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Auttapol SUEBPONGSAKORN

THE EVALUATION OF PRODUCTIVITY CHANGE OF THE CONSTRUCTION COMPANIES IN THAILAND: AN APPLICATION OF MALMQUIST INDEX

Abstract

The objectives of this paper aim to estimate the efficiency scores of the top 20 construction companies of Thailand ranked by their profit earnings in 2009, and to detect the nature of the productivity change during the 2005–2009 periods. In this study, the traditional data envelopment analysis (DEA) based on input – oriented approach and the Malmquist index are estimated in order to serve these objectives. The results showed that although the construction companies earned large amount of profits in 2009, 12 companies (RT, ACC, CUEL, TOC, VAT, CMC, STEC, SYNTEC, CK, ST, TRC, and CNT) still operated below the efficient frontier line, while the Malmquist Index indicated the productivity change of the construction firms especially during 2007/2008 period.

Key words:

Efficiency, Malmquist Index, Data Envelopment Analysis (DEA).

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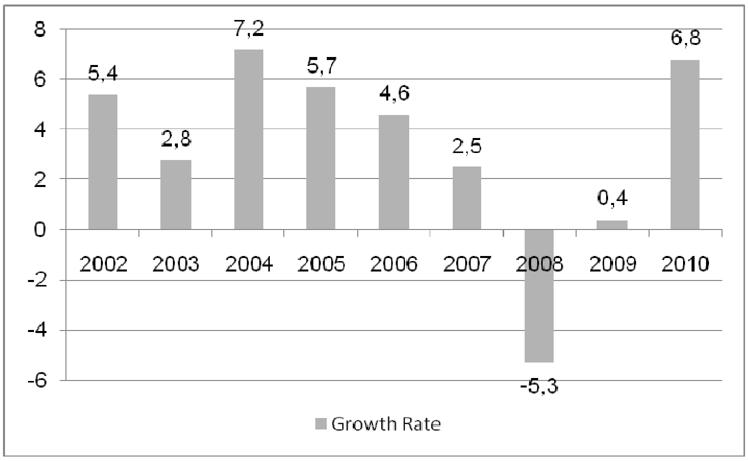
Suebpongsakorn Auttapol, Ph. D. (Economics), Lecturer, School of Economics, University of the Thai Chamber of Commerce, Thailand.

1. Introduction

The construction industry has been known as one of the strongest industries in Thailand. Notwithstanding, the performance of this industry is indeterminate due to the fluctuation of the Thai economy during the previous lustrum (2006–2010). This can be seen from the growth rate of this industry shown in figure 1.

Figure 1

Growth Rate of the Construction Industry of Thailand



Source: Bank of Thailand.

Beginning with the high growth rate of 7.2% in 2004, the growth rate of the construction industry in Thailand tended to decrease over the period of 2005–2007 and had the negative growth rate in 2008 (the period of the global financial and economic crisis), and then it rebounded back to the rate of 0.4% and 6.8% in 2009 and 2010, consecutively during the recovery period. For the year of 2011, the growth rate of this industry is predicted to increase continuously from last year at the rate of 4.0%–6.5%, especially for the expansion of the public construction such as trains, roads, and several infrastructures which are the main factor contributing to the growth of this sector. For the private construction, the growth rate is projected to be declined from last year at the rate of 3.5% –

5.5% due to the problems of oversupplies of housing, the upward trend of Thai interest rate concomitant with the end of supporting policies for residential investment and the risk for the incoming bubble economy (Kasikorn Research Center. 2010: www.kasikornresearch.com).

Due to the fluctuation of the rate of growth in the construction industry, there are several questions related to the performance of the firms in this industry, such as which firms produced on or under the efficiency frontier, how their productivity levels are changed during this period, how to measure the input and output slacks in order to provide the recommendation for improving the performance of each firm.

Generally, one of the most popular methods to measure the productivity of the particular firms is known as the Data Envelopment Analysis (DEA) and its related applications. From the past till present, the DEA technique can be applied to any fields of studies related to the measurement of efficiency. Thompson, Brinkmann, Dharmapala, Gonzalez-Lima, and Thrall (1997) applied the methods of Data Envelopment Analysis (DEA), Assurance Region (AR) and Linked – Cone profit ratios (LC) to measure the efficiency of the U.S.'s 100 largest banks ranked in asset size from 1986 to 1991. The results showed that with the method of DEA, the efficiency scores were insensitive to errors in the data comparing with another two methods. Barros and Alves (2003) estimated total productivity change and decomposes the efficiency score into technically efficient change and technological change for a Portuguese retail store chain by employing DEA method in order to search for the best practices and provide the recommendation to improve the performance of the whole retailed chain in Portugal. Odeck (2006) used DEA technique to examine the target achievements of the operational units of the Norwegian Public Roads Administration (NPRA) charged with traffic safety services, and extended his study to include DEA-based Malmquist index so as to measure productivity growth in his interested target achievements. Finally, Sueyoshi and Goto (2011) presented the new DEA approach to measure the unified efficiency of energy firms in Japan by including both desirable outputs (e.g., electricity) and undesirable outputs (e.g. CO_2) within the computational framework of DEA.

