries which are relatively labour-intensive as measured by low capital labour ratios include furniture and fixtures, machinery, and electrical machinery industries.

III. Methodolgy

The Parametric Approach

The frontier is defined as a set of best obtainable positions obtained as a locus of constrained maximum or minimum values. Thus, an industry which operates on the production frontier is said to produce its potential or maximum output by following the "best practice" techniques given the technology. This concept, which was initiated by Farrell (1957), has paved the path for many theoretical as well as empirical applications of the frontier methodology.

Unlike the conventional stochastic frontier approach, the frontier model used here is not based on the assumption that Hicks-neutral technology underlies the shifts of the production frontier. The assumption on the underlying technology is relaxed to allow non-neutral shifts in the production frontier such that the marginal rate of technical substitution at any input combination changes over time. This follows from Kalirajan and Shand's (1994) argument that with the same level of inputs, different levels of output are obtained by following different methods of applications. Furthermore, as this model relies on the generalized least squares estimation technique, it does not require the imposition of an *ad hoc* assumption on the distribution of technical efficiency which is purely based on the attractiveness of the statistical properties of the assumed distributions without any theoretical justification.[2]

The generalized version of the adopted model can be written as:

$$\ln Y_{it} = \gamma_{1i} + \sum_{j=1}^{n} \gamma_{ij} \ln X_{ijt} \tag{1}$$

where i represents number of industries
j represents number of inputs used
t represents time period
Y = output
X = inputs used
γ_{1i} = intercept term of the ith industry
γ_{ij} = actual response of output to the method of application of the jth input used by the ith industry

Since intercepts and slope coefficients can vary across industries, we can write:

$$\gamma_{ij} = \bar{\gamma}_j + u_{ij}$$
$$\gamma_{1i} = \bar{\gamma}_1 + v_{1i} \tag{2}$$

where $\bar{\gamma}_j$ is the mean response coefficient of output with respect to the jth input
u_{ij} and v_{1i} are random disturbance terms
$E(\gamma_{ij}) = \bar{\gamma}_j$, $E(u_{ij}) = 0$ and $\mathrm{Var}(u_{ij}) = \sigma_{uit}$

Combining equations (1) and (2):

$$\ln Y_{it} = \bar{\gamma}_1 + \sum_{j=1}^{n} \bar{\gamma}_j \ln X_{ijt} + \sum_{j=1}^{n} u_{ij} \ln X_{ijt} + v_{1i}$$

Following Aitken's generalized least squares method suggested by Hildreth and Houck (1968) and the estimation procedure by Griffiths (1972), the industry-specific and input-specific response coefficient estimates of the above model can be obtained. The highest magnitude of each response coefficient and intercept form the frontier coefficients of the best practice production frontier. Based on the above, the model for this exercise underlies the Cobb-Douglas production technology[3] and is given by:

$$\mathrm{Ln}\, Y = a_0 + a_1 T + \left(\beta_0 + \sum_{m=1}^{8} \beta_m D_m\right) \mathrm{Ln}\, L_{it} + \left(\alpha_0 + \sum_{m=1}^{8} \alpha_m D_m\right) \mathrm{Ln}\, K_{it}$$

where Y = Value added output measured in 1978 prices
T = Time trend
D_m = Industry dummies grouped at the 2-digit manufacturing industry level
L = Labour measured by number of workers employed
K = Capital expenditure measured in 1978 prices

A time trend is to capture all variations over time that affect industries' output. Also, the data is pooled for estimation and the dummy variables used provide different input shares for different industries. A fortran program, TERAN, which was developed at the Australian National University was then used for estimation. Using the parameter estimates (discussed later in Table 2) from the above model, TFP growth is calculated for each industry using the framework set out in Appendix 2.

The Nonparametric Approach

Here, the Malmquist TFP growth index is calculated using DEA. One advantage is that DEA envelopes observed input-output data without requiring *a priori* specification of functional forms. Different specifications of the production function under the parametric approach provide different results and this remains a methodological problem. Another advantage as argued in Gong and Sickles (1992) is that DEA is more appealing than the econometric model as inefficiency is likely to be correlated with the inputs.

