An Empirical Productivity Analysis of ASEAN Economies in Transition Towards Knowledge- Based Economy

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Abstract
Over the past few decades, countries in the Association of South East Asian Nations (ASEAN) have achieved varying levels of economic development. In this paper, the nature and extent of productivity changes in Cobb-Douglas production function components and the growth of the knowledge economy of selected ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea are analyzed over the period 2005 to 2010. Utilising non-parametric Data Envelopment Analysis (DEA) and the Malmquist total factor productivity (TFP) index, individual country's efficiency and productivity changes which took place within this period are estimated. Although there are vast numbers of studies conducted on firm-level and industry-level efficiencies, there is scant literature on inter-country productivity comparisons using the Malmquist productivity index (MPI). The Malmquist TFP index, calculated within the framework of DEA, is broken down into three constituent elements accounting for different sources of productivity growth, namely technological progress, efficiency change, and the effects of economies of scale. Our results indicate that the Philippines and Singapore reported the highest increase in TFP within the referred years, and this growth in productivity is derived from both technical efficiency gains and technological progress. On the other hand, for the knowledge economy model, there is a remarkable growth in TFP for Thailand and Philippines. A comparison with better performing countries helps to identify policies for further improvement in ASEAN member countries.

Keywords: Malmquist Productivity Index, Cobb-Douglas, Knowledge Economy, Technical Efficiency, Technological Change, Human Capital, ICT, Productivity Growth, ASEAN

1. Introduction

The early 1990s saw a restoration of the neoclassical growth framework used to explain the economic miracle of East Asia with a particular importance on Total Factor Productivity Growth (TFP) (Taylor, 2007; World Bank, 1993; Krugman, 1994; Young, 1994).The findings of many studies, for instance Kim and Lau (1994), Young (1994) and Krugman (1994) stated that the levels of growth experienced by the East Asian economies are the results of high accumulation of both capital and labour with little or no role played by technological progress. In short, growth for many South East Asian countries is input driven rather than productivity driven.

This implies that growth of many of the East Asian economies will cease as soon as diminishing returns set in. Therefore growth is not sustainable in the long run. Under such circumstances, without technical progressand without developing as a knowledge-

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based economy (KBE), the growth potential of these economies will be limited (Bashar, 2012) (see reference for a discussion of the characteristics of a KBE). The advantage of a KBE over a production based (P-Based) economy is that the former is considered an economy where knowledge, creativity and innovation play an ever-increasing and important role in generating and sustaining growth whereas in a P-based economy knowledge plays a less important role in growth. In a P-based economy, growth is driven much more by the accumulation of the factors of production of land, labour and physical capital (Afzal & Lawrey, 2012a, 2012b). The growth of human capital and information and communication technology (ICT) are the essence of the knowledge economy. Thus the motivation for this study is to investigate the current state of conventional total factor productivity growth (TFP) i.e. the Cobb-Douglas production function and knowledge economy growth in selected countries of ASEAN in order to aid in policy formulation. The development of ICT and human capital investment can support the effective use of the technology and innovation. To achieve the above-mentioned objective, we employ the non-parametric frontier method of Data Envelopment Analysis (DEA) to compute the Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea. This technique allows us to decompose the Malmquist TFP index into three components: (a) shifts in production technology, (b) pure changes in technical efficiency, and (c) effects of economies of scale. We calculate the conventional Cobb-Douglas production function and the growth of the knowledge economy by using the Malmquist productivity index to show the current state of the ASEAN economies. The paper comprises five major parts. Following the introduction, Section 2 highlights a brief literature review on East Asian Total Factor Productivity (TFP) growth. Section 3 describes the research framework, sources of data, and methodology. Results and discussion are presented in Section 4. And Section 5 draws conclusions and policy suggestions.