Therefore, the main objectives of this study include:

1.1. To measure the technical efficiency score of the firms in construction industry by using the technique called Data Envelopment Analysis (DEA).

1.2. To gauge the productivity change of the construction firms during the previous lustrum by computing the Malmquist index.

The remainder of the paper is organized as follows. Section 2 explains the theoretical framework used in this study called the method of DEA and the Malmquist index. Section 3 defines the inputs and outputs of the DEA model and their descriptive statistics. Section 4 reports the computational results of technical efficiency scores and the Malmquist index, and Section 5 are the conclusion of this study and the recommendations for further studies.

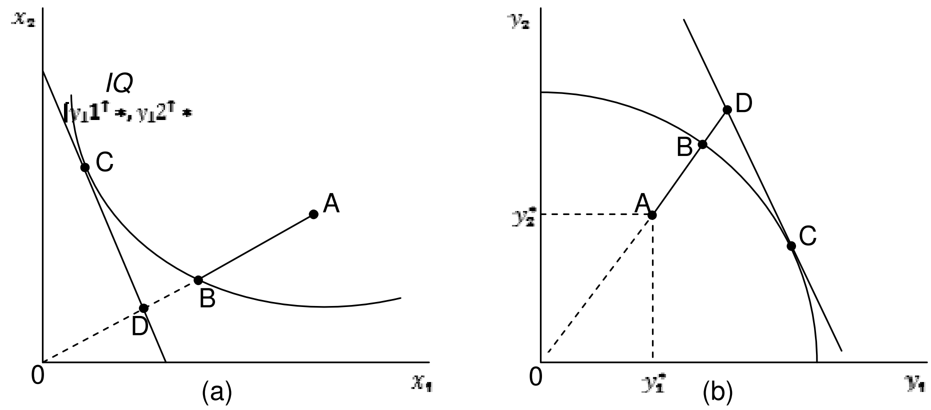
2. Theoretical Framework for the Measurement of Efficiency

In this study, the paper aims at evaluating the construction firms' efficiency by using the concept of technical efficiency developed by Farrell (1957). The technical efficiency herein refers to the situation where a firm acquires the maximum level of outputs from a given amount of inputs. Normally, there are 2 ways to measure the technical efficiency, namely the input – oriented measure and the output – oriented measure. The input – oriented measure can be explained as the optimal combination of inputs to produce a given level of output, while the output – oriented measure defines efficiency as the optimal amount of output that could be produced under the given set of inputs. Diagram 2(a) and 2(b) illustrated the case where a firm used 2 inputs (x_1, x_2) to produce 2 outputs (y_1^*, y_2^*).

Figure 2(a) shows the way to evaluate the technical efficiency by using the input – oriented measure. Here, the $IQ(y_1^*, y_2^*)$ curve represents the isoquant curve which indicates the minimum levels of inputs used to produce the output (y_1^*, y_2^*). If this firm used the combination of inputs at point A to produce, its production is ineffective, since the same level of outputs can be produced with less inputs (but at the same combination) at point B. Therefore, the level of technical efficiency defined by the input – oriented measure of this firm can be computed as the ratio between the distances 0B and 0A (or 0B/0A).

Figure 2

Input (a) and output (b) oriented efficiency measures



On the other hand, Figure 2(b) explained the way to compute the technical efficiency by using the output – oriented measure. Point A in figure 1(b) represents the combination of outputs (y_1^*, y_2^*) produced by a particular firm using a given amount of inputs. Anyway, if this firm produces at the efficient level, it should produce more of both outputs at point B on the production frontier line by using the same level of inputs as before. Thus, the level of technical efficiency defined by the output – oriented measure in this case can be calculated as the ratio between the distances 0A and 0B (or 0A/0B).

In order to fulfill the objectives of this study, the input – oriented measure for evaluating the efficiency score is employed by using the non – parametric technique called Data Envelopment Analysis (DEA). Moreover, for the sake of measuring the productivity change overtime, the method called Malmquist index is computed. The roughly details for each approach are as follow:

2.1. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is the non – parametric approach used for evaluating the efficiency score. This method uses the information from the extreme observations (treated as the body of the data) to determine the best practice efficiency frontier (Lewin and Lovell, 1990). The objective of DEA is to construct the production frontier in the way that all the observed data points (all characteristics for each DMU[1]) lay below or on this envelopment frontier. This can be done by specifying the following linear programming problem (Charnes, Cooper and Rhodes, 1978):

2.1.1. Under the assumption of constant returns to Scale (CRS)

In this case, each DMU is assumed to be operated with the appropriate scale of production. Thus, the linear programming problem is to:

$$Max_{u,v}\left(\frac{u'y_i}{v'x_i}\right) \text{ subject to } \left(\frac{u'y_j}{v'x_j}\right) \leq 1\ (j = 1,2,\ldots,N) \text{ and } u,v \geq \mathbf{0} \quad (1)$$

where, y_i are vectors of outputs from the $M \times N$ output matrix, Y (M outputs from N DMUs), x_i are vectors of inputs from the $K \times N$ output matrix, X (K inputs from N DMUs), $i = 1,2,\ldots,N$, and u,v are vectors of $M \times \mathbf{1}$ output weights and $K \times \mathbf{1}$ input weights, consecutively.

