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EFFICIENCY AND PRODUCTIVITY GAINS IN KNOWLEDGE-BASED PRODUCTION: THE CASE OF EAST ASIAN ECONOMIES

This study examines the technical change and efficiency in knowledge-based production of the selected East-Asia Countries using a panel stochastic frontier analysis. The empirical results indicate that Japan, Singapore, Korea, Malaysia and China appear to be the most efficient countries in the region in term of high-tech production. Indonesia and Philippines, on the other hand, appear to be the least efficient ones. In regard to the issue of catch-up and convergence, the results show that Malaysia and Korea are catching up with their developed counterpart, Japan; while the others are still not on the right path of catching up. In general, all the ASEAN-five-plus-three countries have exhibited good technical progress and have achieved a positive total factor productivity (TFP) growth in the period of 1992-2005. The overall increase in technical change indicates evidence of innovation in these countries.
JEL: D24; O47; O32

1. Introduction

Technological upgrading for sustainable economic growth and development has been one of the central issues for researchers and policy makers in particular during this era of knowledge-based economy. While the level of technological sophistication of a country's exports is an important predictor of future growth, the efficiency and technological shift in high-tech production can be adopted as a measure of knowledge-based performance of the economy.

High-technology is often employed to refer to firms and industries whose products or services comprise of advanced and innovative technologies. Such firms have in common a reliance on advanced scientific and technological expertise and are often identified by high

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research and development expenditures (See Keeble & Wilkinson, 2000). High-technology sectors contribute to rapid growth in both manufacturing and services by improving the overall efficiency of labor and capital. In addition, it also provides firms with a competitive advantage by changing the key factors of success. Reich (1991) argued that high-technology industries will be the primary source of wealth generation in the future, as compared to the resource, labor and capital-intensive based industries that so dominated the twentieth century.

One of the recent studies by Montobbio (2005) show that during the 1990s, Asian countries such as China, Malaysia, Singapore, and Thailand improved significantly on their overall importance in world exports, and at the same time displayed a relatively higher degree of innovativeness and technological intensity of trade. In Korea, Malaysia, Philippines, Singapore, Thailand, China, Indonesia and Japan, the share of high-tech products on total exports increased substantially (see Table 1).

Table 1

High-Technology Exporters in Asia (1992 and 2003)

Category	2003		1992	
	Country	Million USD	Country	Million USD
High-technology exports accounting for more than 30% of manufactured exports	Korea (32%)	57.161	Korea (20%)	14.048
	Malaysia (59%)	47.332	Malaysia (38%)	10.221
	Philippines (74%)	23.942	Philippines (28%)	1.114
	Singapore (59%)	71.421	Singapore (45%)	21.774
	Thailand (30%)	18.203	Thailand (22%)	4.781
High-technology exports accounting for 10%-30% of manufactured exports	China (27%)	107.540	China (6%)	4.355
	Indonesia (14%)	4.580	Indonesia (3%)	496
	Japan (24%)	105.450	Japan (24%)	78.519

Source: World Bank, World Development Indicators.

Among the Asian emerging markets, South Korea, Malaysia, Philippines, Singapore and Thailand appear to be in the lead in the transition to a knowledge-based economy as is indicated by the level of high-technology exports as a share of manufactured exports (See World Bank, 2001). However, large differences still remained between these countries. The factors contributing to these disparities include a few crucial areas such as investment in knowledge innovation and growth of a high-skilled workforce (See OECD, 2001; Mani, 2000).

In this study, high-technology exports represent technology creations that indicate innovation strength in generating knowledge. These high-technology exports are products with high R&D intensity. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery (United Nations). High-technology goods are considered as an innovative output indicator. Technology has become one of the main determinants of international competitiveness and of oligopolistic markets. It follows that trade in high-technology products has become an outstanding subject for both study and political reflection (Papagni, 1992).

The objective of this study is to assess the performance of knowledge-based production of the ASEAN-plus-3 countries by measuring their efficiency comparatively with the aid of a stochastic frontier production analysis. Our purpose in using this method is to determine the efficiency of Malaysia in terms of generating the knowledge-based output, as compared to its other ASEAN-plus-3 counterpart countries. In doing so, we used high-technology exports as the proxy for knowledge-based output. For each country we estimated the level of technical efficiency and then compute their technical efficiency change, technical change, and finally, the total factor productivity (TFP).

The structure of the paper is as follows. Section 2 provides a brief discussion on the intra-industry trade and production network in the Asian region. Meanwhile, Section 3 explains the stochastic frontier production function methodology employed to measure the rates of TFP. Section 4 describes the data while section 5 reports the empirical results and discussion. Section 6 concludes.

2. Trade in the Asian Region

Trading among Asian countries constitute an enormously important element in regional integration in terms of value-chain production and the importance of multinational activities. The latter is not surprising since multinationals have invested substantially in the export-oriented economies of East Asia over the last few decades, tapping on the benefits of FDI-friendly policies and cheaper factors of production offered in many of these countries. In fact, many of the Southeast Asian countries' exports are driven mainly by multinational activities, especially those concerning high technology product exports. In this sense, these foreign firms have played an integral part in transferring knowledge and technology to these economies although the degree of technology transfer remained debatable in many cases. Nonetheless, the increasingly expanding trade activities in the region are driven strongly by intra-regional trade especially surrounding the ever-growing influence of China.

Essentially, the pattern of trade in this region favours a vertical intra-industry trade that is made possible through the involvement of adequate FDI thus enabling the growth of a sophisticated production network. Such developments have enabled many of these emerging Asian economies to reap the required and necessary technology transfer that enabled them to "catch-up" with their more illustrious and industrialized counterparts both in the Asian region and elsewhere. However, the "catch-up" process may be different for these countries, visible in those which presumably, enjoyed significant technology transfer from the FDI which eventually see them producing more high technology exports or knowledge-based production activities.

Overall, the burgeoning trade activities in Asian has seen their share of world trade increased significantly, this largely due to enormous increased in regional trade flows. While trade flows in the rest of the world increased around three times between 1990-2006, inter-regional trade involving emerging Asia rose five times while intra-regional trade within emerging Asia increased by 8.5 times. As of 2006, intra-regional trade accounts for more than 50% of total trade in Asia (Gruenwald & Hori, 2008). In the context of intra-regional trade, most of them are motivated by vertical specialization in the production chain hence reflecting specialization according to comparative advantage exploitation that ultimately, fostered a production network that targets foreign markets. As such, the trading of intermediate goods among Asian economies is much higher than most parts of the world (Gruenwald & Hori).

