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Evaluating the Comparative Performance of Knowledge-Based Economies (KBEs) in ASEAN: A Data Envelopment Analysis (DEA) application of Additive Efficiency

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Abstract

The objective of this paper is to measure the technical efficiencies of knowledge-based economies in the Association of South East Asian Nations Five (ASEAN-5), namely Indonesia, Malaysia, the Philippines, Singapore, Thailand plus South Korea using Data Envelopment Analysis (DEA). This technique allows the assessment of the efficiency of a firm, organization, country or region in converting its inputs to output variables. For each country in each knowledge dimension, the efficiency rating of two basic DEA models - CCR (Charnes, Cooper and Rhodes, 1978) and BCC (Banker, Charnes and Cooper, 1984) and one extension of basic DEA models; the Additive Model are calculated. The two years 1995 and 2010 are considered to assess the cross-section performance of KBE dimensions. Data are collected from World Development Indicators (WDI), World Competitiveness Yearbook (WCY) and ASEAN publications. Findings show that the most efficient countries in one referred year or other are Indonesia in the knowledge acquisition dimension, Singapore, South Korea and Thailand in the knowledge production dimension, Singapore in the knowledge distribution dimension and the Philippines and S. Korea in the knowledge utilization dimension. This paper provides empirical evidence to measure the comprehensive efficiency of KBEs that would allow governments to determine areas for greater investment in order to develop the KBE dimensions of their economies. This is the first study of its kind by applying DEA CCR, BCC and the Additive Model in ASEAN-5 considering all KBE dimensions.

Key words: Knowledge economy, Knowledge-Based Economy frameworks, ASEAN, DEA, CCR, BCC, additive efficiency, knowledge economy dimensions

1. Introduction

The concept of the Knowledge-Based Economy (KBE) was first introduced by the OECD (Organization for Economic Development and Co-operation), which defined it as an economy which is directly based on the production, distribution and use of knowledge and information (OECD, 1996). Later APEC (Asia-Pacific Economic Co-operation Forum) (2000&2004) and the WBI (World Bank Institute) (1999) referred to a KBE as an economy in which the production, distribution and use of knowledge is the main driver of growth, wealth creation and employment across all industries. New ideas and innovation are the comparative advantage of KBEs. To produce new ideas, the KBEs need a framework where knowledge and technical progress contribute quantitatively to economic growth. Therefore, different international development organizations and statistical departments of individual countries are trying to build a comprehensive KBE framework in order to quantify the performance of KBEs among the countries to ascertain their competitiveness. In this connection, the OECD, WBI and APEC proposed a large set of variables in order to indicate the level of knowledge-based economic development (Afzal & Lawrey, 2012a).

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These frameworks have one common trait in that they all give a basic analysis of the environment a KBE should possess and claim that a successful KBE should have the four core dimensions, namely, knowledge acquisition, knowledge production, knowledge distribution and knowledge utilization. However, none of the current methodologies explicitly divide the KBE indicators under these four core dimensions and extend to measure efficiency of the countries using the proposed variables. That is the approach taken in this paper where our first objective is to segregate the available KBE indicators under these four dimensions as knowledge input-output indicators for a better understanding of the performance of a KBE (see, for example, Afzal & Lawrey, 2012a; Lee, 2001; Tan, Hooy, Manzoni & Islam 2008 and Karahan, 2011). Our second objective is to understand the efficiencies of the countries while moving towards KBE using these indicators. This paper tries to fill these two gaps in existing literature by building a policy-focused KBE framework and measuring the relative technical efficiencies of the ASEAN-5 countries by using the Data Envelopment (DEA) Analysis. It extends previous work in the analysis of input-output efficiencies in KBEs by comparing the results of the CCR, BCC and Additive Models (see Afzal and Lawrey 2012b, 2012c and 2012d). DEA is chosen because, as an established quantitative tool, it provides researchers with the tools to measure and compare relative technical efficiencies of the countries in transferring their KBE inputs to KBE outputs. The approach of the DEA method in cross-country studies is not yet widely applied; particularly at state or country knowledge economy assessment levels (Tan et al., 2008). This paper is organized as follows: Section 2 describes the research framework of the DEA methodology, the empirical results are presented and discussed in Section 3 and Section 4 presents conclusions

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2. Research Framework

The reference period is determined by an early adoption and the start of the KBE framework concept by the OECD in 1995-1996 and ends at the availability of selected indicators at national level in 2010. Therefore we use 1995 and 2010 as two cross-section years to measure the efficiencies of ASEAN-5 in all KBE dimensions. Data are collected from WCY-2010, WDI-2010 and ASEAN statistical yearbooks. However, before going into the DEA methodology, we first formulate our policy-focused KBE framework in order to apply the DEA method. We build a policy focused KBE framework based on the OECD (1996) KBE definition considering four knowledge dimensions under which there are four output variables and some selected input variables. The KBE input-output variables are selected from the OECD, WBI KBE frameworks by observing timely data availability, literature surveys and the preference that data be available for all the study countries for the two reference years for the purposes of comparison (ABS, 2002; Afzal &Lawrey, 2012a). This study subsequently applies the DEA approach by using the policy focused KBE framework for ASEAN-5. Table 1 shows our policy focused KBE framework.

