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Evaluating the Comparative Performance of Technical and Scale Efficiencies in Knowledge-Based Economies (KBEs) in ASEAN: A Data Envelopment Analysis (DEA) Application

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Abstract

The objective of this paper is to measure the technical and scale efficiencies of KBEs in the Association of South East Asian Nations (ASEAN) using Data Envelopment Analysis (DEA). DEA enables one to assess the efficiencies of firms, organizations, countries, and regions in converting inputs to outputs. For each country in each knowledge dimensions, the efficiency rating and a measure of returns to scale: increasing returns to scale (IRS), constant returns to scale (CRS) and decreasing returns to scale (DRS) 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. Indonesia in knowledge acquisition; Singapore, South Korea and Thailand in knowledge production; Singapore in knowledge distribution; the Philippines and S. Korea in knowledge utilization are the most productive and 100% efficient countries in either one or both of the years investigated. This is not the first study of its kind, although it is the first for ASEAN countries considering all KBE dimensions.

Keywords: Knowledge-based economy, knowledge economy dimensions, policy-focused framework, ASEAN, DEA, CRS, VRS, IRS, scale efficiency, technical efficiency

JEL Classification Codes: O57, P17, O11

Paper type: Research paper

1. Introduction

The concept of the knowledge-based economy (KBE) was first introduced by the OECD, defining it as an economy which is directly based on the production, distribution and use of knowledge and information (OECD, 1996). Later APEC (2000&2004) and WBI (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. The advantage of 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 growth is driven much more by the accumulation of the factors of production of land, labour and physical capital.

New ideas and innovations are the comparative advantage of KBEs. To produce new ideas, KBEs need a framework where knowledge and technical progress contribute in a measurable way 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 relative to other countries to assess their competitiveness. In this context, the OECD in its KBE framework report, The Growth Project (OECD, 2001), emphasized the importance of a stable and open macroeconomic environment with effective functioning markets; diffusion of ICT; fostering innovation; development of human capital; and stimulating firm creation. Under these core KBE dimensions they proposed a large set of indicators (Table 1A: Appendix: 01).

The World Bank Institute (1999) has also developed the Knowledge Assessment Methodology (KAM)[1] as a KBE framework for its member states in order to indicate their level of knowledge-based economic development and as policy input to the achievement of sustainable economic growth. The WBI KAM is based on 83 structural and qualitative variables that serve as proxies for the four knowledge economy pillars (Table 1A: appendix: 01). 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, it is interesting to note that none of the current methodologies explicitly divide the KBE indicators under these four core dimensions or extend their analysis 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, Lee, 2001; Tan, Hooy, Manzoni & Islam 2008 and Karahan, 2011). The second objective is to understand the efficiencies with which countries convert knowledge inputs to knowledge outputs as they develop as KBEs, using these indicators.

This paper tries to fulfil these two gaps in existing literature by building a policy-focused KBE framework and measuring the relative technical and scale efficiencies of the ASEAN countries by using the Data Envelopment (DEA) Analysis. DEA is chosen because, as an established quantitative tool, it provides researchers with the ability to measure and compare relative technical and scale efficiencies of the countries in transferring their KBE inputs to KBE outputs. DEA analysis has been widely used to assess operational efficiencies where traditional measures have been found wanting (Tan et al., 2008). This paper is organized as follows: Section 2 briefly discusses the existing literature of the use of DEA in country studies; Section 3 describes the research framework. The empirical results are presented and discussed in Section 4 and Section 5 presents conclusions.

2. Literature Review of DEA Cross-country Studies

The use of the DEA method in cross-countries studies is not yet widely applied; particularly at state or country knowledge economy assessment levels (Tan et al., 2008). DEA involves the application of the linear programming technique to trace the efficiency frontier. It was originally developed to investigate the performance of various non-profit organizations, such as educational and medical institutions, which were not suitable for traditional performance measurement techniques like regression analysis due to the complex relations of multiple inputs and outputs, absence of price and non-comparable

[1] (www.worldbank.org/kam)

units. The principles of DEA date back to Farrel (1957). The recent series of discussions on this topic started with the article by Charnes, Cooper and Rhodes (1978). A good introduction to DEA is available in Norman and Stoker (1991). Cooper, Seiford and Tone (2000) provide recent and comprehensive material on DEA (Ramanathan, 2003). Studies on cross-country and knowledge economy performance assessment that employ the DEA method are given in Table1.