The vertical specialization pattern in Asia's intra-regional trade is also important in terms of the "catching-up" process; i.e. less developed economies moving up the production value chain, producing more high technology exports as opposed to lower value added products or intermediary ones. The process could be aided by the necessary technology transfer that alters the comparative advantage of the respective countries thus allowing the allocation of resources to producing higher technology products. The "catching-up" process could also have been made possible by technological improvement, i.e. greater investment in technology that improves the productivity of the inputs, improvement in human resources capabilities or increased imports of machinery and other productive imports as opposed to intermediate or raw materials imports.

3. Methodology

3.1 Stochastic Frontier Analysis (SFA)

The stochastic frontier analysis (SFA) model will be employed in this paper. This model, originally developed by Farrell (1957) and later popularized by Aigner *et al* (1977), and Meeusen and Van den Broeck (1977), is closely related to the concept of output-oriented technical efficiency. The major difference between the production frontier technique and the traditional growth-accounting method is that the former allows for production below the best practice output (Wu, 2000). The best practice output model can be shown as follows:

$y_{it}^F = f(x_{it}, t)$, t = 1, … T and I = 1,…, N

where

y_{it}^F represents the potential output level on the frontier for the *i*th country at time t, given technology f(•).

x_{it} represents the vector of inputs for the *i*th country at time t.

Any observed output y_{it}, given input x_{it}, could be expressed as follows:

$y_{it} = y_{it}^F TE_{it} = f(x_{it}, t)TE_{it}$

transform into:

$y_{it} = f_x x_{it} + f_t + TE_{it}$

where,

TE_{1t} = technical efficiency, defined as the ratio of the observed output over the best practice output. Dotted variables denote time derivatives.

f_x = output elasticity with respect to x.

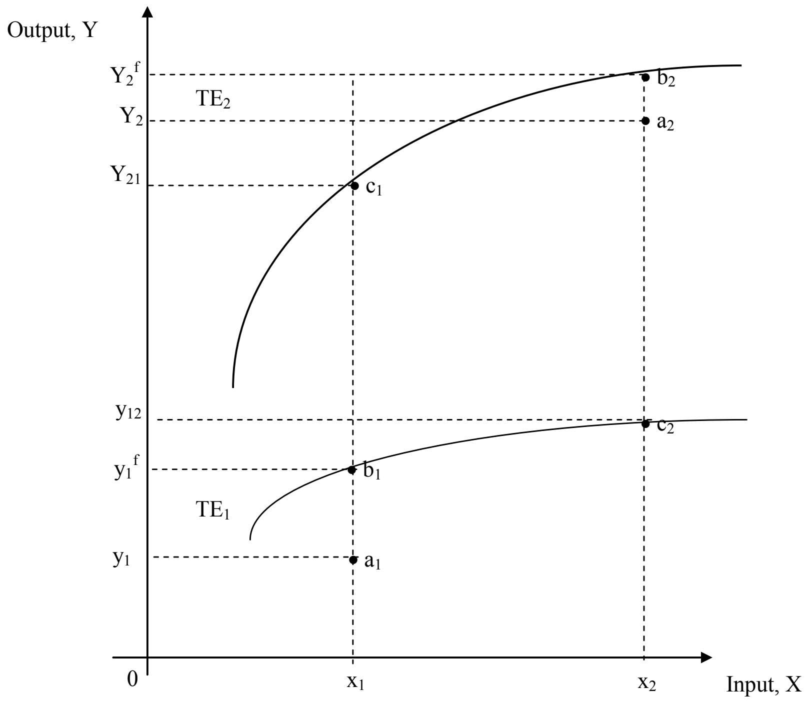
f_t = output elasticity with respect to t.

In this study, countries are producers of knowledge-based outputs (high-technology export) given knowledge-based inputs (Manufactures imports, GDP per capita, ICT expenditure per capita and gross capital formation per capita). Countries can be thought of as operating either on or within the frontier; with the distance from the frontier reflecting inefficiency. Over time, a country can become less inefficient and 'catch up' to the frontier or the frontier itself can shift over time, indicating technical progress (technological improvement). In addition, a country can move along the frontier by changing inputs. In other words, output growth can be thought of in terms of three different components: efficiency change, technical change and input change. Economists often refer to the first two components collectively as 'productivity change' (Koop et cetera, 1999).

Following Kalirajan *et al* (1996) and Nishimizu and Page (1982), the decomposition output growth can be graphically illustrated in figure 1. Given technology points a_1 and a_2 are the observed levels of output y_1 and y_2 at times 1 and 2 with the corresponding frontier or potential outputs of y_1^f and y_2^f at points b_1 and b_2 respectively. The difference between the observed and potential outputs in each period provides an indicator of technical inefficiency. Technical efficiency change between the two periods is then measured by the difference between TE_1 and TE_2 in figure 1.

Figure 1

Decomposing Output Growth



Symbolically,

$\Delta y = y_2 - y_1 = (y_2^f - TE_2) - (y_1^f - TE_1) = (y_2^f - y_1^f) + (TE_1 - TE_2) = (y_2^f - y_{12}) + (y_{12} - y_1^f) + (TE_1 - TE_2)$

Thus, output growth ($y_2 - y_1$) is decomposed into technological progress ($y_2^f - y_{12}$), growth due to input changes ($y_{12} - y_1^f$) and change in technical efficiency ($TE_1 - TE_2$). Based on decomposition, total factor productivity growth (TFP) is the growth in output not explained by input growth but rather, the sum of technological progress and changes in technical efficiency. It is:

$TFP_{it} = TP_{it} + TE_{it}$, $t = 1,\ldots,T$, $i = 1,\ldots,N$.

This decomposition offers a framework for answering a number of questions like: Is Malaysia efficient in generating the knowledge-based outputs, as compared to other ASEAN-plus-3 countries? Which countries are making most efficient use of their knowledge-based inputs? Do countries removing inefficiencies and moving closer to the world production frontier drive economic growth? Or do movements of or along the frontier itself drive it? These questions are particularly contemporary in light of recent research into issues of country convergence. For instance, if countries are lying on or near different parts of the frontier, then observed differences in GDP per capital should be due largely to input mix. Policies that prescribe increases in incomes should then focus on changing the input mix, perhaps by increasing the stock of capital. However, if inefficiencies are found to play a role, policy prescriptions should stress the need for improvements in productive efficiency (e.g. improving the legal system, establishing political and macroeconomic stability, welcoming transnational corporations with greater organizational skills, and so on).