Table 1: Policy Focused KBE framework

Dimensions	Knowledge acquisition	Knowledge production	Knowledge distribution	Knowledge utilization
Input	1.Trade Openness=(Exports + imports)/GDP 2. FDI inward flows as % GDP	1. R & D expenditure as % GDP 2.Intelectual Property Rights (IPR)	1. Education expenditure as % GDP 2. Net enrolment ratio at secondary school	1. Knowledge Transfer rate (university to industry) 2.FDI inflows % of GDP
Output	Real GDP growth	Scientific & Technical publications per 1000 population	Computer users per 1000 population	High-tech export % of Total export

Table 1 is an example of variable segregation out of many KBE indicators depending on data availability. Many of the factors listed above define the knowledge economy and its effect on entrepreneurial activities and economic development (Kassicieh, 2010). For instance, Derek, Chen and Dahlman (2004) emphasized that education and skilled workers are key to efficient knowledge

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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. Accordingly, we consider education expenditure and the school enrolment ratio as an input variable and computer users per thousand populations as the output variable for the knowledge distribution dimension.

The World Bank Institute (1999) has stated that an effective innovation system depends on research and development (R&D) expenditure, foreign direct investment (FDI) inflows, and knowledge sharing between universities and industry. These variables are often considered as knowledge utilization inputs in order to produce domestic knowledge intensive products in a national innovation system (Poorfaraj, Samimi and Keshavarz, 2011). Hence, we consider FDI inflows and the knowledge transfer rate as input variables and high-tech exports as a percentage of total exports as the output variable in the knowledge utilization dimension.

In many developing countries, knowledge and technology is nurtured from foreign sources and enters the country through FDI, imports of equipment and other goods which are promoted by trade openness and licensing agreements (Poorfaraj, Samimi and Keshavarz, 2011). These variables can make an enormous contribution to economic growth provided the existence of a sound, transparent legal and regulatory system in the individual countries. Therefore we consider FDI, trade openness, transparency and legal and regulatory quality as inputs while real GDP growth is the output variable in the knowledge acquisition dimension.

Dahlman and Andersson (2000) have stated that East Asian economies are weak in innovation activities compared to other, advanced economies, which account for nearly 90 per cent of global R&D expenditures and about the same proportion of patents granted and scientific and technical papers produced. They also argue that stronger protection of intellectual property rights enhances the efficiency of innovation systems in a KBE. Hence in our policy focused framework, we include these variables under the knowledge production dimension. In subsequent sections we will illustrate the best performing countries among the ASEAN-5 nations in each KBE dimension using the DEA technique.

2.1 Data Envelopment Analysis (DEA)

DEA measures the efficiency of the Decision Making Units (DMU) by the comparison with the best producer in the sample to derive compared efficiency. A distinctive feature of the DEA approach is that, for each DMU (e.g. an individual country), it calculates a single relative ratio by comparing total weighted outputs to total weighted inputs for each unit without requiring the proposition of any specific functional form. According to the original CCR (Charnes, Cooper and Rhodes, 1978) model, the DEA efficiency value has an upper bound of one and a lower bound of zero. Two types of DEA models, namely the input-oriented and the output-oriented models, have been widely articulated by operational researchers. Though the input-oriented model focuses on the cost minimization while the output-oriented model focuses on the output maximization, evidence indicates that research results are not sensitive to which of the models is being used (Hsu, Luo and Chao, 2005, Ramanathan, 2003). In the application of DEA, a linear programming model needs to be formulated and solved for each DMU. Banker, Charnes and Cooper (1984) improved the original CCR model examining the sum of weights which are determined in the CCR (Charnes, Cooper and Rhodes) model. This modification to get the returns to scale in DEA is called the BCC model named after Banker, Charnes and Cooper. There are two types of measures in DEA, viz. radial and non-radial. Both CCR and BCC are radial models. Radial means the inputs (or outputs) are reduced (increased) proportionally while maintaining the outputs (or inputs). The additive model is a non-radial DEA model, which moves an inefficient DMU to the efficient frontier by reducing inputs and increasing outputs concurrently. However, in this model the optimum value of additive efficiency is zero,unlike the efficiency measures in the CCR and BCC models where maximum efficiency is shown as one (Kuah, Wong and Behrouzi, 2010; Charnes, Cooper and Rhodes, 1978).