Table 1: The DEA method in country's macroeconomic and KBEs studies

Authors	Data sets	Input and outputs used in DEA model	Key results
Golany and Thore (1997)	From Statistical department of 72 developed and developing countries, 1970-1985	Inputs: real investment as % GDP, real gov. consumption as % GDP, education expenditure as % GDP Outputs: real GDP growth, infant mortality, enrolment ratio for secondary schools, welfare payments.	Japan, USA, Canada, Asian tigers show increasing returns to scale (IRS), Scandinavian and very poor developing countries show decreasing returns to scale (DRS).
Stanickova and Skokan (No date)	EUROSTATS, OECD data base	DEA on 27 Euro countries. Inputs: R&D expenditure as % GDP, employment rate, real investment as % GDP. Outputs: Real GDP (PPS) and Labour	Bulgaria, Romania, Italy, Greece Lithuania show DRS while Luxembourg, Malta and Cyprus show IRS.
Roman (No Date)	2003 and 2005, EUROSTAT, National Institute for Statistics of Romania and Bulgaria	Inputs: R&D expenditure, total researchers, Outputs: patents, scientific & technical articles, high-tech exports as % of total	Both the countries show DRS in knowledge production, Bulgaria is slightly better than Romania.
Hsu, Luo and Chao (2005)	WCY-2004	WCY-2004 pillars used as inputs and output variables for OECD & non-OECD countries.	Indonesia and Argentina outperform in all efficiencies scores and Turkey, Poland and Mexico appear stable efficiencies.
Abdelfattah, Ablanedo-Rosas and Gemoets (2011)	WDI-2005 data set for 54 developing countries	Only output variables from MDG programme	29 countries show as efficient
Ramanathan (2006)	Selected Middle east & North African countries, WDI-1999	Inputs and Outputs: ratio of labour to population, life expectancy, primary education teachers, GNP per capita, literacy rate, Mortality rate etc	Bahrain, Jordan, Kuwait and UAE are most efficient while Yemen is the least efficient country.
Christopoulos (2007)	Selected OECD & Non-OECD countries	Human capital, openness, are input variables while real GDP is the output variable	Movements towards openness increase the efficiency performance of the non-OECD countries
Mohamad (2007)	Selected Asia-Pacific countries. Data sets collected 1996, 2000, 2003	Inputs: Gov. expenditure as % GDP, Output: real GDP growth, the real employment rate, inflation rate	Only seven of twenty-five selected countries are efficient
Tan, Hooy, Islam & Manzoni (2008)	2001	Inputs: R&D expenditure, labour productivity, average schooling. Output: mobile phone users, internet users, PC penetration, hi-tech exports	India, Indonesia, Thailand and China are inefficient countries due to outflow of human resources.

In summary, these empirical studies using the DEA method reveal that research and development (R&D) expenditure, foreign direct investment inflows (FDI), trade openness and education expenditure can be considered as input variables, while real GDP growth, high-tech exports as a percentage of total manufacturing exports, computer users, patents, and scientific and technical journal articles are commonly considered as output variables for assessing the performance of a country's macro as well as knowledge economy.

2.1. Need for Transformation to KBE in ASEAN

Southeast Asia has been the world's leading emerging market for several years. To promote economic, cultural and political cooperation in the region, the Association of Southeast Asian Nations (ASEAN) comprising Indonesia, Malaysia, The Philippines, Singapore and Thailand was established in 1967. Brunei, Myanmar, Laos and Vietnam joined later. The ASEAN economies, particularly the ASEAN-5 (Indonesia, Malaysia, The Philippines, Singapore and Thailand, the first founder members), have been pursuing export-led and foreign direct investment-led development strategies. In earlier decades, the economic development of the ASEAN-4 (excluding Singapore) was largely resources-based and they competed in the world market as exporters of primary products, both agricultural and mineral. In the late 1980s, the ASEAN-5 began to move from resources-based to industrialized economies and steadily graduated to the World Bank's middle income and high-income economies (Yue, 1999). Growth in the ASEAN-5 has been accompanied by rapidly falling unemployment rates and poverty incidence. But in the light of the regional currency and financial crisis in 1996-1997, the ASEAN-5 was running out of steam. For instance Thailand's annual export growth fell from 24% in 1995 to -1.9% in 1996 and 3.2% in 1997; Malaysia's from 26.6% in 1995 to 7.3% in 1996 and 6.0% in 1997; Indonesia's from 18.0% in 1995 to 5.8% in 1996, recovering to 11.2% in 1997 (Lo, 2003). After the slowdown of economic growth during these years, those countries started to question the sustainability of their development policies. KBE can be considered as an alternative or complementary development policy option for long run, sustainable growth. In order to transform into KBE, countries should know the key KBE dimensions in which to invest.

3. Research Framework

The reference period is determined by the start of the KBE framework concept by the OECD in 1995-1996 and ends at the availability of selected indicators at the national level in 2010. Accordingly, we use 1995 and 2010 as the two years for cross-section analysis to measure the efficiencies of the ASEAN-5 namely Indonesia, Malaysia, the Philippines, Thailand and Singapore in all KBE dimensions. Data are collected from WCY-2010, WDI-2010 and ASEAN statistical yearbooks. Before describing the DEA methodology, we first formulate our policy-focused KBE framework, with relevant input and output variables, 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 various selected input variables. The output variables are real GDP growth for knowledge acquisition, scientific and technical journal articles per 1000 populations for knowledge production, computer users per 1000 people for knowledge distribution and high-technology exports as a percentage of total manufacturing exports for knowledge utilization.