3.2 Model Specification – The Translog Production Function

With the aim to determine the efficiency of Malaysia in generating the knowledge-based outputs, as compared to other ASEAN-plus-3 countries, we adopt the model utilized by Battese and Coelli's (1992) stochastic frontier model. This model specifies a time variable as a proxy for technical change over time and renowned as a translog stochastic production frontier. The translog functional form is used because it offers great flexibility in specifying the nature of production. The translog model can be interpreted as a second-order approximation to the unknown, but true, functional form. Duffy and Papageorgiou (2000) argued that the Cobb-Douglas form of the production function is typically assumed when econometric estimation of the production function undertaken is wrongly specified.

In this study, the knowledge-based output of a country is assumed to be a function of the four knowledge-based inputs of manufactures imports, GDP per capita, gross capital formation per capita and ICT expenditure per capita. This model specifies non-neutral technical change and also consisted of two error terms (see below). It is as follows:

$$\ln(Y_{it}) = \beta_0 + \beta_M \ln(M_{it}) + \beta_G \ln(G_{it}) + \beta_K \ln(K_{it}) + \beta_E \ln(E_{it}) + \frac{1}{2}\beta_{MM}[\ln(M_{it})]^2 + \frac{1}{2}\beta_{GG}[\ln(G_{it})]^2 + \frac{1}{2}\beta_{KK}[\ln(K_{it})]^2 + \frac{1}{2}\beta_{EE}[\ln(E_{it})]^2 + \beta_{MG}\ln(M_{it})\ln(G_{it}) + \beta_{MK}\ln(M_{it})\ln(K_{it}) + \beta_{ME}\ln(M_{it})\ln(E_{it}) + \beta_{GK}\ln(G_{it})\ln(K_{it}) + \beta_{GE}\ln(G_{it})\ln(E_{it}) + \beta_{KE}\ln(K_{it})\ln(E_{it}) + \beta_{Mt}\ln(M_{it})t + \beta_{Gt}\ln(G_{it})t + \beta_{Kt}\ln(K_{it})t + \beta_{Et}\ln(E_{it})t + \beta_t t + \beta_{tt}t^2 + V_{it} + U_{it}$$

Where ln refers to the natural logarithm, and

Y_{it} = a kx1 vector of knowledge-based outputs of the *i*-th country in the t-th year. This knowledge-based output is proxy by high-technology exports of the *i*-th country in the t-th year.

M_{it} = a kx1 vector of manufactures imports of the *i*-th country in the t-th year.

G_{it} = a kx1 vector of Gross Domestic Product (GDP) of the *i*-th country in the t-th year.

K_{it} = a kx1 vector of Gross Capital Formation of the *i*-th country in the *t*-th year.

E_{it} = a kx1 vector of total expenditure on Information and Communication Technology (ICT) of the *i*-th country in the *t*-th year.

t = a time trend.

V_{it} = random error term of the *i*-th country in the *t*-th time period. It is a systematic error component which captures random variation in output due to factors outside the control of the country (such as war, strikes, luck, etc. on the value of the output variable), is assumed to be independently and identically distributed as $V_{it} \sim$ i.i.d. $N(0, \sigma^2_t)$ with the variances possibly time-specific, independently of μ_{it}.

U_{it} = the technical inefficiency in production relative to the stochastic frontier which are non-negative random variables independently and identically distributed and obtained by truncation of the $N^+(\mu_{it}, \sigma^2_u)$ distribution.

β = a vector of unknown parameters. These parameters of the production frontier will be estimated by employing maximum likelihood method[4] with the truncated normal distributional form of U_{it} and V_{it}. It is also known as the structural parameters of coefficients.

Country specific technical efficiency will be obtained, employing the following relationship:

$$TE_{it} = \frac{Y_{it}}{\exp(X_{it}\beta)} = \frac{\exp(X_{it}\beta - \mu U_t)}{\exp(X_{it}\beta)} = \exp(-U_{it})$$

This output-orientated measure is first proposed by Farell (1957) to measure technical efficiency. It indicates the magnitude of the output of the *i*-th decision-making unit (DMU) relative to the DMU that could be produced by a fully-efficient DMU using the same input

[4] Using Coelli (1992) FRONTIER 4.1 software.

vector (Coelli, 1992). This technical efficiency measure takes a value between zero and one, with one indicating the DMU being technically efficient and lying on the production frontier; while efficiency scores of anything below one indicating the existence technical inefficiency on the part of the DMU, i.e. the DMU could have produced more output given the inputs being used. A positive change in the technical efficiency score implies that the country is catching up with the world's best practice, whereas negative changes in the measure imply that the country has moved away from the grand frontier.

Due to a high possibility of multicollinearity as a result of the squared and interaction terms in the translog function, many parameters (even if they are non-zero) could still turn out to be non-significant in the usual t-test. As such, a number of likelihood ratio (LR) tests are performed to identify the appropriate functional form and to test for the presence of inefficiency among the countries. As a consequence, it is preferable not to look at the single t-ratios but to carry out LR test to involve more than one parameter at the same time instead. The generalized likelihood-ratio test statistic is computed as follows:

$\lambda = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$,

Whereby, $L(H_0)$ and $L(H_1)$ represent the likelihood function under the null hypothesis, H_0, and the alternative hypothesis, H_1. This statistic has asymptotic chi-square distribution with degrees of freedom equal to the difference in the number of parameters in H_1 and H_0, if H_0 is true.

3.3 Decomposition of Total Factor Productivity (TFP) Change

The parameter estimates found from the maximum-likelihood method will be employed for the decomposition of productivity change as follows:

(i) Technical Efficiency change (TEC),

$$TE = \frac{d\ln TE}{dt} = \frac{TE_{t+1} - TE_t}{TE_t}$$

(ii) Technical change (TC),

$$\mathbf{TC} = \frac{\partial \ln f(x_i, t)}{\partial t} = \hat{\beta}_t + \hat{\beta}_{tt}t + \hat{\beta}_{Mt}\ln(M_{it}) + \hat{\beta}_{Gt}\ln(G_{it}) + \hat{\beta}_{Kt}\ln(K_{it}) + \hat{\beta}_{Et}\ln(E_{it})$$

(iii) Estimated k-based output elasticity with respect to manufactures imports,

$$\hat{\varepsilon}_M = \frac{\partial \ln f(x_i, t)}{\partial \ln(M)} = \hat{\beta}_M + \hat{\beta}_{MM}\ln(M_{it}) + \hat{\beta}_{MG}\ln(G_{it}) + \hat{\beta}_{MK}\ln(K_{it}) + \hat{\beta}_{ME}\ln(E_{it}) + \hat{\beta}_{Mt}t$$

