Assessing Carbon dioxide Emissions Impact on ASEAN-5 Plus 3 Productivity

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Abstract: This study measures carbon dioxide (CO_2) emissions impact on ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore and Thailand) plus 3 (China, Japan and Republic of Korea) productivity growth and the factors that determined their growth. An extensive growth theory model was generated from the production functions to measure the productivity growth of the countries under study. This model had a gap that cast doubt in the results generated. A statistical analysis was provided to close this gap. Exclusion of externalities such as pollutant emissions created a deficiency in growth accounting models as CO_2 emissions is internalised to calculate the green total factor productivity (TFP). The results show a slowdown in the contribution of TFP growth and a negative impact of CO_2 emissions produced by these economies on productivity growth in general and TFP growth in particular in comparison with other productivity indictors of these economies.

Keywords: ASEAN-5 plus 3, CO_2 Emissions, Green TFP, Productivity Growth

1 Introduction

Changes in productivity are a major concern in any economy because of the link between productivity and living standards. The ultimate goals of productivity improvement are greater competitiveness, higher profitability, higher living standards and better economic and social prosperity. In general, growth in productivity is associated with a growth in real wages and, ultimately, an improvement in living standards. This article reviewed most of the past studies related to productivity growth analysis. Combined previous studies related to productivity analysis in general and those related to productivity and environmental impact analysis which is called green productivity in particular. The concept of Green Productivity (GP) is drawn from the integration of two important developmental strategies namely productivity improvement and environmental protection. Productivity provides the framework for continuous improvement, while environmental protection provides the foundation for sustainable development. Therefore, GP is a strategy for enhancing productivity and environmental performance for overall socioeconomic development.

GP was launched in 1994 in line with the 1992 Earth Summit recommendations that both economic development and environmental protection would be key strategies for sustainable development. With the support from the government of Japan, the Asian Productivity Organisation (APO, 2002) introduced GP as a practical way to answer the challenge of sustainable development. The objective of the APO's GP programme is to enhance productivity and simultaneously reduce the negative impacts on the environment. It seeks to realise this objective by propagating GP consciousness. The APO pledges to continue the progress in the Asia-Pacific Region and through cooperation, extend GP to accelerate a growing green global marketplace. Markandya (1998) demonstrated the situation of air and water pollutant emissions as the fast growing region in the world; Asia has witnessed a remarkable increase in the level of economic activity over the last quarter century. Inevitably, this has been accompanied by increases in emissions of pollutants, with the industrial, energy and transportation sectors being responsible for both the largest increases in output as well as environmental pollution. In the early years of development, policymakers paid little attention to the environment. Economic growth was the priority and imposing any restraints on the growth was seen as erroneous. Of course some controls on emissions were introduced, but the level of effort that went into environmental regulation remained very low. The same applied to investments in infrastructure, in clean technology, and in the collection and treatment of industrial wastes. The public sector simply did not treat this as a priority category and the incentives on the private sector to undertake such investments remained weak or non-existent.

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 economic growth of these countries. This study aims at contributing to the available literature on the growth accounting method, in that it will draw methods to calculate the total factor productivity (TFP) growth as residual by internalising the CO_2 emissions in addition to the input terms in the conventional production function. Accordingly, TFP growth became an indicator of GP, 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, 2001), Harchaoui et al. (2002) and Elsadig (2006, 2007, 2008). For the purpose, the model suggested by Jorgenson et al. (1987) was modified and used in this study. In this regard, justifying why pollution emissions are input would be useful. It is done in Baumol and Oates (1988).