2. Literature Review of East Asian TFP Growth

In 1994, Young ranked the Asian countries according to total factor productivity change. He showed in his study that Taiwan, South Korea, Japan and Singapore have higher factor accumulation growth than other South-East Asian countries. However, in 1995, Young revealed that many East Asian economies has significantly lower TFP growth values to those in industrial economies. TFP growth in Singapore, for instance, was estimated to be 0.2% for 1986-90. Young's findings are consistence with studies conducted by Yuan (1986, 1985) and Kim and Lau (1994).

In subsequent application of the growth accounting approach, Taylor (2007) indicated that almost all of Singapore's output growth in 1966-80 could be the reason of increase in the quantities of factor inputs especially labour input rather TFP growth. He added in his book Singapore during that time period were highly dependent on conventional factors of production to generate higher economic growth rate.

Kim and Lau (1994) presented several reasons for the lack of measured growth in productivity efficiency over time for the newly industrialized countries (NICs) in late 1950s and 60s. Firstly, there is the possibility of scale effects which is difficult to measure with conventional econometric growth accounting approach. Second, research and development was relatively unimportant in the East Asian NICs due to the lack of investment in public R&D expenditure as well as the scarcity of indigenous technological improvements. Thirdly, the rapid capital deepening in the NICs is not knowledge-intensive nor ICT driven. Finally, poor natural and specially human resource endowment may have reverse the potential gains in technical progress.

In our study we initially use the conventional Total Factor Productivity formula before using non-parametric test to see the consistency of TFP growth between parametric vs. non-parametric test. We briefly highlight the results here.

The Cobb-Douglas production function can be expressed as

$$Y = A * L^{a} * K^{(1-a)} \quad (1)$$

This expression is referred to as a measure of total factor productivity; that is, the scalar A has an economic meaning. The denominator is a geometric-weighted average of the inputs used to produce real output. Thus, A can be interpreted as real output per unit of input. This is a better measure of productivity when compared to Y/L, Y/K, or Y/land which are measures of partial productivity. Partial productivity measures do not take into account the possibility of differing amounts of other inputs used in production which might account for the greater or lesser productivity of a single input. One of the known methods of model for parametric estimation is the Ordinary Least Squares (OLS) method (Taylor, 2007). Estimation and calculation by Cobb-Douglas production function has been done in this part by collected data of real gross domestic product (GDP), gross fixed capital formation (GFCF) as a percentage of GDP represents capital (K), total labor force (15-64 years) as L, and secondary school enrolment as a percentage of total school age population represents the human resource endowments during 2005-2010. The functional form looks like,

$$LGDP= \alpha+\beta_{1LnL}+\beta_{2LnK}+\beta 3_{LnSe}+\mu \quad (2)$$

and we are interested in the intercept α which represent the scalar A. Taking each α value for every country, we take the antilog and finds the value of scalar A. For each country we run the same regression with same set of variables and time period. Our results exhibits that the Philippines having 3.8 intercept value rank the top most position compare to other six economies. South Korea and Thailand having 3.46 and 3.09 intercept values ranked second and third position respectively. On other hand Singapore and Malaysia scores 3.01 and 2.05 respectively during the time span. However, Indonesia having 1.9 intercept value is a less successful countries in ASEAN during our referred years while converting input to output factors of production. We are expecting the similar kind of ranking when we apply DEA MPI method in Cobb-Douglas production function analysis. As we see it is difficult to capture scale effect through the parametric regression analysis, we apply a non-parametric DEA MPI test to analyze the TFP growth in ASEAN. The brief review of advantages of using DEA MPI method is given in Table 1A in Appendix 1.

3. Research Framework

In this study we first calculate the conventional Cobb-Douglas production function using real gross domestic product (GDP), gross fixed capital formation (GFCF) as a percentage of GDP, total labour force (15-64 years), and secondary school enrolment as a percentage of total school age population as inputs. The output for the DEA Malmquist Index analysis comprises real GDP. Data are collected from the World Competitiveness Yearbook 2010 (WCY-2010), World Development Indicators 2010 (WDI-2010) and ASEAN statistical yearbooks.