The KBE input-output variables are selected from OECD, WBI KBE frameworks by observing time series data availability, literature surveys and the requirement that data preferably be available for all the study countries for the two reference years for the purposes of comparison (ABS, 2002; Afzal and Lawrey, 2012). This study applies the DEA approach by using the policy-focused KBE framework for ASEAN-5. Table 2 shows our policy focused KBE framework. All source of the variables are given in Appendix 1A, Table 2A.

Table 2: 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 exports

Table 2 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 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 population 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 export as the output variable in the knowledge utilization dimension.

In many developing countries, knowledge and technology are nurtured from foreign sources and enter 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 and trade openness 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.

3.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a methodology based upon an application of linear programming. It was originally developed for performance measurement. It has been successfully employed for assessing the relative performance or technical efficiency of a set of firms that use a variety of identical inputs to produce a variety of identical outputs. DEA is a non-parametric approach that calculates efficiency levels by doing linear programming for each unit in the sample. It measures the efficiency of the decision making units (DMU) by 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 Charnes, Cooper and Rhodes (CCR) (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 cost minimization while the output-oriented model focuses on output maximization, evidence indicates that research results are not sensitive to which of the models is being used (Hsu, Luo and Chao, 2005). In the application of DEA, a linear programming model needs to be formulated and solved for each DMU. Such a requirement makes the calculation of efficiency scores for all of the studied countries a tedious job, but now by using software such as IDEAS, DEA-Solver, DEAP and EMS analysts can estimate the efficiency scores for all DMUs in one DEA model that eliminates any potential human error. In addition to countries, DMUs can include manufacturing units, departments of big organizations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, and defence bases, a set of firms or even practising individuals such as medical practitioners. Recently this method has been applied for measuring efficiencies of knowledge economies as well (Tan et al., 2008).

3.1.1. Theoretical Construction of DEA System

As we have seen, DEA is based on Technical Efficiency (TE) or performance efficiency, which can be shown as:

$$\text{Technical efficiency (TE)} = \frac{\sum WO}{\sum WI}$$

WO= weighted output, WI= weighted input

Mathematically we can express the above relation by the following formula:

$$E_k = \frac{\sum_{j=1}^{M} U_j O_{jk}}{\sum_{i=1}^{N} V_i I_{ik}}$$

E_k = TE for the DMU_k (between 0 and 1)

K = Number of DMU_k, in the sample

N=Number of inputs used (i= 1, L, *N*)

M= Number of outputs (j= 1, L, *M)*

O_{jk} = The observed level of output j from DMU_k

I_{ik} = The observed level of input i from DMU_k

V_i = The weight of input i

U_j = The weight of output j

To measure TE_k for DMU_k by using linear programming the following problem must be solved which is

Max TE_k

Subject to $E_k \leq 1$, k= 1,2, L, K

Where TE_k is either maximizing outputs from given inputs or minimizing inputs for a given level of outputs. The above problem cannot be solved as stated because of difficulties associated with nonlinear (fractional) mathematical programming. Charnes, Cooper and Rhodes (1978) have developed a mathematical transformation called CCR (the initials of their names) model which converts the above nonlinear programming to a linear one under constant returns to scale (CRS).

Modified linear programming by the following formula

$$\text{Max } \sum_{j=1}^{M} U_j O_{jk}$$

S.t.