2 Methodology and Estimation Procedures

An attempt was made to apply the conventional growth accounting framework used by Stigler (1947), Abramovitz (1956), Kendrick (1956) to this study. This approach was initially developed by Solow (1956, 1957), finally brought to fruition by Kendrick (1961) and further refined by Denison (1962), Denison and Edward (1979), Griliches and Jorgenson (1962), Jorgenson et al. (1987), Dollar and Sokoloff (1990) and Elsadig (2006, 2007, 2008). The production of each economy is expressed as a function of capital, labour and time. It is assumed that the production process is characterised by constant returns to scale for each economy, so that the proportional increase in all inputs results in a proportional change in total 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 i*th* economy can be represented as follows:

$$\mathrm{GDP}_i = F(K_i, L_i, \mathrm{CO}_{2i}, T_i) \tag{1}$$

where output GDP of countries $i = (1,\ldots,8)$ is a function of economy physical capital input K, labour input L, CO_2 emissions and time T, that proxies for TFP as a technological progress of the economise of ASEAN-5 plus 3.

The main procedure has been to apply the aforementioned 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 and labour growth), an un-priced public bad [CO_2 emissions], and TFP growth. In other words, considering the data at any two discrete points of time, say T and $T - 1$, the growth rate of GDP for an economy can be expressed as a weighted average of the growth rates of capital (K), labour (L), and CO_2 emissions plus a residual term typically referred to as the rate of growth of TFP. Hence the TFP growth of each economy is computed as the difference between the rate of growth of GDP and weighted average of the growth in the capital, labour and CO_2 emissions.

According to 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). She has mentioned that this approach does not require the explicit specification of a production function, but the major drawback is that it is not based on statistical theory and, hence, statistical methods cannot be applied to evaluate their reliability, thus casting doubts on their results. This study attempts to close this gap by developing this model and applying to ASEAN-5 plus 3 case into a parametric model and providing statistical analysis for it in the first step as follows:

$$\Delta\ln\mathrm{GDP}_{iT} = a + \alpha \cdot \Delta\ln\mathrm{K}_{iT} + \beta \cdot \Delta\ln\mathrm{L}_{iT} + \lambda \cdot \Delta\ln\mathrm{CO}_{2iT} + \varepsilon_{iT} \tag{2}$$

$$T = 1965\text{-}2006$$

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 CO_2, a is the intercept or constant of the model,[1] ε_{iT} is the residual term,[2] Δ is the difference operator denoting proportionate change rate and ln is the log applied to transform the variables.

Because 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

$$\Delta \ln TFP_{iT} = \Delta \ln GDP_{iT} - [\alpha \cdot \Delta \ln K_{iT} + \beta \cdot \Delta \ln L_{iT} + \lambda \cdot \Delta \ln CO_{2iT}]$$
$$T = 1965\text{-}2006,\ 1965\text{-}1987 \text{ and } 1988\text{-}2006$$

where the weights are given by the average value shares as follows:
$\Delta \ln GDP_{iT}$ is the growth rate of output;
$\alpha \cdot \Delta \ln K_{iT}$ is the contribution of the capital;
$\beta \cdot \Delta \ln L_{iT}$ is the contribution of the labour;
$\lambda \cdot \Delta \ln CO_{2iT}$ is the contribution of the CO_2 emissions;
$\Delta \ln TFP_{iT}$ is the total factor productivity growth.

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

3 Sources of Data

The data for this article were collected from various sources. Real Gross Domestic Product (GDP) in U.S. dollars millions, real fixed physical capital in U.S. dollars millions, number of employment, was collected from Asian Development Bank: Key indicators of developing Asia and Pacific countries, Statistical and Data Systems Division and international financial statistics of International Monetary Fund and World Development Indicators online database system. Because of lack of data on man-hours of work, the labour input index is constructed based on the number of persons employed. Data of CO_2 emissions (CO_2 in kilo tonne (Kt)) was found to match with the time series data of the other variables of the study for the period of 1965-2006 at World Development Indicators online database.

4 Results and Discussion

Autoregressive estimator has been applied to Equation (2) of the model being generated from Cobb–Douglas production function to measure the shift in the production functions of ASEAN-5 plus 3. An annual time series data over the period of 1965-2006 for GDP, aggregate fixed physical capital, number of employment and CO_2 emissions (CO_2 in kilo tonne (Kt)) were employed for the individual countries.