However, DEA is not free from drawbacks, either. These drawbacks, which are in turn the advantages of the stochastic frontier model, include the following. First, measurement error and statistical noise are assumed to be non-existent. Second, it does not allow for statistical tests typical of the parametric approach.

The Malmquist TFP Growth

The Malmquist index is defined using distance functions. Here, an output distance function is used to consider a maximum proportional expansion of the output, given the inputs. More specifically, the Malmquist TFP index measures the TFP growth change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following Färe et al. (1994), the output-oriented Malmquist TFP change index between period s (the base period) and period t is given by

$$m_0(y_s, x_s, y_t, x_t) = \left[\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \times \frac{d_0^t(y_t, x_t)}{d_0^t(y_s, x_s)}\right]^{1/2} \tag{3}$$

where the notation $d_0^s(x_t, y_t)$ represents the distance from the period t observation to the period s technology. A value of m_0 greater than one indicates positive TFP growth from period s to period t while a value less than one indicates a TFP growth decline.

An equivalent way of writing this productivity index is

$$m_0(y_s, x_s, y_t, x_t) = \frac{d_0^t(y_t, x_t)}{d_0^s(y_s, x_s)}\left[\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \times \frac{d_0^t(y_t, x_t)}{d_0^t(y_s, x_s)}\right]^{1/2} \tag{4}$$

where the ratio outside the square brackets measures the change in the output-oriented measure of Farrell technical efficiency between periods s and t.[4] That is, the efficiency change is equivalent to the ratio of the Farrell technical efficiency of period t to that of period s. The remaining part of the index in equation (4) is a measure of technical change which is the geometric mean of the shift in technology between the two periods, evaluated at x_t and x_s. In other words, TFP growth can be decomposed as,

$$\text{TFP Growth} = \text{Technical Efficiency Change (Catching up Effect)} \times \text{Technical Change (Frontier Effect)} \tag{5}$$

According to Grifell-Tatjé and Lovell (1995), the constant returns to scale (CRS) technology must be imposed to estimate the above distance functions for the accurate calculation of a Malmquist TFP index.[5] This makes the model compatible for comparison with the Cobb-Douglas stochastic frontier model estimated earlier. The required distance measures for the decomposition in equation (5) can be calculated using a mathematical linear programming (LP) technique called DEA. This requires the solving of four LPs for each industry. For this sample consisting of sixteen years, forty-six LPs must be solved for each industry. The LPs are:

$$\begin{aligned} [d_0^t(y_t, x_t)]^{-1} &= \max_{\phi\lambda} \phi, \\ \text{st} \quad -\phi y_{it} + \mathrm{Y}_t\lambda &\geq 0, \\ x_{it} - \mathrm{X}_t\lambda &\geq 0, \\ \lambda &\geq 0, \end{aligned}$$

$$
\begin{aligned}
[d_0^s(y_s, x_s)]^{-1} &= \max_{\phi\lambda}\ \phi, \\
\text{st} \quad -\phi y_{is} + \mathrm{Y}_s\lambda &\geqslant 0, \\
x_{is} - \mathrm{X}_s\lambda &\geqslant 0, \\
\lambda &\geqslant 0,
\end{aligned}
$$

$$
\begin{aligned}
[d_0^t(y_s, x_s)]^{-1} &= \max_{\phi\lambda}\ \phi, \\
\text{st} \quad -\phi y_{is} + \mathrm{Y}_t\lambda &\geqslant 0, \\
x_{is} - \mathrm{X}_t\lambda &\geqslant 0, \\
\lambda &\geqslant 0,
\end{aligned}
$$

and
$$
\begin{aligned}
[d_0^s(y_t, x_t)]^{-1} &= \max_{\phi\lambda}\ \phi, \\
\text{st} \quad -\phi y_{it} + \mathrm{Y}_s\lambda &\geqslant 0, \\
x_{it} - \mathrm{X}_s\lambda &\geqslant 0, \\
\lambda &\geqslant 0,
\end{aligned}
$$

where y_{it} is a MX1 vector of output quantities for the *i*-th industry in the *t*-th year;
x_{it} is a KX1 vector of input quantities for the *i*-th industry in the *t*-th year;
Y_t is a NXM matrix of output quantities for all N industries in the *t*-th year;
X_t is a NXK matrix of input quantities for all N industries in the *t*-th year;
λ is a NX1 vector of weights and
ϕ is a scalar.