[1] Under the DEA context, DMU is abbreviated for the decision making units. In other words, DMUs are the firms under our consideration.

Equation (1) can be equivalently transformed into the envelopment form as follows:

$$Min_{\theta,\lambda}\theta \text{ subject to } -y_i + Y\lambda \geq 0, \theta x_i - X\lambda \geq 0, \text{ and } \lambda \geq \mathbf{0} \qquad (2)$$

where, θ is a scalar $(\theta \leq 1)$, and λ is a $N \times 1$ vector of constants.

In order to include the input and output slacks[2], Ali and Seiford (1993) suggested the following model:

$$Min_{\lambda,OS,IS} - (M_1^{'}OS + K_1^{'}IS) \text{ subject to}$$
$$-y_i + Y\lambda - OS = 0, \theta x_i - X\lambda - IS = 0, \text{ and}$$
$$\lambda \geq 0, OS \geq 0, IS \geq \mathbf{0} \qquad (3)$$

[3]

where, $M_1^{'}$ and $K_1^{'}$ are the $M \times 1$ and $K \times 1$ vectors of ones, respectively, OS is a $M \times 1$ vector of output slacks ,and IS is a $K \times 1$ vector of input slacks.

2.1.2. Under the assumption of variable returns to Scale (VRS)

Due to the effect of imperfect competition in the market (price rigidity, contracts, law and regulations and etc.), the assumption of CRS is not suitable for the real world, since most of DMUs may not be operated at the optimum scale. Thus, by imposing the assumption of VRS, the linear programming problem in equation (2) can be transformed into (Banker, Charnes, and Coopers, 1984):

$$Min_{\theta,\lambda}\theta \text{ subject to}$$

$$-y_i + Y\lambda \geq 0, \theta x_i - X\lambda \geq 0, N_1^{'}\lambda = \mathbf{1} \text{ and } \lambda \geq \mathbf{0} \qquad (4)$$

where, N_1 is a $N \times 1$ vector of ones (the convexity constraint).

Equation (4) allows us to decompose the technical efficiency score (under CRS assumption: TE_{CRS}) into 2 components, namely 1) pure technical efficiency score (TE_{VRS}) and 2) scale efficiency score (SE) as follows:

$$TE_{CRS} = TE_{VRS} \times SE \qquad (5)$$

Moreover, in order to determine the nature of returns to scale used by each DMU. The linear programming equation (4) can be solved by imposing with the non – increasing returns to scale restriction to produce the NIRS efficiency frontier as follows:

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[2] Input slacks refer to the surplus amount of inputs that could be decreased without the reduction of outputs, while the output slacks refer to the deficient amount of outputs that a firm could produce by using the given amount of inputs

[3] Equation (3) is the two – step procedure, since the parameter θ in equation (3) is no longer variable, and is obtained from the results of the calculation from equation (2).

$Min_{\theta,\lambda}\theta$ subject to

$$-y_i + Y\lambda \geq 0, \theta x_i - X\lambda \geq 0, N_1'\lambda \leq 1 \text{ and } \lambda \geq 0 \quad (6)$$

As a result, if the technical efficiency score computed from equation (6), or TE_{NIRS} is not equal to TE_{VRS} from equation (4), the nature of the particular DMU is increasing returns to scale (IRS). However, if they are equal, it means that decreasing returns to scale (DRS) is applied for this DMU.

2.2. Malmquist Productivity Index

This paper attempts to capture the over time efficiency change of construction firms in Thailand by using the Malmquist index based on DEA. Generally, the Malmquist Index measuring the productivity growth can be decomposed into the technical change and the technical efficiency change. In order to understand the basic idea of Malmquist Index, Farrell (1957) suggested the way to measure the technical efficiency as follows:

At time period t , the set of all feasible N input and M output vectors are determined by and $y^t = (y_1^t, y_2^t, \ldots, y_M^t)$, consecutively where $x^t \epsilon R_+^N$ and. Moreover, the technology can be demonstrated by the input requirement set $(L^t(y^t))$:

$$L^t(y^t) = \{x^t : (x^t, y^t) \epsilon S^t\}, t = 1,2, \ldots, T \quad (7)$$

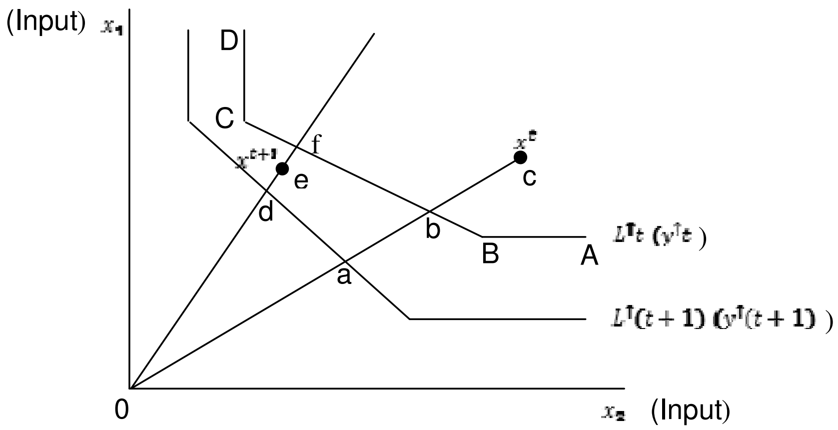
where, $[S]^t t = \{(x^t t, y^t t) : x^t t$ can produce $y^t t\}$ or the set of technology at period t . In other words, Equation (7) showed all feasible vectors of input (x^t) used to produce the output vector.