In view of the fact that the model used in this study was specified in first differences and the calculated growth rates were used in the discussion of results and findings of the study, the model was found to be stationary. In addition, (Table 1) presents the results of the unit root tests conducted. Likewise, Engle and Granger (2003) state that if economic relationships are specified in first differences instead of levels, the statistical difficulties due to non-stationary variables can be avoided because the differenced variables are usually stationary even if the original variables are not.

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 accounts for the technological progress of the economy through the quality of input terms.

Table 1 Results of the Phillips–Perron (PP) unit root test first difference

Country	GDP	Capital	Labour	CO_2
1. China	−6.26*	−6.13*	−6.32*	−3.99*
	−6.25**	−6.15**	−6.24**	−3.98**
2. Indonesia	−3.34*	−4.00*	−7.17*	−5.94*
	−3.89**	−4.59**	−7.07**	−5.93**
3. Japan	−1.53*	−2.42*	−4.75*	−3.32*
	−3.67**	−3.72**	−6.01**	−3.98**
4. Korea	−2.30*	−3.65*	−6.14*	−5.69*
	−3.90**	−4.81**	−6.06**	−6.87**
5. Malaysia	−5.16*	−4.08*	−6.34*	−6.78*
	−5.11**	−4.13**	−6.26**	−6.72**
6. Philippines	−4.91*	−4.37*	−6.26*	−5.01*
	−5.50**	−4.82**	−6.19**	−5.26*
7. Singapore	−3.46*	−2.92*	−6.07*	−6.77*
	−4.31**	−3.78**	−6.29**	−6.83**
8. Thailand	−3.51*	−3.48*	−6.27*	−5.53*
	−3.67**	−3.55**	−6.25**	−5.79**

Note: Values in this table are *t*-test-values showing significance at 1, 5 and 10%.
*Constant without trend.
**Constant with trend.

Analysis of the data using Equation (2) showed that the estimated coefficients of the explanatory variables of the model mainly were significant at 5 and 10% levels. According to Durbin-H values, the model has no problem of autocorrelation (Tables 2 and 3).

4.1 Empirical Analysis

Analysis was carried out to compare the productivity indicators between the ASEAN-5 plus 3 economies for the entire period of 1965-2006. To study the effect of governments' policies in improving the productivity growth, the study period was divided into two phases. These phases, which corresponded to the major policy changes, were 1965-1987 and 1988-2006. The period of the 1960s and 1970s witnessed the labour driven policies in these countries and the birth of new era of export-oriented economies. The decades of 1980s, 1990s and 2000s saw a further diversification of the economies of these countries into more advanced industries through investment driven policies and trade liberalisation that had attracted foreign direct investment (FDI) which brought to these countries through Transnational Corporations (TNCs) investment. As a result of these polices, the range of economic activities and sources of growth had become more diversified. During these decades, the economic structural transformation took place in most economies of these countries. The manufacturing sector became the engine of growth in these countries. Finally, it includes the period of 1988-2006, that is, it was the period of pre and post Asian financial crisis of 1997.

The use of TFP overcomes the problems of single productivity indicators such as labour productivity and capital deepening by measuring the relationship between output and its total inputs (a weighted sum of all inputs), thereby giving the residual output changes not accounted for by total factor input changes. Being a residual, changes in TFP are not influenced by changes in the various

Table 2 Estimated coefficients of ASEAN 5+3, without CO_2, 1965-2006

Country	Intercept	Capital	Labour	Adjusted^2	D-H
1. China	1.06 (6.41)**	0.58 (7.27)**	0.42 (3.74)**	0.96	0.39
2. Indonesia	0.90 (3.13)**	0.65 (9.11)**	0.35 (2.37)**	0.98	–0.93
3. Japan	0.30 (1.49)	0.82 (15.0)**	0.18 (2.49)**	0.99	0.66
4. Korea	0.36 (1.74)*	0.73 (16.0)**	0.27 (2.59)**	0.98	0.73
5. Malaysia	1.60 (7.57)**	0.54 (2.78)**	0.46 (2.69)**	0.94	0.66
6. Philippines	0.93 (2.57)**	0.72 (13.1)**	0.28 (4.56)**	0.95	0.19
7. Singapore	1.49 (13.07)**	0.55 (12.4)**	0.45 (10.0)**	0.95	0.72
8. Thailand	1.05 (2.12)**	0.52 (7.19)**	0.48 (5.52)**	0.94	0.25

Note: Values in parentheses are *t*-values; values are estimated using Equation (2).
*Significant at 10% level.
**Significant at 5% level.