To measure knowledge economy productivity, we consider education expenditure and the school enrolment ratio as an input variable and computer users per thousand populations as the output variable. OECD (1996), WBI (1999), Derek, Chen and Dahlman (2004) emphasized that education and skilled workers are key to efficient knowledge dissemination which tends to increase productivity when shared by information and communication technology (ICT) infrastructure. ICT infrastructure refers to the accessibility of computers, internet users, mobile phone users etc. The sample period for this study spans from 2005-2010, a total of 6 years. Subsequently this study measures both Cobb-Douglas and knowledge economy productivity using the Malmquist index for selected ASEAN countries.

3.1 DEA and the Malmquist Productivity Index (MPI) Methodology

DEA was originally developed by Charnes, Cooper and Rhodes (1978). It involves the use of linear programming methods to construct a non-parametric frontier approach over the data, so as to be able to calculate efficiencies relative to this frontier. DEA does not require a functional form like parametric techniques. Instead, DEA uses input and output data to compute a technically efficient production frontier, i.e. a surface formed by the most efficient units. The best units receive an efficiency score of one (or more practically, 100 per cent), while the other units receive scores below one, depending upon their position in comparison with the most efficient units.

In this paper, Data Envelopment Analysis (DEA) is utilized to compute the distance functions of the Malmquist Productivity Index (MPI). All of the Malmquist indices of each country's data were derived using the program DEAP Version 2.1 developed by Coelli (1996). This software has been written to conduct data envelopment analysis for the purpose of calculating efficiencies in production for both cross-section and time series analysis. Malmquist productivity analysis uses panel data to calculate indices of total factor productivity change, technological change, technical efficiency change, pure technical efficiency change and scale efficiency change. Fare, Grosskopf and Lovell (1994) have provided a detailed discussion of this decomposition. Our main focus is to explain the methodology in a non-technical way for easier understanding of the method. The functional form of the DEA MPI explanation is given in Appendix 1 at the end of this article.

Malmquist indexes have a number of desirable features. They do not require input prices or output prices in their construction, and are also unit independent. They are easy to compute, as demonstrated by Färe et al. (1994). The MPI is capable of accommodating multiple inputs and outputs without worrying about how to aggregate them. An attractive feature of the Malmquist productivity index is that it decomposes into two components – technical efficiency change and technical change (Färe et al., 1994). Technical efficiency refers to the ability to use a minimal amount of input to produce a given level of output. Over time, the level of output an industry is capable of producing will increase due to technological changes that affect the ability to optimally combine inputs and outputs. Thus for any organization in an industry, productivity improvements over time may be either technical efficiency improvements (catching up with their own frontier) or technological improvements (because the frontier is shifting up over time), or both. The value of this decomposition is that it provides insight into the sources of productivity change.

The original MPI assumes constant returns to scale for the production process. As a result, the original MPI typically overestimates productivity change if the production process displays decreasing returns to scale or underestimates it for increasing returns to scale. To cope with the issue of variable returns to scale, Fare et al. (1994) recommended the use of a generalized MPI that includes an additional component, called scale index, to represent the effect of economies of scale on productivity. We also include such a scale factor in our analysis. Scale efficiency refers to the extent to which an organization can take advantage of returns to scale by altering its size towards optimal scale.

One way to measure a change in productivity is to see how much more output has been produced, using a given input level and the present state of technology, relative to what could be produced under a given reference technology using the same input level. An alternative is to measure the change in productivity by examining the reduction in input use that is feasible given the need to produce a given level of output under a reference technology. These two approaches are referred to as the output-oriented and input-oriented measures of change in productivity, respectively (Coelli, 1996). This study concentrates on the output-oriented Malmquist productivity index.

The Malmquist DEA approach derives an efficiency measure for one year relative to the prior year, while allowing the efficiency frontier to shift. A value greater than unity indicates positive total factor productivity growth whereas a value of less than unity indicates productivity decline. The next section presents the results and discussion.