IV. Data Sources

Data on value added, capital, and labour from 1982–96 for twenty-eight manufacturing industries were compiled from the *Annual Survey of Manufacturing Industries,* published by the Department of Statistics, Malaysia. The data for 1981 was from the 1981 census data also published by the Department of Statistics, Malaysia. As data on capital expenditure was not published, fixed capital stock was used instead. The disadvantage of the use of this "lumpy" capital data is that in some years it would seem that very large investment in capital has taken place and in other years, this figure would appear small, thereby underestimating or overestimating the amount of capital expenditure. With labour, the number of workers employed was used due to the lack of data on man-hours. The value-added variable was deflated by the GDP deflator for the manufacturing sector and the capital variable was deflated using the gross domestic fixed capital formation deflator. Both deflators with 1978 as the base year were obtained from the *Yearbook of Statistics*, published by the Department of Statistics, Malaysia.

V. Empirical Results

Table 2 shows the parameter estimates of the stochastic production frontier. At the outset, it must be noted that the ratio of the variance of u_{it} to that of $(u_{it} + v_{it})$ was found to be 0.62 with a likelihood ratio test statistic of 3.187. As this ratio is statistically significant based on the chi-square distribution, it indicates that the adopted random coefficient frontier model is valid for interpretation.

As expected in the manufacturing sector, the capital share given by α is higher than the labour share, β. Most of the industries' input shares are statistically significant and the sum of the input shares is close to one as expected of the adopted Cobb-Douglas production function. The model also satisfied various diagnostic tests on functional form, autocorrelation and homoscedasticity. Using the above estimates, TFP growth is first calculated for each industry and the TFP growth rate for the manufacturing sector was obtained as a weighted sum of each of the manufacturing industry's TFP growth, using value-added output share as weights.

With the nonparametric model, as no standard errors are obtainable, it is not possible to test for statistical differences of the results obtained from parametric and nonparametric models. Neither can the statistical reliability of the results provided by the nonparametric model be tested in the usual way. Although nonparametric tests such as bootstrap methods are available, these are more easily discussed than actually undertaken given the inherent problems in the testing procedures (Simar 1999). Table 3 compares the TFP growth rates of the two models with previous studies.

Although the parametric model provides negative TFP growth rates and the nonparametric model provides positive TFP growth rates over time, both models show a decline in the 1990s.[6] This conforms to the findings of Tham (1996,

TABLE 2
Parameter Estimates of the Stochastic Production Frontier

Variables	*Parameter*	*Estimates*
Constant	a_0	1.77 (0.901)*
Time Trend	a_1	1.21 (0.513)*
Labour (Industry 31)	β_0	0.32 (0.097)*
Labour (Industry 32)	β_1	−0.0034 (0.0062)*
Labour (Industry 33)	β_2	0.0172 (0.0011)*
Labour (Industry 34)	β_3	0.0141 (0.0482)
Labour (Industry 35)	β_4	0.0028 (0.0012)*
Labour (Industry 36)	β_5	0.0145 (0.0058)*
Labour (Industry 37)	β_6	0.0137 (0.0036)*
Labour (Industry 38)	β_7	−0.0161 (0.0412)
Labour (Industry 39)	β_8	0.0019 (0.0002)*
Capital (Industry 31)	α_0	0.67 (0.0811)*
Capital (Industry 32)	α_1	0.0316 (0.0072)*
Capital (Industry 33)	α_2	0.0059 (0.0007)*
Capital (Industry 34)	α_3	0.0048 (0.0021)*
Capital (Industry 35)	α_4	0.0045 (0.0165)
Capital (Industry 36)	α_5	−0.0014 (0.0028)
Capital (Industry 37)	α_6	0.0031 (0.0008)*
Capital (Industry 38)	α_7	0.0025 (0.0006)*
Capital (Industry 39)	α_8	−0.0016 (0.0054)

NOTES:
See Appendix 1 for Industry Codes.
Figures in parenthesis are asymptotic standard errors.
* means that the coefficient is significant at the 5 per cent level of significance.
SOURCE: Author's estimations.