Table 3 Estimated coefficients of ASEAN 5+3, with CO_2, 1965-2006

Country	Intercept	Capital	Labour	CO_2	Adjusted^2	D-H
1. China	1.05 (1.55)	0.43 (2.12)**	0.20 (1.90)*	0.37 (1.69)*	0.93	0.33
2. Indonesia	0.55 (1.17)	0.61 (3.91)**	0.20 (2.97)**	0.19 (2.04)**	0.94	0.38
3. Japan	0.42 (0.75)	0.63 (12.1)**	0.14 (1.89)*	0.23 (2.53)**	0.98	0.72
4. Korea	0.77 (2.99)**	0.62 (13.9)**	0.13 (1.68)*	0.25 (4.56)**	0.97	0.85
5. Malaysia	1.56 (7.56)**	0.49 (4.16)**	0.25 (1.69)*	0.26 (1.94)*	0.93	0.66
6. Philippines	0.84 (1.59)	0.52 (8.23)**	0.16 (4.91)**	0.32 (2.41)**	0.94	0.16
7. Singapore	1.46 (12.6)**	0.44 (9.87)**	0.37 (8.00)**	0.19 (1.94)*	0.94	0.52
8. Thailand	0.78 (1.50)**	0.39 (5.16)**	0.22 (1.69)*	0.39 (5.61)**	0.94	0.66

Note: Values in parentheses are *t*-values; values are estimated using Equation (2).
*Significant at 10% level.
**Significant at 5% level.

factors that affect technological progress such as the quality of factors of production, flexibility of resource use, capacity utilisation, quality of management, economies of scale and so on so forth (Rao and Preston, 1984).

In measuring the impact of pollutant emissions on the AEAN-5 plus 3 productivity growth, the carbon dioxide emissions was used as a measure of air pollutant emissions. The results show that the contribution of GDP and input terms (such as capital and labour) were no different whether CO_2 emissions were included or not in the model (Tables 4 and 5). There were, however, differences in the growth rates of TFP growth in all of the study periods. A significant decline in the growth rates of TFP growth was observed during the entire period of the study and sub-periods, when CO_2 emissions variable was added to the model. The CO_2 emissions had impacted the productivity growth through the declining contribution of TFP growth in comparison with traditionally calculated (Tables 4 and 5). The sub-period of 1965-1987 was found to be a combined period of labour and investment driven policies. On the other hand, the sub-period of 1988-2006 was the perceived period of investment driven. As a result, the performance of the economies of these countries was rapid when compared with the period before the transformation of these economies into investment driven that supported by FDI with high amount pollutants emissions being produced as undesirable output besides the desirable output.

Table 4 ASEAN 5+3 productivity indicators (in percentage), without CO_2

Country	GDP	Capital	Labour	TFP
China				
1965-2006	6.00	7.86	8.50	1.08
1965-1987	7.19	8.02	9.04	1.11
1988-2006	8.76	8.66	9.12	1.06
Indonesia				
1965-2006	5.37	7.35	7.19	1.25
1965-1987	6.56	8.18	7.84	1.34
1988-2006	5.47	6.06	8.36	1.16
Japan				
1965-2006	6.17	11.4	10.8	1.47
1965-1987	7.24	10.6	11.8	1.93
1988-2006	5.18	11.8	12.0	2.21
Korea				
1965-2006	6.49	9.60	9.59	1.32
1965-1987	9.37	8.03	10.6	1.39
1988-2006	7.28	10.7	11.2	1.52
Malaysia				
1965-2006	6.58	9.21	4.93	1.04
1965-1987	6.72	8.11	5.67	1.23
1988-2006	5.34	6.07	6.28	1.33
Philippines				
1965-2006	6.14	4.53	8.85	0.90
1965-1987	4.82	5.22	7.74	0.82
1988-2006	7.75	6.12	10.19	0.92
Singapore				
1965-2006	8.39	10.1	8.13	1.13
1965-1987	9.29	8.89	9.24	1.29
1988-2006	6.23	10.4	10.7	1.44
Thailand				
1965-2006	7.01	5.71	7.29	1.00
1965-1987	5.90	4.51	8.34	1.08
1988-2006	6.29	6.11	9.38	0.92

