Carbon Dioxide Emissions Impact on Malaysia's Manufacturing Productivity Growth

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INTRODUCTION

The transformation of Malaysia's economic structure from that led by import substitution in the early 1960s to the export-orientation towards the second half of 1980s was responsible for spurring growth of the manufacturing sector. The manufacturing sector's share of total Gross Domestic Product (GDP) rose from less than 10 percent in the early 1960s to 26 percent in three decades later. The manufacturing output growth declined by 4.9 percent between 1981-85 due to stiff competition and excess supply of electrical and electronics component parts which dominated that sector and the onset of recession in 1985. However, it recovered in 1986 and recorded an average growth of 12.6 percent per annum from 1986-89. The period of the early nineties continued to see a steady growth in manufacturing output culminating to an average of 14.5 percent annual growth in 1995 and 12.5 percent in 1997. Nevertheless, 1998 marked a drastic decline in manufacturing output by 5.8 percent. This was mainly due to the financial crises in the East Asian region that lowered sales, depressed domestic demand and increased global competition (Economic Report, Malaysia).

Efforts were made by the government to reduce Malaysia's dependence on primary exports and to increase foreign earnings through exports of manufactured goods. The manufacturing sector became the engine of growth in the Malaysian economy taking over from the agricultural sector since the structural transformation took place in the Malaysian economy in 1987. As the Malaysian economy continues to face the challenges brought about by the dynamics of globalisation, it has to be more resilient and competitive. To achieve this, economic fundamentals have been strengthened with the emphasis on the productivity and quality driven growth strategies that enhanced efficiency in the utilisation and management of productive resources. In this context, the enhancement of TFP is imperative (Productivity Report, 2001). The sustainability of higher economic growth is likely to continue to be productivity- driven through the enhancement of TFP. Such enhancement needs to put an emphasis on the quality of workforce, demand intensity, economic restructuring, capital structure, technical progress and environmental standards. In the Seventh Malaysia Plan (1996-2000), an approximately RM1.9 billion was allocated in the Government's development budget for the improvement and protection of the environment as well as to conserve and promote sustainable resource use.

Our study attempts to close the gap of the divisia translog index approach that was developed by Jorgenson et al (1987). Their study did not include the explicit specification of a production function that created a major drawback in other studies of Tham (1995); Choong and Tham (1995); Tham (1997) in Malaysian manufacturing sector productivity growth. These studies were not based on statistical theory and, hence statistical models cannot BE applied to evaluate their reliability, thus casting doubts on their results. Our study suggests closing this gap by providing statistical analysis in the first step of the estimation and in the second step plugging the parameters of the variables into the model of the above mentioned divisia translog index. This approach enables us to calculate the growth rates of productivity indicators including the calculation of the residual of the model (i.e. total factor productivity growth (TFP)) and output growth.

Economists are interested in intensive growth, which is expressed in the form of growth in output per worker (labour productivity). Moreover, an economy's standard of living is not determined by its total output but by the amount of output available per person as stated by many economists like Dollar and Sokoloff, (1990). Our study also uses the second model in addition to the first one which was used in previous studies, in order to decompose labour productivity growth into contributions of capital deepening, increased usage of materials input per unit of labour, and the simultaneous contribution of the quality of these factors expressed as the TFP per unit of labour growth. Furthermore, the most obvious deficiency in the growth accounting models used in previous studies was found to be the exclusion of externalities such as pollutant emissions generated by the manufacturing sector. Our study aims at contributing to the available literature on growth accounting method, in that, it will draw methods to calculate the real TFP and real TFP per unit of labour growth by internalising the pollutant emissions in addition to the input terms in the conventional production function. Accordingly, TFP and TFP per unit labour growth became an indictor of green productivity, which takes into account economic development and environmental protection such as those in Pittman (1983); Gollop and Roberts (1983); Chaston *et al.*, 1997; Gollop and Swinand (1998); Gollop and Swinand (2001); Harchaoui *et al.* (2002).

Two model variations suggested by Jorgenson et al., (1987); Dollar and Sokoloff (1990) were modified and used in our study. Our analysis used annual time series data over the period of 1970-2001 for gross value of output; number of employment, value of fixed assets, and cost of input which were obtained from Malaysia's Department of Statistics. In addition, CO_2 emissions generated by the manufacturing sector were obtained from Institute of Advanced Studies of United Nations University, Tokyo, and Department of Environment of Malaysia for the same period. Furthermore, in order to study the effect of government policies to improve the sector's productivity growth, the study period was split into three phases corresponding with the major policy changes, namely 1971-1979, 1980-1986, and 1987-2001. The period of 1970s witnessed the birth of Malaysia's era of export-oriented economy. The decade of 1980s saw further diversification of the economy into more advanced industries while the period of 1987-2001 witnessed further diversification of the economy into more advanced industries.