$$\sum_{i=1}^{N} V_i I_{ik} = 1$$

$$\sum_{j=1}^{M} U_j O_{jk} \leq \sum_{i=1}^{N} V_i I_{ik}$$

U_j , $V_i \geq \mathcal{E} > 0$

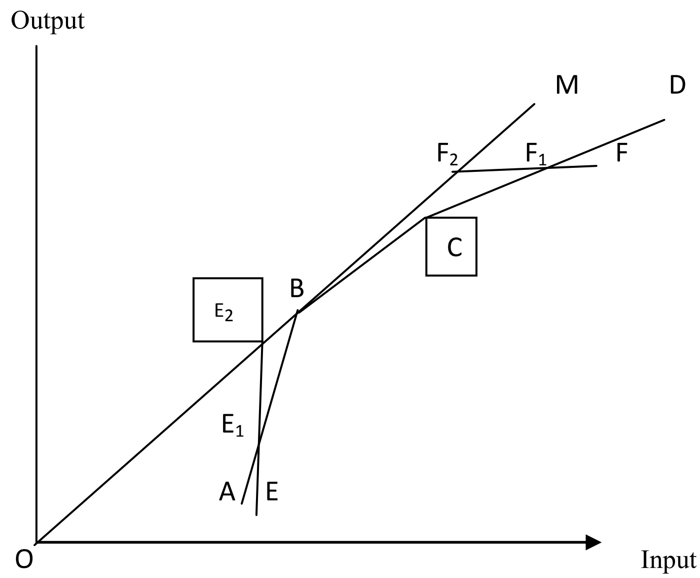
$\mathcal{E} > 0$

The above procedure can also be done by using input weights V_i and variable I_{ik} in place of U_j O_{jk} and subject to an output constraint under CRS. As a whole, the optimization procedure in DEA ensures that the particular DMU, in our study the countries, being evaluated is given the highest score possible by maximizing its relative efficiency ratio, at the same time maintaining equity for all other DMUs. DEA establishes relative efficiency scores led by the benchmark of unity (1 or 100%) as the highest score possible for one or more DMUs. For all DMU (countries) there are two efficiency scores namely overall technical and scale efficiencies (TSE) and scale efficiency (SE). TSE refers to the extent to which countries achieve the overall productivity attainable in the most efficient manner (Banker, Charnes and Cooper, 1984). TSE can be further decomposed into pure technical efficiency (PTE) and scale efficiency (SE). PTE refers to how efficiently countries transform their inputs into outputs. Scale efficiency, on the other hand represents how productive is the scale or size of the operation. Increasing returns to scale exist when a proportional increase in all inputs causes outputs to increase by a greater proportion. Decreasing returns to scale is the situation when a proportional increase in all inputs causes output to increase by a smaller proportion. It is the ratio of TSE from the original CCR model to PTE obtained from the variable returns to scale BCC model. The scale efficiencies of a DMU reveals whether a DMU is performing increasing (IRS), decreasing (DRS) or constant returns to scale (CRS). The scale efficiency of a DMU operating in its most productive size is thus 1.

Banker, Charnes and Cooper (1984) developed the concept of variable returns to scale (VRS) by examining the sum of weights which are determined in the CCR (Charnes, Cooper and Rhodes) model. They added a modification in the original CCR model by arguing that if the sum of weights of inputs and outputs in the CCR model add up to more than 1, the scale size of the DMU is DRS. To achieve CRS or optimum productive size a DMU should reduce the excess use of inputs. However, if the sum of weights adds up to less than 1, a DMU is said to have IRS. To achieve the most productive size i.e. 1, this DMU should expand or increase the use of productive resources. This modification to get the returns to scale in DEA is called the BCC model named after Banker, Charnes and Cooper.

Here,
CCR = Charnes, Cooper and Rhodes original model
CRS= Constant Returns to Scale
BCC= Banker, Charnes and Cooper model
VRS= Variable Returns to Scale
IRS= Increasing Returns to Scale
DRS= Decreasing Returns to Scale
TSE = Technical and Scale Efficiencies
PTE= Pure Technical Efficiencies
SE=Scale Efficiencies
MPSS = Most Productive Scale Size

Figure 1: CRS and VRS efficiency illustrated



As shown in Figure 1, we can explain scale efficiencies by considering the case of a single input and a single output. There are six DMUs, A, B, C, D, E and F. The piecewise linear frontier A-B-C-D is the BCC model (Banker, Charnes and Cooper) which follows the VRS assumption. Here in Figure 1, the VRS frontier shows that the four observations A, B, C and D are pure technical efficient (PTE). But an observation like E is inefficient and according to the BCC model, in contrast to the CCR model, the best practice for E is the projection E_1 on AB. Similarly, point F_1 can be obtained as a convex combination of the corner points C and D. The CCR model satisfies the following 'ray property': if (X, Y) is a feasible production point, then (kX, kY) is also a feasible point, where k is a non-negative scalar. The ray O-B-M is the CCR frontier i.e. constant returns to scale where the optimum efficiency score is 1. Observation B is CCR-efficient. All other observations are CCR inefficient which means they are not following the CRS assumption. The best CCR practice for F is the projection F_2 on O-B-M. Therefore, the CCR frontier exhibits CRS while the BCC frontier exhibits IRS along A-B and DRS along B-C-D. In sum we can state that the CCR model (without the convexity constraint) estimates the gross efficiency of a DMU i.e. TSE. This efficiency comprises technical efficiency and scale efficiency.

Technical efficiency describes the efficiency in converting inputs to outputs, while scale efficiency recognizes that economy of scale cannot be attained at all scales of production, and that there is one most productive scale size, where the scale efficiency is maximum at 100 per cent (Ramanathan, 2003; Bilal, Ahmed, Ahmed and Akbar, 2011). One can argue that a DMU can show an optimum technical efficiency (100% efficient) while operating in inefficient scale size. A firm or country may be technically efficient but may still be able to improve its productivity by exploiting scale economics. And that is what we illustrate in our research results by showing TSE, PTE and their scale size efficiencies. The DEA method does not require an explicit a priori determination of a production function i.e. there is no need for defining a functional relationship between inputs and outputs, and it does not require information on prices. Therefore DEA is suitable for measuring the efficiency of our study countries in this paper.

3.2. Model Specification

The fundamental DEA models can be grouped as (1) the models for DMUs with constant returns to scale (CRS) under CCR formulations or the models for DMUs with variable return to scale (VRS) under BCC formulations and (2) input-oriented models or output-oriented models. To select the exact model, one needs to answer the following series of questions (Ramanathan, 2003):

1. Are the DMUs within the data set experiencing CRS or VRS?
2. Are the policy makers more flexible and interested in changing (increasing/maximizing) the outputs of the DMUs or changing (reducing/minimizing) the inputs of the DMUs?