Note: Values in this table were calculated using Equation (3).

5 Conclusion

The sustainability of higher economic growth continued to be driven by productivity through the enhancement of TFP. In this regards, TFP development strategies emphasised on the quality of the workforce, capital structure and technical progress. This article contributes to the available literature of the growth accounting method in the area of calculating the real TFP as residual growth by internalising CO_2 emissions

Table 5 ASEAN 5+3 productivity indicators (in percentage), with CO_2

Country	GDP	Capital	Labour	CO_2	TFP
China					
1965-2006	6.00	7.86	8.50	14.2	0.87
1965-1987	7.19	8.02	9.04	13.7	0.76
1988-2006	8.76	8.66	9.12	14.8	0.67
Indonesia					
1965-2006	5.37	7.35	7.19	11.4	0.38
1965-1987	6.56	8.18	7.84	10.8	0.17
1988-2006	5.47	6.06	8.36	12.2	0.14
Japan					
1965-2006	6.17	11.4	10.8	13.6	0.44
1965-1987	7.24	10.6	11.8	13.4	0.29
1988-2006	5.18	11.8	12.0	13.9	0.61
Korea					
1965-2006	6.49	9.60	9.59	11.7	0.75
1965-1987	9.37	8.03	10.6	11.0	0.58
1988-2006	7.28	10.7	11.2	12.6	0.94
Malaysia					
1965-2006	6.58	9.21	4.93	10.2	0.55
1965-1987	6.72	8.11	5.67	9.41	0.65
1988-2006	5.34	6.07	6.28	11.3	0.77
Philippines					
1965-2006	6.14	4.53	8.85	10.5	–0.96
1965-1987	4.82	5.22	7.74	10.1	–1.31
1988-2006	7.75	6.12	10.19	10.8	–0.55
Singapore					
1965-2006	8.39	10.1	8.13	10.1	0.50
1965-1987	9.29	8.89	9.24	9.47	0.36
1988-2006	6.23	10.4	10.7	10.7	0.75
Thailand					
1965-2006	7.01	5.71	7.29	10.9	–0.81
1965-1987	5.90	4.51	8.34	9.94	–0.86
1988-2006	6.29	6.11	9.38	11.7	–0.75

Note: Values in this table were calculated using Equation (3).

in addition to the conventional input terms in the production functions of ASEAN-5 plus 3 in comparison with traditionally calculated. By this technique TFP growth became an indicator 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

ASEAN-5 plus 3 economies as identified in this study using this model are the individual contributions of capital, labour, 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 these countries economic development had slowed the growth rates of TFP in comparison with traditionally calculated. This impact is due to internalising the CO_2 emissions generated by these countries economic growth in addition to the traditional input terms in the form of an un-priced public bad or undesirable output produced.

Finally, this article found that economic activities are related to the growth rate of CO_2 emissions generated by the economies of these countries. This appears in the form of an un-priced public bad that had slowed the productivity growth of these economies in general and the contributions of TFP growth of the these economies in particular.

A CO_2 emission data was found to match with the time series data of the other variables of the study for the period of 1965-2006. Furthermore, there are no environmental taxes introduced by most of these countries for the abatement of pollutant emissions by the firms involved in the economic activities in them and tradable permits to curb the pollution. In addition, no money values are attached to the environmental regulations to protect the environment in these countries.

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