2.2 Model Specification

In this paper we consider all CCR, BCC and additive efficiency scores because the variables are not conventional factors of production. They may exhibit increasing, constant or decreasing returns to scale. Our research considers the output oriented model because we want to see if government wish to maximize/increase output from given inputs what will be the possible efficiency scores for our study countries in various KBE dimensions.

3. Results and Discussions

DEA analyses of the data presented in Table 2 to Table 9 are carried out using DEAP (Data Envelopment Analysis Programme) and Efficiency Measurement System (EMS) software. Note that listed efficiencies should be viewed as relative to the best performing country in the particular year and particular KBE dimension. Based on the rule of thumb of DEA, the number of DMUs should be greater than double of the sum of inputs and outputs. Therefore we add South Korea, a member of ASEAN plus three countries to make robust results for DEA analysis. The results will follow the sequence of our policy focused KBE framework.

Table 2: Efficiency scores of ASEAN-5 countries for Knowledge Acquisition Dimension in the year 1995

DMU	CCR	BCC	Additive efficiency
Indonesia	0.744	0.914	0.07
Malaysia	0.266	1.000	0
Philippines	0.224	0.507	4.5
Singapore	0.122	0.816	1.8
Thailand	0.392	1.000	0
South Korea	1.000	1.000	0

Table 3: Efficiency scores of ASEAN-5 countries for Knowledge Acquisition Dimension in the year 2010

DMU	CCR	BCC	Additive efficiency
Indonesia	1.000	1.000	0
Malaysia	0.432	0.817	1.6
Philippines	0.991	1.000	0
Singapore	0.389	1.000	0
Thailand	0.691	0.986	0.11
South Korea	1.000	1.000	0

The first and immediate result of the DEA calculations is an efficiency rating of each observation (here, country). A rating of 100% (or 1) in the CCR and BCC models and 0 in the Additive Model indicates that the country is located on the efficiency frontier. An efficiency rating less than 100% in the CCR, BCC model and greater than 0 in the Additive Model signals non-optimal behaviour. Tables 2 and 3 show the results for the knowledge acquisition dimension where South Korea has the highest efficiency score in both years. This indicates that South Korea is using its knowledge acquiring inputs - trade openness and FDI - more efficiently than other members of ASEAN. However, from our analysis, it appears that all other countries in both the years show inefficient use of their resources except Indonesia in 2010. Indonesia improved its efficiency in 2010 compared to 1995. This inefficiency for other member countries means that it would be possible for these countries to reduce inputs while still obtaining the same amounts of outputs, or increase output without altering the use of inputs in the knowledge acquisition dimension.

Table 4: Efficiency scores of ASEAN-5 countries for Knowledge Production Dimension in the year 1995

DMU	CCR	BCC	Additive efficiency
Indonesia	0.508	1.000	0
Malaysia	0.635	0.674	1.7
Philippines	0.478	1.000	0
Singapore	0.622	0.653	6.5
Thailand	1.000	1.000	0
South Korea	1.000	1.000	0

Table 5: Efficiency scores of ASEAN-5 countries for Knowledge Production Dimension in the year 2010

DMU	CCR	BCC	Additive efficiency
Indonesia	0.330	1.000	0
Malaysia	0.314	0.387	1.4
Philippines	0.216	1.000	0
Singapore	1.000	1.000	0
Thailand	1.000	1.000	0
South Korea	0.706	0.757	6.1

Tables 4 and 5 show the efficiency score in the knowledge production dimension where Thailand and South Korea in 1995 and Singapore and Thailand in 2010 are the best performers.

Table6: Efficiency scores of ASEAN-5 countries for Knowledge Distribution Dimension in the year 1995

DMU	CCR	BCC	Additive efficiency
Indonesia	0.054	1.000	0
Malaysia	0.310	0.509	5.1
Philippines	0.039	0.039	1.9
Singapore	1.000	1.000	0
Thailand	0.124	1.000	0
South Korea	0.316	0.372	1.3

Table7: Efficiency scores of ASEAN-5 countries for Knowledge Distribution Dimension in the year 2010

DMU	CCR	BCC	Additive efficiency
Indonesia	0.111	1.000	0
Malaysia	0.556	1.000	0
Philippines	0.151	1.000	0
Singapore	1.000	1.000	0
Thailand	0.197	0.376	2
South Korea	0.965	0.966	2.7