(iv) Estimated k-based output elasticity with respect to Gross Domestic Product (GDP),

$$\hat{\varepsilon}_G = \frac{\partial \ln f(x_i, t)}{\partial \ln(G)} = \hat{\beta}_G + \hat{\beta}_{GG}\mathbf{In(G_{it})} + \hat{\beta}_{MG}\mathbf{In(M_{it})} + \hat{\beta}_{GK}\mathbf{In(K_{it})} + \hat{\beta}_{GE}\mathbf{In(E_{it})} + \hat{\beta}_{Gt}\mathbf{t}$$

(v) Estimated k-based output elasticity with respect to Gross Capital Formation,

$$\hat{\varepsilon}_K = \frac{\partial \ln f(x_i, t)}{\partial \ln(K)} = \hat{\beta}_K + \hat{\beta}_{KK}\mathbf{In(K_{it})} + \hat{\beta}_{KM}\mathbf{In(M_{it})} + \hat{\beta}_{GK}\mathbf{In(G_{it})} + \hat{\beta}_{KE}\mathbf{In(E_{it})} + \hat{\beta}_{Kt}\mathbf{t}$$

(vi) Estimated k-based output elasticity with respect to total expenditure on Information and Communication Technology (ICT)

$$\hat{\varepsilon}_E = \frac{\partial \ln f(x_i, t)}{\partial \ln(E)} = \hat{\beta}_E + \hat{\beta}_{EE}\mathbf{In(E_{it})} + \hat{\beta}_{EM}\mathbf{In(M_{it})} + \hat{\beta}_{EG}\mathbf{In(G_{it})} + \hat{\beta}_{KE}\mathbf{In(K_{it})} + \hat{\beta}_{Et}\mathbf{t}$$

(vii) The sum of the k-based output elasticities,

$$\hat{\varepsilon} = \sum_{i=1}^{l} \hat{\varepsilon}_i (x_i, t) = (\hat{\beta}_M + \hat{\beta}_G + \hat{\beta}_K + \hat{\beta}_E) + (\hat{\beta}_{MM} + \hat{\beta}_{MG} + \hat{\beta}_{MK} + \hat{\beta}_{ME})\ln(M_{it}) + (\hat{\beta}_{GG} +$$

$$\hat{\beta}_{MG} + \hat{\beta}_{GK} + \hat{\beta}_{GE})\ln(G_{it}) + (\hat{\beta}_{KK} + \hat{\beta}_{MK} + \hat{\beta}_{GK} + \hat{\beta}_{EK})\ln(K_{it}) + (\hat{\beta}_{EE} + \hat{\beta}_{ME} + \hat{\beta}_{GE} +$$

$$\hat{\beta}_{EK})\ln(E_{it}) + (\hat{\beta}_{Mt} + \hat{\beta}_{Gt} + \hat{\beta}_{Kt} + \hat{\beta}_{Et})t$$

(viii) Total Factor Productivity Change (TFPC) = TEC + TC

4. Data

In the production function, the knowledge-based output is proxy by high-technology exports. Four knowledge-based inputs (k-input) and general inputs of manufactures imports, Gross Domestic Product (GDP), Gross Capital Formation and total expenditure on Information and Communication Technology (ICT) are included (see Table 2).

The choices of the variables are made in order to designate and quantify knowledge development of a country. The knowledge-based output, which is High-Technology Exports, represents technology creations that indicate innovation strength in generating knowledge. These high-technology exports are products with high R&D intensity. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery (United Nations). On the other hand, the knowledge-based input (k-input) is a set of variables that measures the sources and supports for knowledge development. It also serves to gauge the supporting environment for knowledge development in each country. It consists of manufactures imports, Gross Domestic Product, Gross Capital Formation and total expenditure on Information and Communication Technology (ICT).

Table 2

Knowledge-Based Output, Knowledge-Based Input, and Its Unit of Measurement

Variables	Unit of Measurement
Knowledge-based outputs High-Technology Exports	USD per capita
Knowledge-based & general inputs	
Manufactures Imports	% of Merchandise Imports
Gross Domestic Product	USD per capita
Gross Capital Formation	USD per capita
Total Expenditure on ICT	USD per capita

The use of ICT expenditure to measure knowledge creation in the economy is based on the arguments of computers' role in the transmission of information and its obvious link to productivity enhancements. In any event, the use of ICT expenditure to measure knowledge creation has been used in many other literatures. Kelleci (2003) stressed on the pressures of global competition leading to firms increasing the scope of technology usage, especially in the case of information and communication technologies (ICT). These firms also try to adopt their organizational structures to the process of knowledge economics. Meanwhile, Seki (2008) also argued that the most important issue in knowledge economy is to generate, use and disseminate knowledge. As such, this gives ICT sector a vital importance since it (ICT) is the fastest way of using and disseminating knowledge. In fact, the power of economic competitiveness of a country depends on the productivity of its ICT sector (Seki, 2008).

In this paper, our emphasis is on 8 countries, namely Malaysia, Indonesia, Philippines, Singapore, Thailand, China, Japan and South Korea. Complete data for these 8 countries were available for 14 years, 1992-2005. These data, consisted of 112 observations for each variable, were collected from the World Development Indicators CD-ROM.

A summary of the data on the different variables in the stochastic frontier production function is reported in Table 3. Indonesia had the lowest high-technology exports as compared to other ASEAN-plus-3 countries while Singapore had the highest high-technology exports from the year 1992 to 2005. Meanwhile, Japan has the highest total expenditure on ICT per capita of USD3,161 and gross capital formation per capita of USD10,534 although it has the lowest manufactures imports per capita of USD45. Malaysia has the highest manufactures imports per capita of USD86 and Philippines has the highest gross domestic product per capita of USD67,362 as compared as compared to other ASEAN-plus-3 countries. Finally, China has the lowest gross domestic product per capita (USD48), total expenditure on ICT per capita (USD7) and gross capital formation per capita (USD150) due to its size of population.

Table 3

Summary Statistics for Variables in the Stochastic Frontier Production Function for ASEAN-plus-3 Countries

Variable	Sample Mean	Standard Deviation	Minimum Value	Maximum Value
High-Technology Exports (USD per capita)	2.367	5.154	3.000	24.223
Manufactures Imports (% of Merchandise imports)	72	10	45	86
Gross Domestic Product (USD per capita)	13.648	19.980	48.000	67.362
Total Expenditure on ICT (USD per capita)	692.000	952.000	7.000	3.161
Gross Capital Formation (USD per capita)	2.695	3.306	150.000	10.534

5. Empirical Results

5.1 Hypotheses Tests and Preferred Model Chosen

In this section, we used tests to test for the existence of the inefficiency effects, the characteristics of the technical change, and the specification of the appropriate production function. Table 4 reports all the alternative models tested that were tested, and the log-likelihood estimates obtained from the respective models.