Under Farrell's method, the technical efficiency can be measured in two ways, namely output – oriented and input – oriented measures. For the output – oriented measure, the efficiency score can be measured by holding the level of output constant and radially decreasing the level of inputs with respect to the technology frontier. On the other hands, under the input – oriented measure which is the main focal points of this study, the technical efficiency score can be obtained by holding the level of input constant and radially expanding the level of output with respect to the technology frontier. Figure 2 illustrated the input – oriented measure of the technical efficiency.

Figure 3 exhibited two piecewise linear isoquants ($L^t[(y]^t)$ and) which represented the technology frontier in two periods (t and $t+1$). In this case, a firm produced at point c in period t and changed the pattern of production to point e in period $t+1$. Under Farrell's measure, the technical efficiency score of this firm in period t can be computed as 0b/0c and the distance function is given by its reciprocal or 0c/0b (Shephard, 1953). Thus, if the production activity is efficient, both efficiency score and the distance function are equal to 1. Moreover, the technical efficiency score ranged between 0 and 1but the distance function is varied from 1 to the value greater than 1.

Figure 3

The Farrell's input – oriented measure of the technical efficiency



If we let $F_i^t(y_t, x_t)$ be the input – oriented technical efficiency score measured by Farrell's concept and $D_i^t(y_t, x_t)$ be the input – oriented distance function, therefore at any time period t :

$$F_i^t(y^t, x^t) = min_\theta\{\theta: \theta x^t \in L^t[(y]^t)\}$$

$$D_i^t(y^t, x^t) = max_\theta\left\{\theta \geq 1: \left(\frac{x^t}{\theta}\right) \in L^t(y^t)\right\} \qquad (8)$$

or,

$$F_i^t(y^t, x^t) = [D_i^t(y^t, x^t)]^{-1} \qquad (9)$$

Furthermore, in order to compute the Malmquist index to capture the productivity change between 2 time periods (t and $t+1$), other 3 more distance functions must be calculated as follows:

$$D_i^t(y^{t+1}, x^{t+1}) = max_\theta\left\{\theta \geq 1: \left(\frac{x^{t+1}}{\theta}\right) \in L^t(y^{t+1})\right\} \qquad (10)$$

$$D_i^{t+1}(y^t, x^t) = max_\theta\left\{\theta \geq 1: \left(\frac{x^t}{\theta}\right) \in L^{t+1}(y^t)\right\} \qquad (11)$$

and

$$D_i^{t+1}(y^{t+1}, x^{t+1}) = max_\theta\left\{\theta \geq 1: \left(\frac{x^{t+1}}{\theta}\right) \in L^{t+1}(y^{t+1})\right\} \qquad (12)$$

Equation (10) represented the efficiency measure using the information in period $t+1$ with respect to the technology frontier of period t, while equation (11) referred to the efficiency measure using the information in period t with respect to the technology frontier of period $t+1$. Finally, the distance function in equation (12) represented the efficiency measure using the information in period $t+1$ with respect to the technology frontier of period $t+1$.

These distance functions can be explained by considering figure 3 above. In this case, the input requirement set in period $t+1$ is represented by the isoquant line. Therefore, $D_i^t(y^{t+1}, x^{t+1})$ is equal to the ratio 0e/0f. By the same token, $D_i^{t+1}(y^t, x^t)$ and $D_i^{t+1}(y^{t+1}, x^{t+1})$ are the ratios 0c/0a and 0e/0d, consecutively. As a result, Caves et al. (1982) showed that the distance functions can be used to construct the Malmquist index in the form of the ratio between 2 distance functions for measuring the change of productivity between period t and $t+1$ as follows:

$$M_i(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D_i^t(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \qquad (13)$$

Afterwards, Fare et al. (1994) computed the Malmquist index as the geometric mean of index in equation (13) between two time periods, or:

$$M_i(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{D_i^t(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^{t+1}(y^t, x^t)}\right]^{\frac{1}{2}} \qquad (14)$$

Moreover, Fare et al. (1994) also showed that index in equation (14) can be factored into the technical and the technical efficiency changes as follows:

$$M_i(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \left[\frac{D_i^t(y^{t+1}, x^{t+1})}{D_i^{t+1}(y^{t+1}, x^{t+1})} \frac{D_i^t(y^t, x^t)}{D_i^{t+1}(y^t, x^t)}\right]^{\frac{1}{2}} \qquad (15)$$

The first term on the right – hand side of equation (15) measures the input technical efficiency change (E_i) of a DMU between two time periods. That is if:

$\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} < 1 \rightarrow$ Progress in the input technical efficiency