The answer to the first question is found by considering both CRS and VRS efficiency scores because the variables are not conventional factors of production. It may exhibit CRS, IRS or DRS. When answering the second question, we consider an output oriented model because in our study we want to see if governments wish to maximize/increase output from given inputs in various KBE dimensions.

4. Results and Discussions

DEA analyses of the data as presented in Tables 3 to Tables 10 were conducted using DEAP (Data Envelopment Analysis Programme) software, Version 2.1 developed by Tim Coelli in 1996. 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 DMU should be greater than double the sum of inputs and outputs. Therefore we add South Korea, a member of ASEAN plus three countries to make robust results for the analysis. The results follow the sequence of our policy focused KBE framework.

Table 3: Efficiency scores of ASEAN-5 countries for the Knowledge Acquisition Dimension in 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.744	0.914	0.814	DRS
Malaysia	0.266	1.000	0.266	DRS
Philippines	0.224	0.507	0.443	DRS
Singapore	0.122	0.816	0.150	DRS
Thailand	0.392	1.000	0.392	DRS
South Korea	1.000	1.000	1.000	CRS

Table 4: Efficiency scores of ASEAN-5 countries for the Knowledge Acquisition Dimension in 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	1.000	1.000	1.000	CRS
Malaysia	0.432	0.817	0.528	DRS
Philippines	0.991	1.000	0.991	DRS
Singapore	0.389	1.000	0.389	DRS
Thailand	0.691	0.986	0.701	DRS
South Korea	1.000	1.000	1.000	CRS

The first result of the DEA calculations is an efficiency rating of each observation (here, country). A rating of 100% (or 1.000) indicates that the country is located on the efficiency frontier. An efficiency rating less than 1.000 signals a non-optimal situation. A second set of calculations provides a measure of the returns to scale of each country. Theoretically, constant returns to scale (CRS) are said to exist at a point on the frontier if an increase of all inputs by 1% leads to an increase of all outputs by 1%. Decreasing returns to scale (DRS) are said to be prevail if outputs increases by less than 1%, while increasing returns to scale (IRS) are present if they increase by more than 1%. Generally a DRS situation is associated with a mature economy where basic economic and social needs have already been met, so that the incremental return of additional efforts is falling. In contrast to DRS, IRS would seem to be associated with high productivity of factors of production where a nation can enjoy increasing incremental returns on economic efforts (Thore and Golany, 1997).

Our calculations of returns to scale have a direct interpretation in terms of KBE policy. It is clear that a country with DRS in any KBE dimension is not using its KBE inputs optimally while a country with IRS can be expected to be engaged in rapid economic growth and higher KBE outputs. Both DRS and IRS are considered as inefficient scale size. The most optimal use of KBE resources is operating at CRS or scale size 1. Tables 3 and 4 show the results in the knowledge acquisition dimension where South Korea gets the highest efficiency score and has the most productive scale size in both the years. It indicates that South Korea is using its knowledge acquiring inputs - trade openness and FDI - most efficiently compared to other members of ASEAN-5. However, from our analysis, it appears that all other countries in both years are experiencing DRS which imply inefficient use of their resources except Indonesia in 2010. Indonesia improved its efficiency in 2010 compared to 1995. This DRS inefficiency for other member countries means that it would be possible for these countries to reduce the use of its inputs while still obtaining the same amounts or more of the outputs in the knowledge acquisition dimension.

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

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.508	1.000	0.508	IRS
Malaysia	0.635	0.674	0.942	DRS
Philippines	0.478	1.000	0.478	IRS
Singapore	0.622	0.653	0.952	DRS
Thailand	1.000	1.000	1.000	CRS
South Korea	1.000	1.000	1.000	CRS

Table 6: Efficiency scores of ASEAN-5 countries for Knowledge Production Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.330	1.000	0.330	IRS
Malaysia	0.314	0.387	0.811	DRS
Philippines	0.216	1.000	0.216	IRS
Singapore	1.000	1.000	1.000	CRS
Thailand	1.000	1.000	1.000	CRS
South Korea	0.706	0.757	0.934	IRS

Tables 5 and table 6 show the efficiency score of the knowledge production dimension where Thailand and South Korea in 1995 and Singapore and Thailand in 2010 are the best performers having the most productive scale size and 100% efficiency. However, Indonesia and the Philippines in both years and South Korea in 2010 are showing increasing returns to scale (IRS). The presence of IRS implies that these countries are enjoying higher outputs in terms of producing innovation and new ideas using their KBE inputs of R&D expenditure and IPR due to their highly productive factors of production. This situation may spur the governments of those countries to invest more on R&D which will be seen as sound investment in a productive workforce and in human capital.