The first null hypothesis considered in Table 4 specifies that the Cobb-Douglas production frontier with neutral technical change is an adequate representation of the data. This null hypothesis is specified by H_0: $\beta_{GG} = \beta_{KK} = \beta_{EE} = \beta_{MM} = \beta_{GK} = \beta_{GE} = \beta_{GM} = \beta_{KE} = \beta_{KM} = \beta_{EM} = \beta_{Gt} = \beta_{Kt} = \beta_{Et} = \beta_{Mt} = \beta_t = \beta_{tt} = 0$. The results for this test saw a test statistic of 138.76, which is more than the $\chi^2_{0.95}$ critical value of 26.30, resulting in a rejection of the null hypothesis of the Cobb-Douglas frontier being an adequate representation of the production technology. It is implying that the translog production function, a more general functional form, better describes the technology for the ASEAN-plus-3 countries instead.

The second hypothesis tested for any technical change over the sample period. The null hypothesis is specified by H_0: $\beta_{Gt} = \beta_{Kt} = \beta_{Et} = \beta_{Mt} = \beta_t = \beta_{tt} = 0$, indicating that all the coefficients associated with the time trend to be zero. The maximum-likelihood estimate of this model is again, reported in the Table 4. The generalized likelihood-ratio test statistic of 47.08 is substantially greater than the critical value of 12.59. As such, there appears to be technological change over the sample period.

The third null hypothesis that is reported in Table 4 is the existence of the Hicks-neutral technical change. If the coefficients of the interactions between the logarithms of the inputs and the time trend are all zero, the technical change is Hicks-neutral. The null hypothesis is stated as H_0: $\beta_{Gt} = \beta_{Kt} = \beta_{Et} = \beta_{Mt} = 0$. Table 4 reports the generalized likelihood-ratio statistic of 40.96, which exceeds the critical value of 9.49. Hence, we reject the null hypothesis of the existence of Hicks-neutral technical change. In short, the appropriate function forms for these ASEAN-plus-3 countries are the translog function without Hicks-neutral technical change. Next, we then turn to test inefficiency in the model.

The fourth hypothesis test considered is a test of the existence of technical inefficiency effects, hence the null hypothesis testing of $H_0 : \gamma = \mu = \eta = 0$ was conducted. As can be seen from the results in Table 4, the value of the likelihood ratio statistic is computed is 69.96, which is more than the critical value 7.05. As such, the null hypothesis of no inefficiency effects is strongly rejected, indicating that the traditional production function is an inadequate representation of the data and will underestimate the actual frontier because of the existence of technical inefficiency effects (i.e. much of the variation in the composite error terms is due to the inefficiency component thus substantiating the use of the stochastic frontier analysis).

Table 4

Generalised Likelihood Ratios of Hypotheses for Parameters of the Stochastic Frontier Production Function and Technical Inefficiency Model for ASEAN-plus-3 Countries

Models	Null Hypothesis H_0	Log Likelihood Value	Test Statistic(λ) $-2\{\ln[L(H_0)] - \ln[L(H_1)]\}$	Critical Value ($\chi^2_{0.95}$)	Decision
Model 1 (Cobb-Douglas Production Function)	$H_0 : \beta_{MM} = \beta_{GG} = \beta_{EE} = \beta_{KK} = \beta_{MG} = \beta_{ME} = \beta_{MK} = \beta_{GE} = \beta_{GK} = \beta_{EK} = \beta_{Mt} = \beta_{Gt} = \beta_{Et} = \beta_{Kt} = \beta_t = \beta_{tt} = 0$ (df = 16)	-68.47	138.76	26.30	Reject H_0
Model 2 (No technical Change)	$H_0 : \beta_{Gt} = \beta_{Kt} = \beta_{Et} = \beta_{Mt} = \beta_t = \beta_{tt} = 0$ (df = 6)	-22.63	47.08	12.59	Reject H_0
Model 3 (Neutral technical progress)	$H_0 : \beta_{Gt} = \beta_{Kt} = \beta_{Et} = \beta_{Mt} = 0$ (df = 4)	-19.57	40.96	9.49	Reject H_0
Model 4 (No Technical Inefficiency)	$H_0 : \gamma = \mu = \eta = 0$ (df = 3)	-34.07	69.96	7.05	Reject H_0
Model 5 (Half-normal distribution of technical inefficiency)	$H_0 : \mu = 0$ (df = 1)	-15.85	33.52	3.84	Reject H_0
Model 6 (Time-invariant technical inefficiency)	$H_0 : \eta = 0$ (df = 1)	-16.81	-35.44	3.84	Accept H_0

* The critical values for the tests are obtained from Table 1 of Kodde & Palm (1986) for joint restriction.

Note: Log-likelihood value for General model is 0.91.

The fifth hypothesis test considered whether the technical inefficiency effects have a half-normal distribution or a truncated normal distribution. Hence a test of the null hypothesis that $H_0 : \mu = 0$ is conducted. From Table 4, the value of the likelihood ratio statistic computed is 33.52, which is more than the critical value 3.84. Thus, the null hypothesis of technical inefficiency effects having a half-normal distribution is rejected, indicating that the technical inefficiency effects follow a truncated normal distribution instead; i.e μ is not equal to 0.

The last null hypothesis considered in Table 4 specifies that the technical inefficiency to be time-invariant. This null hypothesis is specified by H_0: $\eta = 0$. The result for this test, listed in Table 4, reports a test statistic of -35.44 which is less than the $\chi^2_{0.95}$ critical value of 3.84, resulting in the non-rejection of the time-invariant technical inefficiency null hypothesis. It is implying that the technical inefficiency model is time-invariant for the ASEAN-plus-3 countries.

From all the tests conducted and reported in Table 4, it appears that the preferred model is the translog frontier with non-neutral technical change and time-invariant technical inefficiency effects.

5.2 Estimation of Stochastic Frontier Production Function

The results of the statistical tests on the estimated parameters for the preferred model are reported in the Table 5. The table reports that almost all parameters of the translog model are significant at the 5 percent level, except β_{GG}, β_{Mt} and β_{Gt}. The positive sign of β_t and β_{tt} imply the acceleration in the change of technological progress. It means the countries have performed well in terms of technological progress perhaps because they have exploited the so-called ‘advantages of backwardness.’ As Abramovitz (1986) argued, backwardness may carry an opportunity for modernization in disembodies, as well as embodied, technology. Countries that are behind may have the potential to leap forward and therefore to catch up with the leaders.