$\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} > 1 \rightarrow$ Regress in the input technical efficiency, and

$\frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} = 1 \rightarrow$ Status Qua

The second geometric – mean term on the right – hand side of equation (15) measures the input technical change (T_i) (or the size of the input frontier shift) of a DMU between two time periods, that is to say if:

$$\left[\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}\right]^{\frac{1}{2}} < 1 \rightarrow$$ Progress in the frontier technology

$$\left[\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}\right]^{\frac{1}{2}} > 1 \rightarrow$$ Regress in the frontier technology, and

$$\left[\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}\right]^{\frac{1}{2}} = 1 \rightarrow$$ Status Qua

Finally, the Malmquist index (M_i) indicates the change of productivity between period t and $t+1$. In this case, the productivity of a DMU improves, declines, and remains unchanged if M_i is less than 1, greater than 1, and equal to 1, respectively.

3. The Inputs and Outputs of DEA Model

The input and output data used in this study are collected from the income statements of construction companies in Thailand available at www.bol.co.th/corpus. The 20 construction firms (DMU) are chosen with respect to the ranking of the construction companies making the highest profits in 2009 (the latest year that the data are available at the time of study). The nature of their returns to scale is computed only for the year of 2009. Moreover, the panel data of these companies during the period of 2005–2009 are used to calculate the Malmquist index. The list of these DMUs is shown table 1 as follows:

Table 1

The top 20 highest profits construction companies of Thailand in 2009

Rank	Company	Profits in 2009 (Baht)	Company Symbol
1	BANGKOK EXPRESSWAY PUBLIC COMPANY LIMITED	1,574,717,818	BECL
2	BENCHACHINDA HOLDING CO.,LTD.	862,597,215	BCH
3	SAMSUNG ENGINEERING CO.,LTD.	797,108,670	SSE
4	RITTA CO.,LTD.	566,754,715	RT
5	ACUMEN COMPANY LIMITED	527,006,777	ACC
6	S-TEC CIVIL & CONSTRUCTION CO.,LTD.	512,204,431	SCC
7	COM-LINK CO.,LTD.	433,037,849	COM
8	CUEL LIMITED	420,741,607	CUEL
9	THAI OBAYASHI CORPORATION LIMITED	393,544,000	TOC

Rank	Company	Profits in 2009 (Baht)	Company Symbol
10	VATANA PHAISAL ENGINEERING CO.,LTD.	384,351,460	VAT
11	CHIANGMAI CONSTRUCTION CO.,LTD.	369,586,414	CMC
12	SINO-THAI ENGINEERING & CONSTRUCTION PUBLIC COMPANY LIMITED	321,954,902	STEC
13	SYNTEC CONSTRUCTION PUBLIC COMPANY LIMITED	320,006,292	SYNTEC
14	CH. KARNCHANG PUBLIC COMPANY LIMITED	217,022,157	CK
15	JASMINE SUBMARINE TELECOMMUNICATIONS CO.,LTD.	212,147,633	JST
16	THAI KAJIMA CO.,LTD.	211,131,540	TK
17	THAI NIPPON STEEL ENGINEERING & CONSTRUCTION CORP.,LTD.	179,868,574	TNS
18	SIAM TONE CO.,LTD.	173,169,389	ST
19	TRC CONSTRUCTION PUBLIC COMPANY LIMITED	171,705,123	TRC
20	CHRISTIANI & NIELSEN (THAI) PUBLIC COMPANY LIMITED	159,090,372	CNT

Source: www.bol.co.th/corpus

The data on inputs and outputs for these DMUs used in this study are shown in table 2. The inputs include the net value of lands, buildings, and equipments, Operating Cost, and Cost of Sales and/or Cost of Services, while the Revenue from Sales and Services (Y_1) and the total revenue of the construction company (Y_2) are treated as outputs. Finally, table 3 showed the descriptive statistics of these variables during the period of 2005–2009.

Table 2

The Inputs and Outputs of DEA Model

Inputs (Millions of Baht)	Output (Millions of Baht)
• Net Value of Lands, Buildings, and Equipments • Operating Cost • Cost of Sales and/or Cost of Services (X_3)	• Revenue from Sales and Services (Y_1) • Total Revenue of the Construction Company (Y_2)

Table 3

Descriptive Statistics for Input and Output Variables of DEA Model

Variables	y_1	y_2	x_1	x_2	x_3
2005					
Mean	3,945.98	4,051.36	437.86	194.24	3,266.82
Max	13,073.43	13,176.56	3,372.73	798.84	12,336.49
Min	0.00	0.03	0.30	0.07	0.00
S.D.	4,174.27	4,233.67	753.04	211.18	3,842.71
2006					
Mean	4,410.72	4,510.77	494.91	238.35	3,837.83
Max	14,472.67	14,570.39	3,683.47	931.73	15,995.54
Min	0.00	18.45	0.17	9.92	0.00
S.D.	4,676.16	4,636.95	801.40	255.27	4,694.86
2007					
Mean	4,398.78	4,596.68	564.60	241.89	3,795.10
Max	17,149.64	17,318.52	3,421.10	921.25	16,877.06
Min	64.71	94.04	0.09	21.65	120.48
S.D.	4,462.09	4,560.70	791.37	240.97	4,347.45
2008					
Mean	5,046.09	5,238.44	550.07	337.61	4,344.31
Max	14,806.56	14,844.73	3,141.55	1,489.04	14,027.94
Min	26.21	26.76	20.37	20.06	12.12
S.D.	4,730.38	4,747.20	748.11	394.98	4,387.15
2009					
Mean	4,681.29	4,985.42	514.41	323.06	3,891.55
Max	20,138.64	20,145.22	2,708.71	1,539.60	17,362.26
Min	64.92	558.75	19.36	18.13	58.20
S.D.	4,969.94	4,835.09	688.63	388.95	4,432.33