TABLE 3
A Comparison of TFP Growth Rates for the Manufacturing Sector

	This Study		*Okamoto (1994)*	*Productivity Report 1999*	*Tham (1996, 1997)*	*World Bank (1989)*
	Parametric Model	*Nonparametric Model*				
1981–84	−0.82	0.40				−1.9
1980–89	−1.06	0.44		2.79		
1986–90	−0.57	0.35	0.3			
1986–91	−0.63	0.38			0.3	
1986–93	−1.18	0.27			0.1	
1990–96	−1.54	0.26		1.6		

SOURCE: Author's estimations; Okamoto (1994); *Productivity Report 1999*; Tham (1996, 1997); and World Bank (1989).

1997), and the *Productivity Report 1999*. This study's low TFP growth magnitudes are also comparable to those of the previous studies although the latter often included intermediate materials as one of the inputs. To compare the sources of productivity growth, the decompositional analysis is undertaken for both models using the framework in Appendix 2 for the parametric model and equation (5) for the nonparametric model. The results are shown in Table 4.

As for the nonparametric model, information on output and input growth are not provided as the DEA technique, unlike the parametric model, only decomposes the Malmquist TFP growth index and not the output growth.[7] It can be seen that similar to previous studies, the parametric model shows that output growth is input-driven rather than TFP growth-driven and as noted before, the TFP growth trends of both models are declining over time.

The parametric model, however, shows positive and increasing technical change, but the increasingly negative gains from technical efficiency are overwhelming, resulting in negative TFP growth rates. The nonparametric model also shows positive and increasing gains from technical change, but the gains from technical efficiency, although positive, have declined over time. Thus, the source of TFP growth as shown by both models is technical change and technical inefficiency is clearly a major concern causing poor TFP growth. How can this be explained?

First, domestic research and development (R&D) in Malaysia has barely increased beyond 1 per cent of its GDP. In fact, the government which had originally set an R&D target of 2 per cent of the GDP by 2000 had to reduce this ratio to 1.5 per cent. Lall (2001) notes that the "R&D gap" is a crucial problem for Malaysia given that the Malaysian industrial and export structure is as "advanced" in the technological spectrum as Korea's and Taiwan's. On the other hand, while Athukorala and Menon (1999) document the significant flow of foreign direct investment (FDI) into Malaysia, the comprehensive MASTIC (Malaysian Science and Technology Information

TABLE 4
Sources of Output Growth and Total Factor Productivity Growth in Malaysia's Manufacturing Sector
(In Percentage)

	1981–84	*1986–90*	*1990–96*
Parametric Model			
Output Growth	1.66	1.69	0.98
Input Growth	2.43	2.26	2.52
TFP Growth	−0.82	−0.57	−1.54
Technical Change	0.25	0.31	0.43
Change in Technical Efficiency	−1.07	−0.88	−1.97
Nonparametric Model			
Output Growth	N.A.	N.A.	N.A.
Input Growth	N.A.	N.A.	N.A.
TFP Growth	0.40	0.35	0.26
Technical Change	0.10	0.18	0.24
Change in Technical Efficiency	0.30	0.17	0.02

NOTE: N.A. means not applicable.
SOURCE: Author's estimations.

Centre, 1994) survey shows that multinational companies (MNCs) rather than the local producers or the government are leading the industrial research effort in Malaysia. Thus, the gains from technical change can be attributed to the use of more advanced imported technology brought about by the promotion and significant flow of FDI into Malaysian manufacturing since 1986.

However, technological mastery did not follow the pace of technology adoption as seen by the declining gains in technical efficiency, which means that the industries were not able to acquire or use appropriate technical knowledge to ensure maximum output from the use of the advanced technology. This is supported by Lall's (2001) observation that, "Malaysia's educational structure lacks the ability to meet the technical needs of the industry". He further notes the industries' complaints on the high turnover rates for middle-level employees. This could affect managers' incentive to provide training to improve workers' skills. Thus, the concern of previous studies on Malaysia are echoed here again, in that, the quality of the labour force needs to be improved urgently, and efforts to significantly increase the current low levels of domestic R&D must be enforced.