According to Tables 6 and 7, the most interesting finding from our analysis is that Singapore achieves optimum efficiency in both years. That is, Singapore is the best performer in the knowledge distribution dimension. Singapore set an example for other ASEAN as well as developing countries by overcoming its size and natural resource constraint by leveraging on the region and the world. It is a manufacturing base, producing increasingly technology and knowledge-intensive goods and increasing the use of ICT and computer users in recent times (Yue and Lim, 2003). In 2010, its computer users were 827.48 per thousand population, which ranked number one in ASEAN (WDI-2010). This supports our finding of Singapore as the most efficient country in this dimension in both years.

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Table 8: Efficiency scores of ASEAN-5 countries for Knowledge Utilization Dimension in the year 1995

DMU	CCR	BCC	Additive efficiency
Indonesia	0.176	0.193	3
Malaysia	1.000	1.000	0
Philippines	1.000	1.000	0
Singapore	0.719	1.000	0
Thailand	0.669	0.770	7.1
South Korea	1.000	1.000	0

Table 9: Efficiency scores of ASEAN-5 countries for Knowledge Utilization Dimension in the year 2010

DMU	CCR	BCC	Additive efficiency
Indonesia	0.205	1.000	0
Malaysia	0.425	0.733	1.7
Philippines	1.000	1.000	0
Singapore	0.437	0.762	1.5
Thailand	0.365	0.414	3.8
South Korea	1.000	1.000	0

Finally, Tables 8 and 9 show the results of the knowledge utilization dimension where Malaysia, the Philippines and South Korea in 1995 and the Philippines and South Korea in 2010 are the most efficient countries. The interesting point from this calculation is the consistent best performance by the Philippines and South Korea in this dimension. We use FDI inflows as a percentage of GDP and the knowledge transfer rate from universities to industry (WCY-2011 executive survey based on an index from 0 to 10) as input variables and high-tech exports as a percentage of total manufacturing exports as the output variable for this dimension. If we explain the results in terms of recent phenomena, we find that the Philippines is the largest manufacturer of high-tech products as a percentage of total exports in 2010. Its percentage of high-tech products as a percentage of total manufacturing exports was 65.65% followed by Singapore at 50.01%, Malaysia at 48.11%, Indonesia at 13.13% and Thailand at 27.12% in the same year (WDI-2010). This implies that the Philippines is making optimum use of its FDI inflows in order to produce new knowledge and ideas in the universities that eventually transfer this knowledge to high-tech industrial growth. Theoretically, investing in the knowledge intensive sector such as ICT, high-tech goods, bio-technology etc. can increase the productive capacity of the other factors of production as well as transform them into new products and processes which leads a country to be more efficient in KBE (Afzal and Lawrey, 2012a; Lee, 2001). Hence, we can say that the inefficient countries can emulate the best performing country in order to achieve optimum efficiency. One other remarkable point from our efficiency scores are the consistency of Additive and BCC efficient scores. In theory if the BCC model shows a DMU to be efficient, that DMU should be additively efficient as well. The reason is that an efficient frontier generated by this Additive Model is exactly the same as the one generated by the BCC model due to the convexity constraint (Kuah, Wong and Behrouzi, 2010; Charnes, Cooper and Rhodes, 1978). Our results are the empirical proof of this phenomenon.

4. Conclusion

The results of our analysis have interesting policy implications for promoting sustainable, knowledge-based economic growth in the ASEAN region. We wish to stress here that findings of the study are critically based on the choice of KBE variables, and hence, the policy implications discussed here should be considered within this perspective. This study has built a policy focused KBE framework which clearly shows the input-output indicators of KBE from the concept of existing KBE frameworks. In this paper we apply the DEA method which is based on the linear programming technique to show the technical efficiency of the ASEAN-5 countries plus South Korea in each KBE dimension using CCR, BCC and Additive Models. We use mostly WDI and WCY data sources to give the current state of performance of the ASEAN-5. The results show that Indonesia in the knowledge acquisition dimension, Singapore, South Korea and Thailand in the knowledge production dimension, Singapore in the knowledge distribution dimension and the Philippines and South Korea in the knowledge utilization dimension are the 100% efficient countries in one referred year or other. The inefficient countries in a particular knowledge dimension can emulate the best performing country in order to achieve optimum efficiency. It is obviously important for governments to ensure that resources are used optimally in order for their nation to become a successful knowledge economy in the future. We believe that the discussion and method presented in this paper will contribute to the future KBE policy formation not only in the ASEAN-5 but also in other emerging economies as well.

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