4. Results of the Study

4.1 The Calculation of the Technical and Scale Efficiency

In this study, the tradition DEA technique is applied to the input and output data only for the year of 2009 so as to measure the technical and scale efficiency and the nature of the returns to scale of the Thailand top 20 construction companies ranked by their profits in this year. The results are shown in Table 4.

Table 4

The Technical Efficiency, Scale Efficiency and Returns to Scale of the Thai Construction Companies in 2009

Firm	TE_{CRS}	TE_{VRS}	SE	Returns to Scale
BECL	1.000	1.000	1.000	–
BCH	1.000	1.000	1.000	–
SSE	1.000	1.000	1.000	–
RT	0.849	0.946	0.897	DRS
ACC	0.769	0.784	0.981	IRS
SCC	1.000	1.000	1.000	–
COM	1.000	1.000	1.000	–
CUEL	0.933	1.000	0.933	DRS
TOC	0.905	0.948	0.954	DRS
VAT	0.801	0.832	0.962	DRS
CMC	0.859	0.861	0.998	IRS
STEC	0.874	1.000	0.874	DRS
SYNTEC	0.970	1.000	0.970	DRS
CK	0.502	0.703	0.714	DRS
JST	1.000	1.000	1.000	–
TK	1.000	1.000	1.000	–
TNS	1.000	1.000	1.000	–
ST	0.977	1.000	0.977	IRS
TRC	0.925	0.930	0.994	DRS
CNT	0.892	0.904	0.987	DRS

Note: 1) The results are computed from the DEAP version 2.1.
2), and SE represented the technical efficiency scores under the assumption of the constant returns to scale, variable returns to scale and the scale efficiency, respectively.

The results showed that under the assumption of constant returns to scale (CRS), the construction companies operating on the efficient frontier line in 2009 consist of 8 companies namely, BECL, BCH, SSE, SCC, COM, JST, TK, and TNS, while the rest of 12 companies are inefficient with the technical efficiency score (TE_{CRS}) ranging from 0.502 to 0.977. Since, these technical efficiency scores are computed under the input – oriented measure, they can be interpreted as the percentage of overall inputs that inefficient DMU can be reduced in order to reach the efficient level. For example, RT and ACC with the value of TE_{CRS} of 0.849 and 0.769, consecutively, this can be interpreted in the way that RT and ACC could reduce their overall inputs by 15.1 (or 1–0.849) percent and 23.1 (or 1–0.769) percent, respectively.

On the other hands, the technical efficiency scores under the assumption of variable returns to scale (TE_{VRS}) exhibited that only 9 construction companies namely, BECL, BCH, SSE, SCC, CUEL, COM, JST, TK, and TNS were operated on the efficient frontier line in 2009, while the TE_{VRS} scores of the rest inefficient DMUs are ranged between 0.703 and 0.946. Moreover, by comparing TE_{CRS} scores with TE_{VRS} using equation (5), the results showed that only 8 companies (BECL, BCH, SSE, SCC, COM, JST, TK, and TNS) are operated with the efficient scale of production in 2009.

Finally, by applying equation (6), the results showed that among the 12 inefficient – scale DMUs, only 3 companies including ACC, CMC and ST have operated with increasing returns to scale (IRS) (or we can say that these companies have relatively small level of production comparing with the optimal – scale level). By contrast, the rest of inefficient scale companies (RT, CUEL, TOC, VAT, STEC, SYNTEC, CK, TRC and CNT) were operated under the decreasing returns to scale (DRS) (or they have relatively large level of production comparing with the optimal – scale level).

4.2. The Input and Output Slacks

The results for the input and output slacks are shown in Table 5. The numbers in the table indicated the size of inputs that can be reduced by maintaining the current output level of the particular firm (input slacks) and the size of outputs that can be raised by using the current level of inputs (output slacks).

In this case, the results showed that the construction companies, namely TOC and CK could increase their revenue from sales and services (Y_1) by the amounts of 43.99 and 1,736.45 million Baht by using the current level of inputs. By the same token, RT, TRC, and CNT could increase their total revenue (Y_2) by 15.58, 4.05, and 0.13 million Baht, respectively by using the current level of inputs.