METHODOLOGY AND ESTIMATION PROCEDURES

An attempt was made to apply the conventional growth accounting framework utilised by Stigler (1947); Abramovitz (1956); Kendrick (1956) to our study. This approach was initially developed by Solow (1956, 1957), finally brought to fruition by Kendrick (1961), and further refined by Denison (1962, 1979), Griliches and Jorgenson (1962), Jorgenson et al., (1987); Dollar and Sokoloff, (1990). The production of each industry is expressed as a function of capital, labour, raw materials, and time. It is assumed that the production process is characterised by constant returns to scale for each industry, so that the proportional increase in all inputs results in a proportional change in industrial output. This approach provides more room for the decomposition of contributions of factor inputs and technological change to economic growth. The production function for the ith industry can be represented as follows:

$$Q = F(K, L, M, CO2, T) \qquad (1)$$

where output Q is a function of sectoral capital input K, labour input L, and intermediate input M, pollutant emissions CO_2, and time T, that proxies for total factor productivity as a technological progress of the manufacturing sector. The main procedure has been to apply the above-mentioned conventional growth accounting framework under assumptions of competitive equilibrium (where factors of production are paid the value of their respective marginal products) and constant returns to scale. The Divisia Index basically decomposes the output growth into the contribution of changes in inputs (such as capital, labour, and materials input growth), an un-priced public bad (CO_2, and total factor productivity (TFP)) growth. In other words, considering the data at any two discrete points of time, say T and T-1 the growth rate of output Q for an industry can be expressed as a weighted average of the growth rates of capital (K), labour (L), intermediate inputs (M) and (CO_2) plus a residual term typically referred to as the rate of growth of TFP. Hence the TFP growth of each industry is computed as the difference between the rate of growth of output and weighted average of the growth in the capital, labour, intermediate inputs, and CO_2 emissions.

According to R. Mahadevan, 2001, the TFP growth studies on the Malaysian manufacturing sector have used the nonparametric translog-divisia index approach developed by Jorgenson et al. (1987). First step as follows: -

$$\ln Q_T = a + \alpha . \ln K_T + \beta . \ln L_T + \lambda . \ln M_T + \theta . \ln CO2_T + \varepsilon_T \qquad T = 1970\text{-}2001 \tag{2}$$

where

- α is the output elasticity with respect to capital
- β is the output elasticity with respect to labour
- λ is the output elasticity with respect to material
- θ is the output elasticity with respect to CO_2 emissions
- a is the intercept or constant of the model[1]
- ε_T is the residual term[2]

ln is the log to reduce the problem of heteroskedasticity.

Since the intercept (a) has no position in the calculation of the productivity growth rate indicators, a second step is proposed, which calculates the growth rates of productivity indicators transforming equation [2] as

$$\Delta \ln TFP_T = \Delta \ln Q_T - [\alpha . \Delta \ln K_T + \beta . \Delta \ln L_T + \lambda . \Delta \ln M_T + \theta . \Delta \ln CO2_T] \qquad T = 1970\text{-}2001, 1971\text{-}1979, 1980\text{-}1986 \text{ and } 1987\text{-}2001 \tag{3}$$

where the weights are given by the average value shares as follows:-

$\Delta \ln Q_T$	is the growth rate of output
$\alpha . \Delta \ln K_T$	is the growth rate of the capital
$\beta . \Delta \ln L_T$	is the growth rate of the labour
$\lambda . \Delta \ln M_T$	is the growth rate of material
$\theta . \Delta \ln CO2_T$	is the growth rate of CO2 emissions
$\Delta \ln TFP_T$	is the total factor productivity growth
Δ	is the difference operator denoting proptionate change rate.

[1] The intercept term, as usual, gives the mean or average effect on dependent variable of all the variables excluded from the model.

[2] The residual term proxies for the total factor productivity growth that accounting for the technological progress of the manufacturing sector through the quality of input terms.

The framework decomposes the rate of gross value of output into the contributions of the rates of growth of the capital, labour material inputs, and CO_2 emissions, plus a residual term typically referred to as the rate of growth of TFP.