Table 7: Efficiency scores of ASEAN-5 countries for Knowledge Distribution Dimension in year 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.054	1.000	0.054	IRS
Malaysia	0.310	0.509	0.609	IRS
Philippines	0.039	0.039	1.000	CRS
Singapore	1.000	1.000	1.000	CRS
Thailand	0.124	1.000	0.124	IRS
South Korea	0.316	0.372	0.851	DRS

Table 8: Efficiency scores of ASEAN-5 countries for Knowledge Distribution Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.111	1.000	0.111	IRS
Malaysia	0.556	1.000	0.556	IRS
Philippines	0.151	1.000	0.151	IRS
Singapore	1.000	1.000	1.000	CRS
Thailand	0.197	0.376	0.523	IRS
South Korea	0.965	0.966	0.999	DRS

According to Tables 7 and 8, Indonesia, Malaysia, the Philippines and Thailand all exhibit IRS in 2010, which implies that they can enjoy multiplying advantages in the use of ICT with their current education expenditure and school enrolments. This can be seen to be intuitively obvious. The more the government invests in education and increases the school enrolment ratio, the better it will get the highest number of computer and ICT users per thousand population under IRS. The increasing rate of ICT users will lead knowledge distribution to be more effective and efficient in the respective economies in the long run. The Philippines shows IRS in 2010, although it was efficient in 1995. However, South Korea shows DRS in our analysis which implies that South Korea is yet to get the optimum use of its education expenditure and school enrolment.

The most interesting finding from our analysis is that Singapore exhibits the most productive scale size in both the years. That is, it is the best performer in the knowledge distribution dimension. Singapore sets 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 number of ICT users in recent times (Yue and Lim, 2003). In 2010, its computer users numbered 827.48 per thousand population, which ranked number one in ASEAN (WDI-2010). Our calculation also finds Singapore to be the most efficient country in this dimension in both the years.

Table 9: Efficiency scores of ASEAN-5 countries for Knowledge Utilization Dimension in year 1995

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.176	0.193	0.913	DRS
Malaysia	1.000	1.000	1.000	CRS
Philippines	1.000	1.000	1.000	CRS
Singapore	0.719	1.000	0.719	DRS
Thailand	0.669	0.770	0.868	DRS
South Korea	1.000	1.000	1.000	CRS

Table 10: Efficiency scores of ASEAN-5 countries for Knowledge Utilization Dimension in year 2010

DMU	TSE (CCR)	PTE (BCC)	Scale efficiency (TSE/PTE)	Returns to scale
Indonesia	0.205	1.000	0.205	IRS
Malaysia	0.425	0.733	0.580	DRS
Philippines	1.000	1.000	1.000	CRS
Singapore	0.437	0.762	0.573	DRS
Thailand	0.365	0.414	0.882	DRS
South Korea	1.000	1.000	1.000	CRS

Finally, Tables 9 and 10 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 productive countries. However, all countries exhibit DRS except Indonesia, which exhibits IRS in 2010. 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 this in terms of recent phenomena, we find that the Philippines has the largest share of high-tech products in manufactured exports in 2010. Its percentage of high-tech products as a percentage of total manufacturing exports was 65.65% followed by Singapore 50.01%, Malaysia 48.11%, Indonesia 13.13% and Thailand 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. Research firm the Meta Group ranked the Philippines No. 1 in the world in terms of knowledge workers (http://www.slcv.edu.ph/news/news7-03.htm). Its Cyber Atlas of 2000 put the Philippines ahead of 47 other countries, including the United States, Australia, France, Canada, and India. 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, 2012; Lee, 2001). Hence, we can say that the other inefficient countries can emulate the best performing country in order to achieve optimum efficiency.

5. 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. In this paper we build a policy-focused KBE framework and apply the DEA method to show the technical and scale efficiency of the ASEAN-5 countries and South Korea in each KBE dimension. 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 most productive and 100% efficient countries in one referred year or the other. In the case of decreasing returns to scale (DRS) inefficiency, government should use their existing resources more efficiently, while with increasing returns to scale inefficiency (IRS), governments can enjoy increasing marginal returns from KBE outputs until they reach the optimum level. This indicative analysis shows that countries exhibiting DRS or IRS have efficiency gains to be made compared to countries exhibiting CRS. The above results raise the interesting issue for future research of how future policy can aid in promoting these available efficiency gains. Finally, we believe that the discussion and method presented in this paper will contribute to future KBE policy formulation not only in ASEAN but also in other emerging economies.

References

1] Abdelfattah B. M., Ablanedo-Rosas, J.M. and Gemoets L.A., 2011. Developing country efficiency assessment by means of a comprehensive model based on data envelopment analysis. *Int. J. Society Systems Science,* 3 (1/2), 58-80.
2] Afzal, M.N.I and Lawrey, R., 2012. KBE frameworks and their applicability to a resource-based country: The case of Brunei Darussalam, *Asian Social Science*, 8(7), 208-218.
3] APEC., 2000. Towards knowledge based economies in APEC. APEC Economic Committee.
4] APEC., 2004. *Indicators of knowledge based economy*. APEC Economic Committee.
5] Australia Bureau of Statistics (ABS). 2002. *Measuring a knowledge-based economy and society – an Australian framework*. Discussion paper (cat. No. 1375.0).

6] Banker RD, Charnes A, Cooper WW., 1984. Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science*, 30 (9), 1078-92.