Table 5

The Input and Output Slacks for the Thai Construction Companies in 2009

Firm	Output Slacks		Input Slacks		
	y_1	y_2	x_1	x_2	x_3
RT	–	15.583	–	–	–
ACC	–	–	–	16.483	–
TOC	43.993	–	–	–	–
VAT	–	–	541.440	–	–
CK	1736.448	–	549.128	–	–
TRC	–	4.058	–	–	–
CNT	–	0.133	–	–	–

Source: Computed Results from the DEAP Version 2.1.

On the other hands, the construction companies, viz., VAT and CK could reduce their net value of lands, buildings, and equipments by 541.44 and 549.13 million Baht without affecting their level of outputs. Finally, ACC could decrease its Operating Cost by 16.48 million Baht by maintaining the current level of output.

4.3. The Productivity Change in the Thai Construction Sector

In order to compute the Malmquist index, the panel data on the inputs and outputs of these companies are collected during the period of 2005–2009. However, the results of the Malmquist Index are calculated only for 18 firms excluding of BCH and SSC, due to the lack of the data on the cost of sales and/or cost of services and the revenue from sales and services (Y_1) of both companies in 2005 and 2006, respectively. The results are shown in Table 6.

4.3.1. The Input Technical Efficiency Scores (E_i) from 2005–2009

By considering the input technical efficiency change (E_i), the results showed that only 4 firms including BECL, COM, JST, and TK have no evidence of changes in the input technical efficiency level during the period of 2005–2009. In the period of 2005/2006, only 5 companies (ACC, SCC, CUEL, CK, and TRC) exhibited a progress in the input technical efficiency, while the E_i scores of the rest 9 companies (RT, TOC, VAT, CMC, STEC, SYNTEC, TNS, ST, and CNT) in the same period indicated a regress in the input technical efficiency level.

Table 6

The Malmquist Indices and their Decomposition for the Thai Construction Companies during the Period of 2005–2009

Firm	2005/2006			2006/2007		
	E_i	T_i	M_i	E_i	T_i	M_i
BECL	1.000	0.963	0.963	1.000	1.043	1.043
RT	1.335	0.810	1.082	0.899	1.177	1.059
ACC	0.755	0.769	0.580	0.665	1.095	0.729
SCC	0.741	0.845	0.626	0.250	1.147	0.287
COM	1.000	0.841	0.841	1.000	1.213	1.213
CUEL	0.940	0.978	0.919	0.920	1.044	0.960
TOC	1.042	1.041	1.085	0.892	1.007	0.899

Firm	2005/2006			2006/2007		
	E_i	T_i	M_i	E_i	T_i	M_i
VAT	1.406	0.743	1.044	0.856	1.264	1.082
CMC	1.348	0.779	1.050	1.121	1.127	1.264
STEC	1.040	1.106	1.151	1.000	1.006	1.006
SYNTEC	1.176	0.891	1.047	0.939	1.105	1.037
CK	0.986	0.881	0.869	0.639	1.276	0.815
JST	1.000	0.768	0.768	1.000	1.204	1.204
TK	1.000	1.139	1.139	1.000	1.172	1.172
TNS	1.041	1.004	1.045	0.936	0.977	0.914
ST	1.344	0.875	1.176	0.903	1.033	0.933
TRC	0.819	0.941	0.771	0.837	1.280	1.072
CNT	1.061	0.989	1.049	1.044	1.022	1.066
Firm	2007/2008			2008/2009		
	E_i	T_i	M_i	E_i	T_i	M_i
BECL	1.000	0.950	0.950	1.000	1.005	1.005
RT	1.130	0.866	0.978	0.965	1.033	0.997
ACC	1.530	0.735	1.124	1.339	1.582	2.118
SCC	5.926	0.711	4.215	1.668	1.690	2.818
COM	1.000	0.673	0.673	1.000	1.533	1.533
CUEL	1.156	1.163	1.344	0.933	0.763	0.712
TOC	1.120	0.930	1.042	0.905	1.024	0.927
VAT	1.268	0.832	1.055	0.925	1.055	0.976
CMC	0.880	0.939	0.826	1.209	1.200	1.451
STEC	0.932	1.054	0.982	0.938	0.938	0.879
SYNTEC	1.126	0.925	1.042	1.018	1.018	1.036
CK	1.319	0.644	0.850	0.749	1.326	0.994
JST	1.000	0.842	0.842	1.000	0.948	0.948
TK	1.000	0.970	0.970	1.000	0.905	0.905
TNS	0.966	0.969	0.936	1.106	1.048	1.159
ST	0.700	0.878	0.614	1.744	1.151	2.008
TRC	1.189	0.783	0.931	1.134	1.020	1.157
CNT	0.961	0.952	0.915	0.986	1.014	1.000

Source: Computed Results from the DEAP Version 2.1.

The situation was changed for the latter year (the end of the prosperous period). During the period of 2006/2007, the results indicated that 11 construction firms (viz, RT, ACC, SCC, CUEL, TOC, VAT, SYNTEC, CK, TNS, ST, and TRC) from the overall 18 construction firms had the evidence of improvement in the input technical efficiency level, while STEC still maintained its technical efficiency at the level of the previous year. Only CMC and CNT exhibited the regression of their input efficiency level.