Secondly, following Dollar and Sokoloff, (1990), Wong (1993), Elsadig (1998) and Felipe (2000), when constant returns $\beta = (1 - \alpha - \lambda - \theta)$ to scale is imposed, equation (2) becomes: -

$$\ln Q_T = a + \alpha . \ln K_T + \lambda . \ln M_T + \theta . \ln CO2_T + (1 - \alpha - \lambda - \theta). \ln L_T + \varepsilon_T \quad {}_T = 1970 - 2001 \tag{4}$$

For the purposes of this study, equation (4) was transformed by dividing each term by L (labour input) and then the output elasticity was calculated with respect to capital deepening, material-labour ratio and CO_2 pollutant emissions intensity, i.e. $[(\alpha = \alpha 1 + \alpha 2) + (\lambda = \lambda 1 + \lambda 2) + (\theta = \theta 1 + \theta 2)] = 1$, respectively. According to Dollar and Sokoloff, (1990), the production function can be in the form:

$$\ln(Q/L)_T = a + \alpha_1 \ln(K/L)_T + \alpha_2 [\ln(K/L)_T]^2 + \lambda_1 \ln(M/L)_T + \lambda_2 [\ln(M/L)_T]^2 + \theta_1 \ln(CO2/L)_T + \theta_2 [\ln(CO2/L)_T]^2 + \rho_T \quad {}_T = 1970 - 2001 \tag{5}$$

Then, it follows that

$\ln(Q/L)_T$ is the labour productivi ty (out per worker)

$\overline{\alpha(K/L)} = \alpha_1 \ln(K/L)_T + \alpha_2 [\ln(K/L)_T]^2$

is the growth rate of the capital depening

$\overline{\lambda(M/L)} = \lambda_1 \ln(M/L)_T + \lambda_2 [\ln(M/L)_T]^2$

is the growth rate of the material per worker

$\overline{\theta(CO2/L)} = \theta_1 \ln(CO2/L)_T + \theta_2 [\ln(CO2/L)_T]^2$

is the growth rate of the material per worker

ρ_T is the residual term that proxies for TFP per unit of labour growth $(\Delta \ln(TFP/L)_T)$

As mentioned above, the intercept (a) has no position in the calculation of the productivity growth rate indicators and its transformation becomes: -

$$\Delta \ln(Q/L)_T = \bar{\alpha} . \Delta \ln(K/L)_T + \bar{\lambda} . \Delta \ln(M/L)_T + \bar{\theta} . \Delta \ln(CO2/L)_T + \Delta \ln(TFP/L)_T \tag{6}$$

where $\bar{\alpha}$, $\bar{\lambda}$ and $\bar{\theta}$ denote the shares of capital deepening, material-labour ratio and total pollutant emissions intensity, respectively and $(TFP/L)_T$, is the translog index of TFP per unit of labour growth.

To calculate the average annual growth rate of TFP per unit of labour growth as well as of other productivity indicators in the model, equation (6) becomes

$$\Delta \ln(TFP/L)_T = \Delta \ln(Q/L)_T - [\overline{\alpha} . \Delta \ln(K/L)_T + \overline{\lambda} .\Delta \ln(M/L)_T + \overline{\theta} .\Delta \ln(CO2/L)_T] \quad (7)$$

$T = 1970 - 2001,\ 1971 - 1979,\ 1980 - 1986$ and $1987 - 2001$

Thus, equation (7) expresses the decomposition of labour productivity growth into the contributions of capital deepening, increasing usage of materials input per unit of labour, CO_2 emissions intensity, and TFP per unit of labour growth.

SOURCES OF DATA

The main source of data concerning Malaysia's manufacturing sector is the Department of Statistics Malaysia. The data covered the period of 1970-2001, in nominal terms (thousands of Malaysian Ringgit), but are transformed into real terms by deflating the gross value of output, the value of fixed assets to measure the capital, the cost of input to measure the material, with producer price index (PPI). Due to lack of data on man-hours of work, the labour input index is constructed based on the number of persons employed. Industrial CO_2 (in kilo tonne (Kt)) used to measure the air pollutant emissions generated by the manufacturing sector. These data from 1970-2001 are obtained from Institute of Advanced Studies of United Nations University (IAS/UNU), Tokyo, Japan and Department of Environment, Malaysia.

RESULTS AND DISCUSSION

Analysis of the data for the model 1 showed that estimated coefficients of labour and material inputs of the manufacturing industry sector were significant at 5 percent level and the estimated coefficients of capital and CO_2 emissions were significant at 10 percent level.