7] Bilal, H., Ahmad, K., Ahmad, H. and Akbar, S., 2011. Returns to scale of Islamic banks versus small commercial Banks in Pakistan. *European Journal of Economics, Finance and Administrative Sciences*, 30, 136-151.

8] Charnes, A., Cooper, W.W. and Rhodes, E., (1978). Measuring efficiency of decision making units. *European Journal of Operational Research*, 3, 429-44.

9] Christopoulos, D.K., 2007. Explaining country's efficiency performance. *Economic Modelling*, 24, 224-235.

10] Coelli, T. 1996. A guide to DEAP version 2.1: A data envelopment Analysis (computer) program. CEPA Working Paper 96/08.

11] Cooper, W.W., Seiford, L.M. and Tone, K., 2000. *Data Envelopment Analysis: A Comprehensive text with Models, Application, References, and DEA software*. New York: Springer.

12] Dahlman, C. J. and Andersson, T., 2000. *Korea and the knowledge-based economy: making the transition*. The World Bank, Washington DC, USA.

13] Derek, H., Chen, C. and Dahlman C. J., 2004. Knowledge and development, the World Bank, World Bank policy research working paper.

14] Farrell, R.M., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society*, 120, 254-90.

15] Golany, B. and Thore, S., 1997. The economic and social performance of nations: efficiency and returns to scale. *Socio-Econ. Plann. Sci.*, 31(3), 191-204.

16] Hsu, M., Luo, X. & Chao, G., 2005. The fog of OECD and non-OECD country efficiency: a data envelopment analysis approach", *In* Johnston, T.C. (Ed)., *Proceedings of the Annual Meeting of the association of collegiate marketing educators*. March 1-5, 2005, Texas, 121-130.

17] Karahan, O., 2011. Input and output indicators of knowledge-based economy. *9th international conference on knowledge, economy & management proceedings,* 23-25 June 2011 Sarajevo-Bosnia &Herzegovina.

18] Kassicieh, S.K., 2010. The knowledge economy and entrepreneurial activities in technology-based economic development. *Journal of Knowledge Economy*, 1,24–47, DOI 10.1007/s13132-009-0005-8.

19] Lee, K. S., 2001. Economic development through knowledge creation- the case of Korea. *Proceedings of the 34th Hawaii International Conference on System Science, 2001*

20] Lo C.C., 2003. The diamond approach of national competitiveness using DEA and benchmarking analysis for Asian countries. Master's Thesis, Institute of Business Administration, National Cheng Kung University, Taiwan.

21] Mohamad, N., 2007. A Linear Programming Formulation of Macroeconomic performance: the case of Asia Pacific. *Matematika,* 23(1), 29-40.

22] Norman, M. and Stoker, B., 1991. *Data Envelopment Analysis: The Assessment of Performance*. Chichester: John Wiley & Sons.

23] OECD. 1996. *The knowledge-based economy*. General distribution, OCDE/GD (96)102

24] OECD. 2001. Science, Technology and Industry Scoreboard. Working paper, OECD, Paris.

25] Poorfaraj, A. Samimi, A.J. & Keshavarz, H., 2011. Knowledge and economic growth: evidence from some developing countries. *Journal of Education and Vocational Research* 1(1), 21-25.

26] Ramanathan, R. 2003. An Introduction to Data Envelopment Analysis a Tool for Performance Measurement. New Delhi: Sage Publications.

27] Ramanathan, R., 2006. Evaluating the comparative performance of countries of the Middle East and North Africa: a DEA application", *Socio-Economic Planning Science*, 40, 156-167.

28] Roman, M. (ND). Regional efficiency of knowledge economy in the new EU countries: The Romanian and Bulgarian case. Working paper, Academy of Economic Studies of Bucharest, Department of Statistics and Econometrics, Bucharest.
29] Staníčková, M. and Skokan, K. (ND). Evaluation of the EU Member States Competitive Potential by Data Envelopment Analysis, working paper, Faculty of Economics, CZECH REPUBLIC.
30] Tan, H.B., Hooy, C.W., Manzoni, A. and Islam, S. M.N., 2008. Relative efficiency measures for the knowledge economies in the Asia Pacific region. *Journal of Modelling in Management*, 3(2), 111-124.
31] World Bank Institute (WBI). 1999. World development report 1998/99: knowledge for development. World Bank, Washington.
32] World Competitiveness Yearbook (WCY CD-ROM). (1995-2010). Switzerland: IMD
33] World Development Indicators (WDI online). (1995-2010). Washington: World Bank
34] Yue, C.S. and Lim, J.J., 2003. Singapore: A regional hub in ICT, Masuyama, S. and Vandenbrink, D. (Ed.), *Towards a Knowledge-based Economy: East Asia's Changing Industrial Geography*, ISEAS & NRI, Singapore & Tokyo, pp. 259.
35] Yue, C.S., 1999. Trade, foreign direct investment and economic development of Southeast Asia. *The Pacific review*, 12 (2).