4. Empirical Results

Table 1 presents the geometric means of the MPI for each country and the breakdown of its

Table 1 Geometric means of MPI and its components (Cobb-Douglas), 2005-2010

DMU	effch	techch	pech	sech	tfpch
Indonesia	1.000	1.073	1.000	1.000	1.073
Malaysia	1.068	1.060	1.000	1.068	1.133
Philippines	1.084	1.059	1.000	1.084	1.148
Singapore	1.076	1.065	0.985	1.092	1.146
Thailand	1.037	1.057	1.046	0.991	1.096
South Korea	1.000	1.000	1.000	1.000	1.000
Mean	**1.044**	**1.052**	**1.005**	**1.038**	**1.098**

Note: Effch – Technical efficiency change, Techch – Technological change, Pech – Pure technical efficiency change, Sech – Scale efficiency change, Tfpch – Total Factor Productivity (TFP) change, DMU – Decision making unit

MPI into five components: technical change (Effch), technological change (Techch), pure efficiency change (Pech), scale change (Sech) and total factor productivity change (Tfpch). In Table 1 we use the components of the Cobb-Douglas production function, namely population of 15-64 age as the labour force, gross capital formation as a percentage of GDP as capital, and secondary school enrolment as a percentage of the total secondary school age population as human capital as input variables and real GDP as the output variable for the MPI model.

If the changes in the total factor productivity (TFPCH) index is greater than one (TFPCH > 1), it shows that there is an increase in TFP. If the TFPCH is lower than one (TFPCH < 1), it means that there is a decrease in TFP. As mentioned previously, there are two components of TFP; these are changes in technical efficiency (EFFCH) and changes in technology (TECHCH). If these two indices are higher than one, it means that there are improvements in both technical efficiency and technology. If they are lower than one, it means that there are decline in both technical efficiency and technology.

We can divide the EFFCH index into two sub-index called changes in pure efficiency (PECH) and changes in scale efficiency (SECH). The SECH index shows the extent tp which production is in an appropriate scale. Decomposition of the Malmquist TFP index is useful to determine the sources of the changes in TFP (Ramanathan, 2003).

As evident from Table 1 (the model with Cobb-Douglas components), South Korea is the reference country for total factor productivity with a score of 1.0. In other words, South Korea is the optimally efficient country on the production frontier. The Philippines and Singapore exhibit average annual positive increases in total factor productivity of 14.8% and 14.6% per annum respectively over the sample period. For Philippines, this increase in TFP was composed of an 8.4% technical efficiency gain and 5.9% due to technological progress. For this country, there has been no change in pure technical efficiency, so the technical efficiency change was solely the product of scale efficiency expansion, which was 14.8%. A similar observation is recorded for Singapore which also exhibited a productivity gain. On the contrary, Malaysia, Thailand and Indonesia recorded a lower value in the TFP compared to the Philippines and Singapore over the sample period. All countries exhibit a positive improvement in technical and technological efficiency. Indonesia, however, appears to be the least successful country and South Korea shows no change in TFP of the MPI. By allowing for constant returns to scale it can be shown that technical efficiency grew in most of the ASEAN countries.

The results presented in Table 2 include knowledge economy growth considering education expenditure and secondary school enrolment as a percentage of the total secondary school age population as the input variable and computer users per 1000 populations as the output variable in computing the MPI. These variables reflect the knowledge dissemination dimension of a KBE (see Afzal and Lawrey, 2012b).