The estimate obtained for gamma (γ) is one and was also found to be strongly significant at 1%.[5] This indicates that the variation in the residual is explained by the one-sided error associated with technical inefficiency and the technical inefficiency effects have significant impact on output (Wadud and White, 2000). The estimated value of Sigma-Squared (σs^2) is also significant at the 5% level. This result is in line with Battese and Coelli (1995) which suggested that a conventional production function is not an adequate representation of the data. However, the economic plausibility of the estimated coefficients is difficult to assess due to the complexity of the translog form. Therefore, we now turn our attention to compute some more easily interpreted estimates.

Table 6 reports the estimated value of the production elasticities of the four inputs and the estimates for the returns-to-scale parameter. The estimated elasticities have the expected positive signs and are significantly different from zero at the 5% level using an asymptotic t-test. As shown in Table 6, the estimated returns-to-scale parameter of 4.43 which is more

[5] Essentially, the parameter of γ lies between the values of 0 to 1 (with 0 indicating that the deviation from the frontier is due entirely to noise while 1 indicates that the deviation is due entirely to inefficiency). The high value of γ indicates that the stochastic frontier is superior to the OLS approach to modeling the production function of the ASEAN+3 countries.

than one implies the existence of increasing return to scale. This value is significantly different from zero based on asymptotic t-test.

Table 5

Panel Estimation of Stochastic Frontier Production Function and Technical Inefficiency Model for ASEAN-plus-3 Countries

Variable	Parameter	Coefficient	Standard Error	t-ratio
Constant	β_0	0.55	0.04	15.11
In(M)	β_M	2.99	0.33	9.09
In(G)	β_G	0.43	0.02	19.64
In(E)	β_E	0.72	0.09	8.13
In(K)	β_K	0.29	0.12	2.43
$[In(M_{it})]^2$	β_{MM}	6.54	1.28	5.11
$[In(G_{it})]^2$	β_{GG}	-0.01	0.04	-0.17
$[In(E_{it})]^2$	β_{EE}	-1.31	0.26	-5.10
$[In(K_{it})]^2$	β_{KK}	-2.45	0.54	-4.52
$In(M_{it})In(G_{it})$	β_{MG}	0.72	0.20	3.64
$In(M_{it})In(E_{it})$	β_{ME}	2.04	0.58	3.51
$In(M_{it})In(K_{it})$	β_{MK}	-2.85	0.70	-4.09
$In(G_{it})In(E_{it})$	β_{GE}	0.40	0.08	5.27
$In(G_{it})In(K_{it})$	β_{GK}	-0.39	0.09	-4.15
$In(E_{it})In(K_{it})$	β_{EK}	1.67	0.37	4.57
$In(M_{it})t$	β_{Mt}	0.05	0.07	0.74
$In(G_{it})t$	β_{Gt}	-0.01	0.01	-1.41
$In(E_{it})t$	β_{Et}	-0.10	0.03	-3.22
$In(K_{it})t$	β_{Kt}	0.10	0.04	2.65
T	β_t	0.07	0.01	8.36
T^2	β_{tt}	0.01	0.00	3.03
Variance Parameters:				
Sigma-Squared	σ_s^2	0.80	0.08	9.89
gamma	γ	1.00	0.00	36,874,692
mu	μ	-1.67	0.24	-6.94
Eta	η	0	0	0
Log-likelihood Function		0.91		

Table 6

Output Elasticities

Variable	Elasticity	Standard Error	t-ratio
Manufactures imports	2.992	0.257	11.628
Income per capita	0.428	0.022	19.837
ICT expenditure	0.722	0.095	7.576
Capital	0.288	0.112	2.580
Returns-to-scale parameter	4.430	0.293	15.126

5.3 Decomposition Results

The estimates of Mean Efficiency Level (TE), Technical Efficiency Change (TEC) and Technical Change (TC) are derived by using the above-mentioned techniques, and the country Total Factor Productivity Change (TFP) is obtained by summing changes in TEC and TC.

5.3.1 Efficiency Level

The first column in Table 7 reports estimates of annual efficiency levels for the ASEAN-plus-3 countries over the 1992-2005 period. The efficiency index lies between zero and one. One indicates full efficiency for a country and zero indicates full inefficiency (Delikta and Balcilar, 2005).

Based on the annual averages of efficiency levels for all countries, Malaysia, Korea, Singapore and China appeared to be the most efficient countries, followed by Japan and Thailand. On the other hand, Indonesia and Philippines appear to be the least efficient countries. The average efficiency level for the transition countries is 0.752 over the 1992-2005 periods, which means that these countries on average could reduce the inputs usage by 24.8% without reducing output. This result is consistent with Roessner and Porter (1996)'s study that Malaysia, Korea, Singapore and China have the capacity to challenge western industrialized nations in high-technology products and will further enhance their future competitiveness in high-tech industries, due to their continuing effort in building the infrastructures and formal commitments to technology policies.

Table 7

Annual Averages of Efficiency Levels and Total Factor Productivity Growth Components for ASEAN-plus-3 Countries over the 1992-2005 Period

Country	Mean Efficiency Level (TE)	Technical Efficiency Change (TEC%)	Technical Change (TC%)	Total Factor Productivity Change (TFP%)
Indonesia	0.510	-0.4	10.6	10.3
Malaysia	0.849	2.3	4.0	6.4
Philippines	0.694	-20.1	1.0	-19.2
Thailand	0.727	-8.3	9.5	1.2
Singapore	0.828	-0.3	-0.8	-1.1
China	0.817	-0.3	17.0	16.8
Japan	0.753	2.4	4.4	6.8
Korea	0.835	1.2	6.2	7.4
ASEAN-plus-3	**0.752**	**-2.9**	**6.5**	**3.6**

5.3.2 Efficiency Change

The second column in Table 7 reports estimates of the average annual rate of change in efficiency for the ASEAN-plus-3 countries. The rate of growth in efficiency is an indicator of a country's performance in adapting the global technology, and thus represents the catch-up factor (Rao et al., 1998). The rate of growth in efficiency also implies a more efficient use of the existing technology over time.

The second column in Table 7 shows the estimates of the average rate of growth in the mean technical efficiency (or catch-up) being -2.9% over the 1992-2005 period, suggesting that the level of efficiency in ASEAN-plus-3 countries has decreased over the whole period. The Philippines exhibited the highest negative technical efficiency growth rate, with an average rate of growth in efficiency of -20.1%, and indicating that the country has suffered from significant decreased in efficiency growth rate over the 1992-2005 period. The average rates of growth in efficiency in the case of Indonesia, Thailand, Singapore and China are -0.4%, -8.3%, -0.3% and -0.3%, respectively, indicating that the average rate of growth in efficiency for these countries had slightly decreased over time. On the other hand, the average rate of growth in efficiency in the Malaysia, Japan and Korea are 2.3%, 2.4% and 1.2%, respectively. These results signify that Malaysia and Korea are catching up with the developed country such as Japan while other ASEAN-plus-3 countries have failed to catch-up with developed countries over the period of this study.