In addition, the Malaysian Government could benefit greatly in the long term if it is selective in the type of FDI sought. The MNCs should be made to provide substantial training to workers to impart knowledge regarding the use of technology. Rasiah (1995) maintains that it is important to continue to attract FDI but this should be done at high levels of skill and technical sophistication, and it is necessary to raise domestic contributions to production and technological activity so as to provide the supplier and service structure that MNCs need for value-added production. The government should also be mindful of the growing pool of foreign unskilled workers who serve as cheap labour that discourage the MNCs from the use of better technology. The shortage of skilled workers highlighted by the World Bank (1989) and Lall (2001) has yet to be solved. Other factors which could help improve technical efficiency and technical change include changes in market structure, economies of scale, infrastructure development, interest rates, and taxation policies. Although important, this exercise of specifying policy options by empirically identifying the casual factors is beyond the scope of this study. However, the TFP growth decomposition undertaken in this study has quantified the components of TFP growth for further investigation.

The decompositional analysis has also served to highlight the following. The rising trend of technical change shows that there is still room to gain from the use of advanced technology, and this is possible as Malaysia's manufacturing industries are yet to mature given that their operations are currently at the middle level of the technology ladder. Jomo, Felkar, and Rasiah (1999) argue that the current level of technological activity in Malaysia cannot be sustained indefinitely into the future although the technology "gap" has so far been compensated by the MNCs. However, due to the limits in the availability of continuously advanced technology, the gains from technical change are constrained. Hence, gains from technical efficiency hold the key to sustainable TFP growth.

VI. Conclusion

This article attempts to check on the robustness of the empirical measure of the Malaysian manufacturing TFP growth by using two different models of the frontier approach. The stochastic frontier model shows that output growth has been mainly input-driven rather than productivity-driven (a result similar to previous studies), and that TFP growth has been consistently negative over time. On the other hand, the DEA model shows consistently positive TFP growth rates. As expected, due to the use of different methods and models, TFP growth rates differ but both models show that TFP growth is low and declines over time. The models are also found to have similar trends in the sources of TFP growth as it is evident that technical change is positive and increasing, while gains from technical efficiency decline. Thus, Malaysia has obtained better technology and equipment via FDI, but it has failed to learn to use it adaptively.

Although the conclusions broadly conform, no one measure of TFP growth from either model should be taken to represent "the right" value, given the advantages and disadvantages of the approaches to productivity measurement. Instead, as policy formulation is often the ultimate objective in productivity analysis, the trends in TFP growth should be of greater interest and considered far more reliable than the *magnitude* of TFP growth *per se*. Also, as TFP growth measures a whole range of things, it is best to decompose TFP growth appropriately to allow an understanding of the sources of productivity growth for policy implementation. The trends of the sources of productivity growth then pave the path for the important exercise (which is beyond the scope of this article) of drawing specific policy options to address each of the low efficiency components of the TFP growth measure.

Previous studies on Malaysia often undertook a regression analysis of possible factors influencing TFP growth as a single measure without recognizing that different efficiency components of TFP growth are at play. This would lead to spurious results as policy options intended to improve TFP growth would be badly misdirected given that the concepts of technical change and technical efficiency are analytically different. This is especially important for Malaysia given that technical change and gains from technical efficiency were evidenced to move in opposite directions.

In conclusion, there is no single accurate value or *magnitude* of TFP growth measure for Malaysia, or for any other economy for that matter, but the concept of TFP is too important to be dismissed lightly. The possibility of the emergence of empirical regularities as more empirical work is done with different methods on the same data should however not be ruled out completely. Given the various advancements in TFP measurement techniques, TFP estimation and decomposition should be seen to offer a *T*ruly *F*ruitful *P*ossibility if used and interpreted appropriately.