We can see in Table 2 (model with knowledge

Table 2 Geometric means of MPI and its components (Knowledge economy), 2005-2010

DMU	effch	techch	pech	sech	tfpch
Indonesia	1.055	1.042	1.000	1.055	1.099
Malaysia	1.025	1.063	1.000	1.025	1.089
Philippines	1.025	1.063	1.000	1.066	1.133
Singapore	1.000	1.052	1.000	1.000	1.052
Thailand	1.069	1.063	1.099	0.973	1.136
South Korea	0.999	1.061	0.998	1.001	1.060
Mean	**1.035**	**1.057**	**1.015**	**1.019**	**1.094**

Note: Effch – Technical efficiency change, Techch – Technological change, Pech – Pure technical efficiency change, Sech – Scale efficiency change, Tfpch – Total Factor Productivity (TFP) change, DMU – Decision making unit

economy components) that the annual average value of EFFCH index is 1.035. This means that there is an improvement in technical efficiency in general. There is no decrease in the components of EFFCH. The mean TECHCH index is increased by 5.7%. The increase in TECHCH causes the increase in TFP. This implies that ICT and human capital have improved in all ASEAN countries.

The reference country for technical efficiency change (EFFCH) is Singapore with a score of 1.000. The value of the EFFCH indexes for Indonesia, Malaysia, the Philippines and Thailand are greater than one. This means that these countries have a higher catching-up effect to reach the optimal production border/frontier. In other words, these countries are successful in catching up with the best production border that is determined by the reference country (Singapore). The most successful country for catch up is Thailand (6.9%). However, South Korea has EFFCH levels lower than 1. This means that there is no catching up effect in South Korea. Singapore is the reference country which means it is stable, on the best production frontier. In other words, annual average technical efficiency level of Singapore is not changed.

According to the technological change index (TECHCH), Malaysia, the Philippines and Thailand obtained the highest technological improvement in the period 2005-2010. South Korea, Singapore and Indonesia follow these countries respectively. In that period all countries experienced technological improvement and the annual average TECHCH index is measured at 1.057 with the TFPCH index measured at 1.094 for all countries. As the TECHCH index is greater than 1, it shows that the annual average of the production frontier has been shifted up by technological improvement. When we look at the TFP of countries, we can see that Thailand and the Philippines have the highest increase in annual average TFP. This implies that both the countries have improved their ICT and human resources development significantly within the reference period. The next section presents the conclusion and policy implications.

5. Conclusion and Policy Implication

This paper seeks to explore whether the growth in productivity in ASEAN is attributed to either technical efficiency change or technological change or both, and how ASEAN countries stand in human capital and ICT development. To achieve the above-mentioned objective, we employ the non-parametric frontier method of data envelopment analysis (DEA) to compute the Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea. The technique used allows us to further decompose the Malmquist TFP index into three components: (a) shifts in production technology, (b) pure changes in technical efficiency, and (c) effects of economies of scale. By allowing for constant returns to scale it can be shown that technical efficiency grew in all selected ASEAN countries. The Philippines claimed the greatest progress in technical efficiency of 8.4% per annum followed by Singapore with increased efficiency of 7.6% per annum There is a positive technological change for all countries using Cobb-Douglas production function components. The highest total factor productivity increase occurred in the Philippines. Singapore and South Korea were identified as the best performers or reference countries.

When education expenditure, secondary school enrolment and computer users per thousand population are used as input variables for knowledge economy growth in the second model, the results indicate that Thailand and the Philippines experienced significant improvement in knowledge TFP growth. Other countries exhibit positive improvements of the TFP but lower than the Philippines in knowledge dissemination.

There are two ways to improve the TFP of knowledge economy growth. First of all, if the selected countries solve the inefficiency problem by reallocation of resources, they can improve their TFP of the ICT sector and become more competitive. Secondly, the technological improvement in these countries creates an expectation about increasing TFP of ICT and human resource development. If there is a sustainable technological improvement by innovation, it will cause a sustainable increase in the TFP of ICT sector and as a result it will cause a sustainable increase in competitiveness. Comparison with better-performing countries helps to identify policies for further improvement. Furthermore, identifying which country lags behind with respect to ICT and human resources adoption provides a benchmark to enhance the cooperation among the ASEAN member countries and other Asian countries in developing the knowledge-based economy for the region as a whole. Human capital is considered to be the fuel to drive the knowledge economy that is based on knowledge assets which is a combination of human capital and ICT. The major weakness of DEA, MPI method is to detect outliers from the sample. In future bootstrapping DEA MPI analysis will certainly improve the quality of the research. We believe the discussion and method presents in this paper will contribute in existing literature of productivity analysis.