5.3.3 Technical Change

The third column in Table 7 reports that the average annual technical change estimate in the ASEAN-plus-3 countries is positive, with a figure of 6.5%, over the 1992-2005 period, indicating technological progress. China exhibited the highest technical progress, with an average technical change of 17% while Philippines exhibited the least technical progress, with an average technical change of 1%. However, there has been technological regress in Singapore over the whole period, with an average technical change of -0.8%. The average annual technical change in the Malaysia, Indonesia, Thailand, Japan and Korea are 4%, 10.6%, 9.5%, 4.4% and 6.2%, respectively. Overall, the average annual technical change ranged from -0.8% to 17% among the ASEAN-plus-3 countries. Generally, all the ASEAN-plus-3 countries have enjoyed technical progress over the 1992-2005 period. Given that all of these countries have positive high-technology export growth rates over the 1992-2005 periods, this result is nonetheless, expected. In addition, the ASEAN-plus-3 countries have also experienced positive and high growth rate in expenditure in ICT, gross capital formation gain and GDP per capita thus further validating the results of positive technical change.

5.3.4 Total Factor Productivity Change

Productivity and economic growth are crucial because they determine the real standard of living that a country can achieve for its citizens. There is a simple link between a nation's productivity growth and standard of living. TFP change is the sum of efficiency and technical changes (Delikta and Balcilar, 2005). These two changes constitute the TFP change index. Besides, the decomposition of TFP change into efficiency and technical changes makes it possible to understand whether the countries have improved their productivity levels through a more efficient use of existing technology or instead relied more heavily on technical (technological) progress. In any event, these two components make up for the overall productivity growth. The fourth column of Table 7 reports the average annual TFP growth for the ASEAN-plus-3 countries.

Overall, the TFP growth rates have been positive due to significant technical progress. This positive TFP growth during the whole period is a consequence of technical progress in the ASEAN-plus-3 countries. The average annual growth in technical efficiency change is -2.9%, but the average annual technical change is 6.5% hence resulting in a total of 3.6% (see Table 7). Thus, the average annual TFP in the ASEAN-plus-3 countries has raised by 3.6% over the 1992-2005 period. This result suggests that the change in technical inefficiency was outweighed by the positive effect of the technical (technological) progress.

On average, China had the largest TFP improvement of 16.8%, followed by Thailand, Indonesia, Korea, Japan and Malaysia with TFP improvements of 12%, 10.3%, 7.4%, 6.8% and 6.4%, respectively. On the other hand, the Philippines had the largest TFP decline with an average of 19.2% while the Singapore had a slight TFP decline of 1.1%. The fall in the Philippines' TFP growth is unsurprisingly as it is also consistent with other studies which also found similar trends (although the negative TFP growth found in this paper is substantially higher); for instance, Cororaton (2005) found negative average TFP growth for the Philippines during the period of 1960-2000. While many possibilities can be attributed to such phenomena, one may be that the Philippines' manufacturing production of exports are largely based on the assembling of imported components thus the net exports on such manufacturing remained small. Cororaton (2005) highlighted the high import-to-GDP figures and the fact that the country's semiconductor export sector was largely raw-material and import-dependent. Meanwhile, the grim statistics on the country's TFP growth could also be due to the lack of skilled manpower (i.e. scientists, engineers and so on) and shortage of financial schemes to encourage technology development at the enterprise-level.[6] Mani (2002) also reported Philippines' low research intensity which was only 0.15% of GDP making it one of the lowest among newly industrializing countries in Southeast Asia. In the context of an input-output methodological analysis of this paper, the Philippines' TFP growth rates may have been compromised as a result of inefficiency in the production transformation process (huge imports to produce the "high-end" outputs due to the assembling nature of the manufacturing sector[7]). Nonetheless, with the 1% change in technological improvement found in this paper, the argument of a lack of innovation may have been overstated but the huge contraction in technical efficiency change (-20.1%) suggests that the country is also suffering from poor resource capability, allocation and efficiency.

While the high figures recorded in the case of Japan is surprising, the Korean figure may be explained on the grounds that the Korean firms had aggressive strategies in acquiring

[6] See Mani (2002) for more detailed discussion on this. Meanwhile, similar concerns were also echoed in the paper by Cororaton (2005) who reported that the problem of the quality of manpower as a possible reason for the low TFP growth performances in the Philippines, suggesting a need to look into an array of issues stemming from the failure of the educational system to produce the necessary skills, the declining efficiency of higher education to the problem of brain drain as well.

[7] Mani (2002) reported that the net exports of electronic items are significantly lower than the gross exports figures for Philippines thus supporting the arguments that many of the Filipino firms being mere assemblers which do not have much research and design capability.

foreign technologies. The capabilities and drives of the *chaebols* of Korea in scaling the technological ladder could have lead to high productivity growth in terms of the production of high end exports manufacturing. Posadas (2006) cited the successful South Korean's corporate technological management as lessons that should be emulated by Philippines firms to reduce their costly dependence on foreign suppliers for technology while also enabling them to improve on their product and process innovations. In the case of Japan, the high TFP growth (6.8%) was attributed to a high technological improvement. Other papers which also found somewhat similar results can be seen in Seki (2008) (which used DEA and Malmquist Index in his study of the contribution of ICT to the productivity of countries) who found Japan to have the highest TFP growth (5.8%) among a selected pool of OECD countries. In his paper, technological improvement contributed more significantly to both Japan and Korea's TFP growth, a pattern likewise also found in our paper. In this sense, it is possible that the success of Korea and Japan in productivity gains is due to their superiority in technological and innovation capabilities. Incidentally, Japan has the highest total expenditure on ICT per capita among the countries in this paper.