APPENDIX 1

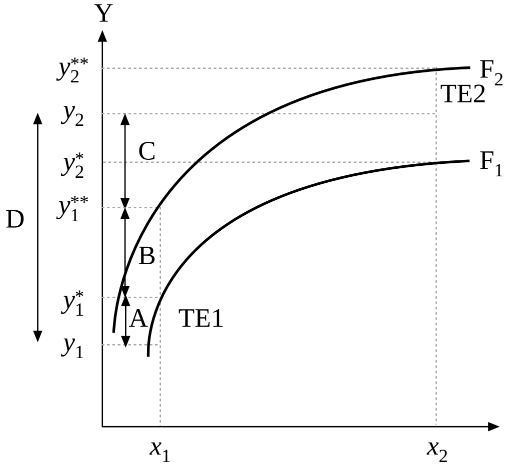
Malaysia's Manufacturing Sector

Industry Code	*Manufacturing Industries*	*Industry Code*	*Manufacturing Industries*
311–312	Food	355	Rubber
313	Beverage	356	Plastic
314	Tobacco	361	Pottery, China & Earthenware
321	Textiles	362	Glass
322	Wearing Apparel	369	Non-Metallic Mineral
323	Leather	371	Iron & Steel
324	Footwear	372	Non-Ferrous Metal
331	Wood	381	Fabricated Metal
332	Furniture & Fixtures	382	Machinery
341	Paper	383	Electrical Machinery
342	Printing, Publishing	384	Transport Equipment
351	Industrial Chemicals	385	Professional, Scientific & Measuring Controlling Equipment
352	Other Chemicals		
353	Petroleum Refineries		
354	Miscellaneous Products of Petroleum and Coal	390	Other Manufacturing

SOURCE: *Annual Survey of Manufacturing Industries* (Department of Statistics, Malaysia).

APPENDIX 2

The Stochastic Frontier Approach to the Decomposition of Output Growth and Total Factor Productivity Growth



Assume that the industry faces production frontiers F_1 and F_2 in period 1 and period 2 respectively. If the industry experiences technical efficiency (TE), output would be on the frontier, that is, industry would be able to produce output y_1^* in period 1, using x_1 input level and output y_2^{**} in period 2, using x_2 input level. However, in periods 1 and 2, industry may be producing output y_1 and y_2 respectively, due to technical inefficiency in production. Technical inefficiency in terms of output forgone is represented by the distance between the frontier output and actual output of a given industry in the figure. The industry in period 1 is said to experience TE1 in period 1 if it is able to increase production from y_1 to y_1^* and TE2 in period 2 if it is able to increase production from y_2 to y_2^{**}. Thus, change in technical efficiency over time is the difference between TE1 and TE2 and technical change is measured by the distance between frontier 2 and frontier 1 given by, $y_1^{**} - y_1^*$ evaluated at x_1 input level. The input growth between the two periods denoted by Δy_x causes output growth of $y_2^{**} - y_1^{**}$. This output growth can be decomposed into three components, that is, input growth, technical change and improvements in technical efficiency, the sum of the latter two constitutes total factor productivity growth.

The decomposition can be mathematically expressed as follows:

$$
\begin{aligned}
D &= y_2 - y_1 \\
&= A + B + C \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2 - y_1^{**}] \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2 - y_1^{**}] + [y_2^{**} - y_2^{**}] \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] - [y_2^{**} - y_2] + [y_2^{**} - y_1^{**}] \\
&= \{(y_1^* - y_1) - (y_2^{**} - y_2)\} + (y_1^{**} - y_1^*) + (y_2^{**} - y_1^{**}) \\
&= \dot{TE} + \dot{TP} + \dot{y}_x^* \\
&= \dot{TFP} + \dot{y}_x^*
\end{aligned}
$$

where $y_2 - y_1$ = output growth between two periods

$\dot{TE}$ = change in technical efficiency

$\dot{TP}$ = technical change

$\dot{y}_x^*$ = change in output due to input growth

$\dot{TFP}$ = total factor productivity growth

SOURCE: Mahadevan and Kalirajan (1999).

NOTES

1. However, evidence on Malaysia's aggregate TFP growth in the 1990s is mixed as discussed in a review by Mahadevan (2002*a*).
2. Most stochastic frontier models assume that technical efficiency follows a half-normal or truncated normal distribution.
3. The coefficients of the second order terms of the more general translog functional form were found not to be significantly different from zero at the 5 per cent level of significance. This implies that the Cobb-Douglas production frontier for the data set is appropriate.
4. The Farrell technical efficiency measure gives an indication of the amount by which output can be increased without requiring extra inputs.
5. The CRS technology can easily be relaxed following Färe et al. (1994).
6. The TFP growth estimates under DEA are likely to be lower than those from the stochastic frontier since any measurement error is considered as technical inefficiency in the DEA approach.
7. For the full decomposition of TFP growth for all industries into technical change, technical efficiency change, pure technical efficiency change, and scale efficiency change, see Mahadevan (2002*b*).

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