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Appendix 1

Functional definition of DEA MPI as follows:

$$M^{t+1}(x^{t+1},y^{t+1},x^t,y^t) = \left[\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}\right]^{1/2} \quad (3)$$

Where D^t is a distance function measuring the efficiency of conversion of inputs x^t to outputs y^t in the period t. As we know, DEA efficiency is considered a distance measure in the literature as it reflects the efficiency of input output conversion of DMUs. In fact if there is a change in technology in the following year which is (t+1), then,

$D^{t+1}(x^t,y^t)$ = efficiency of altering input in period t to output in period t $\neq D^t(x^t,y^t)$.

Hence we can say technically Malmquist Productivity Index (MPI) is a geometric average of the efficiency and technological changes in the two referenced periods and it is thus can be written as:

$$M^{t+1}(x^{t+1},y^{t+1},x^t,y^t) = \left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\right]\left[\frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}\frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)}\right]^{1/2} \quad (4)$$

M = ET

Where E is the technical efficiency change and T is

Table A1 The Comparison between econometric and DEA MPI productivity analysis methods

	Econometric	DEA MPI
Characteristic	Parametric method	Non- Parametric method
Efficiency measurement	Technical change and TFP change in terms of significant variables. Does not reveal scale, technological changes in the productivity.	Technical efficiency, scale elasticity, scale efficiency, allocative efficiencies, technical change and TFP change, Technological efficiencies changes
Strengths	1. It does not assume that all firms are efficient in advance 2. Regression analysis makes accommodation for statistical noise such as random variables of weather, luck, machine breakdown and other events beyond the control of firms and measure error. 3. It is capable to hypothesis test 4. It estimates based on average not as best practice frontiers 5. Econometric method are not unit invariant.	1. It does not assume that all firms are efficient in advance. 2. It could handle with efficiency measurement of multiple outputs but weak in measuring noise in the analysis. 3. It does not need to price information available. 4. It does not need to assume function type and distribution type 5. While sample size is small, it is compared with relative efficiency 6. Both the CCR and BCC models have nature of unit invariance which leads MPI unit invariant too.
Weakness	1. It needs to assume functional form and distribution type in advance 2. It needs enough samples to avoid lack of degree freedom 3. The assumed distribution type is sensitive to assessing efficiency scores	1. It does not make accommodation for statistical noise such as measurement error 2. It is not capable to hypothesis test. 3. When the newly added DMU is an outlier, it could affect the efficiency measurement.
Application	It has applied to measure productivity performance of organizations in terms of single output or dependent variable. Econometric regression or growth accounting method hardly can incorporate more than one dependent variable.	It has applied to assess productivity performance of non-profit/profit organizations or branches of firm with multiple input and output which gives MPI superiority over regression analysis.

Source: Coelli et. al. (1996)

[i] The Cobb-Douglas production function can be expressed as $Y = A * L^a * K^{(1-a)}$
where: Y is real output
A is a scalar (measure of change due to technological improvement)
L is a measure of the flow of labour input
K is a measure of the flow of capital input

the technology change. E measures the change in the CRS technical efficiency of period t+1 over that in t. If E is greater than 1, we assume there is an increase in the technical efficiency. However, T represents the average technological change over the two referred periods.

Advantages of using MPI

Usually for econometric analysis researchers tends to use growth accounting method where a Cobb-Douglas production function regress to find the productivity changes across the nations. However, due to its limitation, we apply DEA MPI method which can capture a robust characteristics of productivity changes. In Table 1 our study reveals the distinction between econometric and DEA MPI methods.