From the results, China, Thailand, Indonesia, Korea, Japan and Malaysia all recorded growth in their TFP which was exclusively due to better improvements in their technological improvements (as opposed to technical efficiency) thus the "catching-up" process by these countries (for example, in the case of less efficient ones like Indonesia and Thailand which had lower mean DEA efficiency scores; see Table 7) which are making the leapt to producing higher technology exports appeared to be aided by increased investment either through local investment or technology transfers from FDIs. The results does offer some support for the arguments of technology transfer given the improvements in technological change in the six countries above especially in the cases of China, Thailand, Indonesia and Malaysia which relied a lot on FDI in their export-industries. China's case may be obvious to some extent given that country's burgeoning export industry growth during the period of study while the cases of Korea and Japan may point towards technological improvements stemming from greater investment in technology and ICT by local firms. For Indonesia, although the TFP growth found in this paper is higher than many other studies, it could be due to differences in methodologies. Our findings revealed a high contribution by technological changes (e.g. innovation) which propelled such lofty TFP growth figures. Perhaps in our defence, a paper by Van der Eng (2009) argued that "the measurement of TFP growth as a residual means (in many studies) may have failed to account for the fact that some aspects of technological change may already have been captured in the measurement of capital stock and education-adjusted employment thus leading to lower TFP growth. In addition, he also argued that even though Indonesia's FDI was not as pronounced as its neighbouring countries like Malaysia, its source of investment originated more from the domestic than the foreign firms.[8] The findings in this paper can as such be referred to as evidence of technical change progress in the case of Indonesia

[8] Indonesia's FDI contributed only about 3.4% to the country total investment during 1998-03 (World Bank 2005: 86). As such, the domestic firms are significantly bigger as a source of investment compared to their foreign counterparts. In addition, there were no indications that foreign firms operating in Indonesia had left the country in large numbers post 1997-crisis (Van der Eng, 2009).

(specifically of "high-technology" manufacturing export areas) from the research and development stemming from local firms.

Finally, the poor TFP performance in the case of Singapore has also been reported in other papers, although albeit at slightly different timeframes (see Young, 1992, 1995); Felipe, 1997). Nonetheless, this paper found Singapore to be suffering from slight negative change in the case of both technical efficiency and technical change, indicating the country's lack of technological progress. As such, factor accumulation as a source of growth is still very much the case for Singapore's economic growth, an argument that was presented in Young's (1995) paper in which he stressed on Singapore's source of growth being mostly about capital accumulation.[9]

6. Conclusion

In this paper, we attempted to assess the performance of the ASEAN-plus-3 countries using stochastic frontier production analysis. Our purpose in using this method was to determine the efficiency of these countries in generating the knowledge-based output using high-technology exports as the proxy for knowledge-based output. In addition, for each country we estimated the level of technical efficiency and then computed technical efficiency change, technical change, and finally the total factor productivity change. The results of a list of hypothesis tests allowed us to accept a non-neutral translog stochastic production function. Based on the annual averages of efficiency levels for all countries, we found that Malaysia, Korea, Singapore and China to be the most efficient countries, followed by Japan and Thailand. However, Indonesia and Philippines appeared to be the least efficient countries from our results.

For each country we estimated the level of technical efficiency and then computed the technical efficiency change, technical change, and total factor productivity change. Based on the SFA, the average annual efficiency level for the ASEAN-plus-3 countries is 0.752, and the average annual rate of growth in technical efficiency is -2.9% for the 1992-2005 period, indicating managerial (pure technical efficiency) or scale inefficiency overall. However, the negative average technical efficiency growth was largely attributed to Philippines' and Thailand's poor technical efficiency scores. Such findings may be perhaps a reflection of the growth in labour productivity that is the result of increases in capital rather than the increase in efficiency of the labour. As such, TFP (as a result of labour productivity increase, for instance) may be growing but not necessarily the efficiency of the worker. Such phenomenon was highlighted by Krugman (1994) in his "perspiration versus inspiration" explanations on the East Asian miracle economic growth of the 1990s.[10] In any event, the lower managerial efficiency in the case of Thailand and Philippines may be due

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[9] However, Felipe (2000), disputed such low TFP growth figures of Singapore in some of the previous papers (like Young, 1992; 1995) on the grounds of methodological reasons. While it is also possible that the finding in our paper can also be subjected to such line of questioning, it is perhaps useful to know that our analysis of technological improvements is concentrated only on the area of high technology goods' production.

[10] The premise of Krugman's argument is one that professes East Asian economies' growth to be a result of input-driven rather than efficiency-driven. See Krugman (1994).

to lower skilled manpower in these countries as compared to their other counterparts in the sample. In addition, the low technical efficiency may also have been caused by scale inefficiency as well. To sum up, the deteriorating performance in the efficient use of resources and technology is apparent here thus further fueling the "perspiration versus inspiration" debate on many of these South-East Asian (Thailand, Philippines, Malaysia and Singapore) countries' economic performance based on the findings in this paper. However, as most of the economies in the sample recorded positive technological progress, it may be more likely that the technical inefficiency is a case of managerial (labour) inefficiency rather than capital utilization problems (Burnside, Eichenbaum and Robelo, 1996).

The average annual technical change in ASEAN-plus-3 countries is 6.5% for the period studied. From the results, there appeared to be technical (technological) progress overall, except for Singapore, which suffered from some technological regress. However, in the case of Singapore, it also experienced negative technical efficiency change as well thus leading to a fall in its overall TFP. The fall in its TFP suggest that the "perspiration versus inspiration" effect is more pronounced in the case of Singapore.[11] Meanwhile, in the case of the ASEAN-plus-3 countries, the sum of the rate of change in technical efficiency and technical (technological) change alas, indicated a 3.6% increase in the average annual TFP. These results suggest that, on average, changes in technical inefficiency was outweighed by the positive effect of the technical progress hence leading a positive change in the total factor productivity change for these countries. The positive change in technological change is evidence of innovation thus the findings suggest that significant innovation has indeed taken place in these countries over the study period of 1992-2005. As many of these countries relied on MNCs for their exports, the results offer some evidence of technology transfer, at least in some of these countries.

Finally, in regard to the issue of catch-up and convergence, we find that Malaysia and Korea are showing results of catching up with the developed countries like Japan while the other ASEAN-plus-3 countries have failed to do so over the period of 1992-2005. Generally, most of the ASEAN-plus-3 countries have enjoyed technological progress (proof of innovation) over the 1992-2005 period with the exception of Singapore, which recorded negative technical change. Ultimately, Singapore's falling TFP (inward shift) has more to do with technological regress than technical (managerial and scale) inefficiency. Malaysia and Philippines are also significantly lagging behind in terms of innovation, with technical change of only 4% and 1% respectively.

We hope that the results of this paper; i.e. evidence of increased innovation, decline in technical efficiency (both managerial or scale inefficiency) and the existence of increasing scale economies can provide some basic benchmarks for policy analysts and makers in assessing where their countries are headed and also in identifying actions that could be taken to shape the course of development and growth in terms of generating innovation (knowledge-based outputs) with their appropriate inputs.

[11] Krugman's assertion was that growth through one-time unrepeatable changes of increasing labour force participation or increasing investment share of GDP will eventually see diminishing growth rates, as with the case of many Asian economies and even quicker in the case of Singapore.

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