Table 1 Output Elasticity of Malaysian Manufacturing Sector Productivity Indicators (1970-2001) (Model 1)

Intercept	0.835 (1.405)
Capital	0.005 (1.844)*
Labour	0.0223 (1.965)**
Material	0.935 (6.220)**
CO2 Emissions	0.023 (1.665)*
Adjusted R^2	0.969
Durbin-Watson	1.909

Notes: Figures in parenthesis are T-values
** Indicates significant at 5% level
* Indicates significant at 10% level

In the second model, estimated coefficients of the input variables were significant at 5% and 10% levels. By Durbin-Watson values the two models were not found to be consistent with problem of autocorrelation (Table1 and 2). In addition, the adjusted R^2 and t-values did not indicate multicollinearity in both models (Table1 and 2).

Table 2 Output Elasticity of Malaysian Manufacturing Sector Productivity Indicators (1970-2001) (Model 2)

Intercept	1.571 (0.428)	
Capital Intensity	α_1 1.234 (2.470)**	α_2 0.317 (2.412)**
Material-Labour Ratio	β_1 0.085 (1.71)*	β_2 0.317 (2.278)**
CO2 Intensity Emissions	λ_1 0.282 (1.985)*	λ_2 0.063 (1.695)*
Adjusted R^2	0.984	
Durbin-Watson	2.059	

Note: Figures in parenthesis are T-values
**Indicates significant at 5% level
*Indicates significant at 10% level

Results of Extensive Growth Model

When the industrial CO_2 emissions were added to the model besides the above mentioned input terms, to measure the impact of CO_2 emissions generated by the manufacturing sector due to the consumption of fuel and other sources of energy in the manufacturing activities, the contributions of gross value of output, capital, labour, and material, to the average annual productivity growth of manufacturing sector remained constant as before the CO_2 emissions were added as undesirable output into production system (see Table 3 and 4). The impact of CO_2 emissions was mainly found IN the TFP growth of the sector, which is indicated as the technological progress of the manufacturing sector. It means that CO_2 emissions affect the quality of input terms, which is expressed in the form of TFP growth.

Table 3 Productivity Indicators of the Malaysian Manufacturing Sector, Without CO2 Emissions (Model 1) %

Productivity Indicators	1970-2001	1971-1979	1980-1986	1987-2001
Total Factor Productivity	0.204	0.043	0.588	0.122
Gross Value of Output	12.72	14.20	7.510	14.26
Capital	13.66	12.33	17.98	12.45
Labour	7.193	10.83	1.943	7.461
Material	12.98	14.62	7.248	14.66

Table 4 Productivity Indictors of the Malaysian Manufacturing Sector, With CO2 Emissions (Model 1) %

Productivity Indicators	1970-2001	1971-1979	1980-1986	1987-2001
Total Factor Productivity	-0.123	-0.304	0.291	-0.209
Gross Value of Output	12.72	14.20	7.510	14.26
Capital	13.66	12.33	17.98	12.45
Labour	7.193	10.83	1.943	7.461
Material	12.98	14.62	7.248	14.66
CO2 Emissions	6.642	7.078	5.317	8.998

The contribution of TFP growth to the average annual productivity growth of manufacturing sector was negative for the entire period of the study (1970-2001), sub-periods of (1971-1979) and (1987-2001). Their contributions were -0.123, -0. 304, and -0.209 percent respectively. And positive contribution was observed for the sub period of (1980-1986) i.e. 0.291 percent (Table 4). The average annual growth rate of CO_2 emissions was very high in all periods of the study. The highest growth rate of CO_2 emissions was 8.998 percent contributed in the sub period of (1987-2001). In this period there were tremendous manufacturing activities, consuming very high levels of fuel and other sources of the energy into the industrial activities. The level of the CO_2 emissions increased rapidly due to the intensive activities of industries. And the lowest CO_2 emissions level was of the sub period of (1980-1986) of 5.317 percent. There was a slow down in the economic activities due to the economic crisis of 1985, as well as slower industrial activities compared to the sub period of 1987-2001, i.e. the period of economic structural transformation, which gave the manufacturing sector the leading role in the Malaysian economy (Table 4).

Results of Intensive Growth Model

The performance of the manufacturing sector was measured using productivity indictors that were obtained from the estimated coefficients of this model. Moreover, to study the impact of CO_2 emissions on the productivity growth of the manufacturing sector, CO_2 emissions per worker was applied to the model. It was found that there was no change in the contribution of labour productivity growth to the manufacturing sector's productivity growth during all the periods of study in comparison with that before adding CO2 per worker emissions to the model, i.e. 1.407 percent for the entire period of 1970-2001; 1.039 percent for the sub-period of 1971-1979; 1.577 percent for the sub-period of 1980-1986; and 1.548 for 1987-2001 sub-period (Table 5 and 6).