Appendix 1

Table 1A: OECD, APEC, WBI frameworks pillars and indicators

OECD	APEC	WBI
1. Knowledge-Based Economy	**1. Business Environment**	**1. Performance**
1.1 Knowledge Investment (education, R&D and software) as % of GDP	1.1 Knowledge based Industries as % of GDP	1.1 Average annual GDP growth (%)
1.2 Education of the adult population as % of the population aged 25-64	1.2 Services Exports as of GDP	1.2 Human Development Index
1.3 R&D expenditure as a percentage of GDP	1.3 High-Tech Exports as of GDP	
1.4 Basic research expenditure as a percentage of GDP	1.4 Foreign Direct Investment inward flow as % of GDP	
1.5 Expenditure of Business R&D in domestic product of industry	1.5 Government transparency rating by World Competitiveness Yearbook	
1.6 Expenditure of Business R&D in manufacturing	1.6 Financial transparency rating by World Competitiveness Yearbook	
1.7 Share of services in R&D expenditure	1.7 Competition policy rating by World Competitiveness Yearbook	
1.8 Expenditure on innovation as a share of total sales	1.8 Openness rating by World Competitiveness Yearbook	
1.9 Investment in venture capital as a percentage of GDP		
2.Information and Communication Technology	**2. ICT Infrastructure**	**2. Economic Incentive and Institutional Regime**
2.1 ICT spending as % of GDP	2.1 Number of mobile telephones in use per 1000 inhabitants	2.1 Tariff and non-tariff barriers
2.2 PC penetration in households	2.2 Number of telephone mainlines in use per 1000 inhabitants	2.2 Regulatory Quality
2.3 Number of internet host per 1000 inhabitants	2.3 Number of computers per 1000 inhabitants	2.3 Rule of Law
2.4 Percentage share of ICT industries in GDP	2.4 Number of internet users as % of population	
2.5 Share of ICT in patents granted by USPTO	2.5 Internet hosts per 10000	
	2.6 Expected e-commerce Revenues, M$US	

Table 1A: OECD, APEC, WBI frameworks pillars and indicators - continued

3. Science and Technology Policies 3.1 Publicly funded R&D as % of GDP 3.2 Government R&D expenditure on health-defense-environment 3.3 Government R&D expenditure in total R&D expenditure 3.4 Business R&D expenditure in total R&D expenditure 3.5 Share of Government-Business R&D expenditure financed together 3.6 Tax subsidies rate for R&D	**3. Innovation System** 3.1 Scientists Engineers in R&D per million of the population 3.2 Full-time researchers per million of the population 3.3 Gross Expenditure on R&D (% of GDP) 3.4 Business Expenditure on R&D (% of GDP) 3.5 US Patents per annum 3.6 The number of technological cooperation among companies 3.7 The number of technological cooperation between company-university	**3. Education and Human Resources** 3.1 Adult Literacy rate (%age 15 and above) 3.2 Secondary Enrolment 3.3 Tertiary Enrolment
4. Globalization 4.1 Share of foreign affiliates in R&D 4.2 Share of foreign and domestic ownership in total inventions 4.3 Number of international technological alliances 4.4 Percentage of scientific publications with a foreign co-author 4.5 Percentage of patents with a foreign co-investor	**4. Human Resource Development** 4.1 Secondary enrolment (% of age group) 4.2 Natural Sciences Graduates per annum 4.3 Knowledge Workers (% of labor force) 4.4 Newspaper (per 1000 inhabitants) 4.5 Human Development Index	**4. Innovation System** 4.1 Researchers in R-D, per million populations 4.2 Patent Applications granted by the USPTO, per million populations 4.3 Scientific and technical journal articles, per million populations
5. Output and Impact 5.1 Scientific publications per 100 000 population 5.2 Share of countries in total EPO patent application 5.3 Share of firm creating any innovative output 5.4 GDP per employed person 5.5 Share of knowledge-based industries in total value added 5.6 Share medium-high technology industries in manufacturing export 5.7 Technology balance of payments as a percentage of GDP		**5. Information Infrastructure** 5.1 Telephones per 1000 persons, (telephone mainlines + mobile phones) 5.2 Computers per 1000 persons 5.3 Internet Users per 10000 persons

Table 2A: Input-Output data source

Input variable	Data source
FDI inflows % GDP	World Development Indicators, WDI-2010
OPENNESS	Pen table, 2010
Intellectual property rights (IPR)	World Competitiveness Yearbook, WCY-2011, IMD WCY executive survey based on an index from 0 to 10
Research and development (R&D) expenditure % GDP	WDI-2010, WCY-2011
Education expenditure % of GDP	WCY-2011
Secondary enrolment % of total	WDI-2010, WCY-2011
Knowledge Transfer rate from university to industry	World Competitiveness Yearbook, WCY-2011, IMD WCY executive survey based on an index from 0 to 10
Output variable	**Data source**
Growth of real GDP	WCY-2011
Number of Scientific and technical Journal articles per year	WDI-2010
High-tech export % of Total export	WCY-2011
Computer user per 1000 population	WCY-2011