Table 5 Productivity Indictors of the Malaysian Manufacturing Sector, Without CO_2 Per-worker Emissions (Mode2) %

Productivity Indicators	1970-2001	1971-1979	1980-1986	1987-2001
TFP per unit of Labour	-0.145	0.718	-3.185	0.756
Labour Productivity	1.407	1.039	1.577	1.548
Capital Intensity	1.594	0.619	4.980	0.597
Material –Labour Ratio	-0.042	-0.298	-0.218	0.194

Table 6 Productivity Indictors of the Malaysian Manufacturing Sector, With CO_2 Per-worker Emissions (Model 2) %

Productivity Indicators	1970-2001	1971-1979	1980-1986	1987-2001
TFP per unit of Labour	-0.219	0. 777	-0.03397	0.666
Labour Productivity	1.407	1.039	1.577	1.548
Capital Intensity	1.559	0.614	4.903	0.565
Material –Labour Ratio	0.054	-0.182	-0.119	2.993
CO2 Intensity Emissions	0.012	-0.132	0.189	0.017

However, the contribution of capital per worker was also positive during all the study periods. There were decreasing growth rates in the contribution of material per worker to the labour productivity growth during the entire period of 1970-2001, and the sub-periods of 1971-1979, 1980-1986 and 1987-2001: their contributions were 0.054, -0.182, -0.119 and 2.993 percent, respectively. The decreasing and negative growth rates were also contributed by TFP per unit of labour growth during the entire period of 1970-2001, and the sub-period of 1980-1986 (-2.190 and -3.397 percent, respectively). Moreover, there were decreasing and positive growth rates of TFP per unit of labour during the sub-periods of 1971-1979 and 1987-2001 (0.777 and 0.666 percent, respectively). The growth rates of the CO2 emissions per worker were 0.012, -0.132, 0.189 and 0.017 percent, respectively during the entire period of 1970-2001 and the sub-periods (see Table 6). The results showed that there was no change in labour productivity contributions to average annual growth rates of the manufacturing sector during the study periods. Their contributions remained as they were before adding CO_2 emissions per worker. There was no significant change on the contributions of the capital per worker and material per worker in terms of its average annual growth rates. There was also a significant impact of CO_2 emissions per worker into TFP per unit of labour growth. This indicates that CO_2 emissions per work had impacted the technological progress (TFP per unit of labour) of the manufacturing sector more than other productivity indicators of the sector as undesirable output.

CONCLUSION

This paper contributes to the available literature of growth accounting method in the area of calculating the real TFP and TFP per unit of labour growth by internalising CO_2 emissions and CO_2 pollutant intensity in addition to the conventional input terms in the production function. By this technique TFP and TFP per unit of labour growth became indictors of green productivity, which puts economic development and environmental protection into consideration. This study closed the gap of extensive growth theory model by providing statistical analysis in a parametric form that removed the doubt in the results generated. The factors affecting the output growth of the manufacturing sector as identified in this study using this model are the individual contributions of capital, labour, material, CO_2 emissions and the combined contribution of the quality of these inputs expressed as the TFP growth. In fact, the higher level of air pollutant emissions generated by the manufacturing sector impacted the growth rates of TFP. This impact is due to internalising the CO2 emissions generated by the sector in addition to the traditional input terms in the form of an un-priced public bad produced. The factors identified as influencing the labour productivity (that is indicated as a good measure of standard of living rather than output because it measures output per person) of manufacturing sector from intensive growth theory model are the individual contributions of capital deepening, material-labour ratio, CO_2 emissions intensity, and the simultaneous contribution of the quality of these factors that are expressed as the TFP per unit of labour. The CO_2 emissions per labour had slowed down the contribution of TFP per unit of labour (technological progress) of the manufacturing sector more than that of the first model due to the problems of labour involved, during the entire period of the study that witnessed the rapid industrial development in the Malaysian economy, which generated higher level of air pollutant emissions.

Finally, putting together the results of the two models, this paper found that industrial activities are related to the growth rate of CO_2 emissions generated by the manufacturing sector. This appears in the form of an un-priced public bad that had slowed the productivity growth of the manufacturing sector in general, and the contributions of TFP and TFP per unit of labour growth of the manufacturing sector in particular.

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