During the period of financial crisis (2007/2008), the results showed the evidence of the regression in the level of input technical efficiency of most firms $(E_i > 1)$ except for CMC, STEC, TNS, and ST. This evidence supports the idea that the fluctuation of the world economic situation has an impact on the efficiency level of domestic construction firms.

Finally, by the end of the financial crisis period (2008/2009), the results showed that the level of input technical efficiency of 7 construction companies (ACC, SCC, CMC, SYNTEC, TNS, ST, and TRC) were worsened than the previous year, while those of the rest 7 companies (RT, CUEL, TOC, VAT, STEC, CK, and CNT) showed the evidence of an improvement on the technical efficiency level.

4.3.2. The input technical change (T_i) from 2005–2009

The computed T_i represented the size of the input frontier shift. The results showed that during the period before the financial crisis, the input technical change scores of the 14 companies (BECL, RT, ACC, SCC, COM, CUEL, VAT, CMC, SYNTEC, CK, JST, ST, TRC, and CNT) that used to have the input technical improvement in 2005/2006 period were turned out to be worsening in 2006/2007 period. Moreover, the T_i scores for TOC, STEC, and TK indicated that the level of input technical change for these three companies was deteriorated during 2005–2006. Only the T_i scores of TNS in 2005/2006 and 2006/2007 periods which were equal to 1.004 and 0.977, respectively indicated the improvement of the level of the input technical change.

The T_i scores during the financial crisis period (2007/2008) showed that all companies except for CUEL and STEC were improve their level of input technical change $(T_i < 1)$. This was possible since all companies attempted to adjust themselves in order to confront with the financial crisis.

Finally, by the end of 2009, the result showed that only 4 companies including CUEL, STEC, JST, and TK exhibited the evidence of an improvement in the level of input technical change $(T_i < 1)$, while the T_i scores of the rest of 18 companies indicated the regression of the technical frontier line in this period.

4.3.3. The Malmquist Index of the Construction Companies from 2005–2009

The results of Malmquist index (M_i) in 2005/2006 period showed that there was an improvement on the productivity level of the 8 construction companies including BECL, ACC, SCC, COM, CUEL, CK, JST, and TRC $(M_i < 1)$. By contrast, the productivity level of the rest 10 companies (RT, VAT, TOC, CMC, STEC, SYNTEC, TK, TNS, ST, and CNT) in the same period was declined. The worse productivity in this period came from the deterioration of the input technical efficiency in most cases.

The situation was changing during 2006/2007 period. The Malmquist indices indicated that only 7 companies (ACC, SCC, CUEL, TOC, CK, TNS, and

ST) had improved their productivity level, while the productivity level of the rest 11 companies was regress. The reduction of the productivity level in this period mostly depended on the regression in the input technical change.

In the period of financial crisis (2007/2008), only 6 from 18 firms (ACC, SCC, CUEL, TOC, VAT, and SYNTEC) exhibited the reduction in the productivity level. However, the rest 12 companies showed the improvement of their productivity. In this period, the source of productivity improvement came from the overwhelming progress of the input technical frontier line over the effect of declining in the input technical efficiency.

Finally, in 2008/2009 period, the Malmquist indices indicated that only 7 firms including RT, CUEL, TOC, VAT, STEC, CK, JST, and TK improved their productivity level M_i . Moreover, the main source of improvement came from the development in their input technical efficiency. On the other hand, the productivity level of the other 10 companies (viz., BECL, ACC, SCC, COM, CMC, SYNTEC, TNS, ST, and TRC) was regressed in the same period due to the contribution of both input technical efficiency regression and the worsen input frontier technology.

5. Conclusion and Recommendation

The measurement of the productivity change of construction companies in Thailand in this study used the technique called DEA and its application of Malmquist index as a tool for analysis. In this case, the financial data on the net value of lands, buildings, and equipments, Operating Cost, and Cost of Sales and/or Cost of Services were used as the input variables, while the Revenue from Sales and Services (Y_1) and the total revenue of the construction company (Y_2) are treated as the outputs. The results from DEA model showed that although the construction companies earned large profits in 2009, 12 companies (RT, ACC, CUEL, TOC, VAT, CMC, STEC, SYNTEC, CK, ST, TRC, and CNT) still operated below the efficient frontier line. Among the inefficient firms, 9 of them (RT, CUEL, TOC, VAT, STEC, SYNTEC, CK, TRC, and CNT) operated within the range of decreasing returns to scale and 3 of them (ACC, CMC, and ST) had increasing returns to scale production function. The results for the input and output slacks suggested that some firms including ACC, VAT, and CK could reduce their inputs and still maintaining the level of their outputs and some of them (RT, TOC, CK, TRC, and CNT) could increase their outputs by using the same level of inputs. Only 8 companies from the top 20 highest profit companies in 2009 operated on the efficiency frontier line and with the optimal scale of production.

The computed results of Malmquist Index indicated the productivity change of the construction firms during 2005–2009 periods. This index can be decomposed into the input technical efficiency (E_i) and the input technical change. The study of the E_i scores exhibited a progress of the input technical efficiency of most firms during 2005/2006, but showed a regress of the input technical efficiency during the crisis period (2007–2009). In contrast, the improvement of the input technical change of most firms was emerged during the financial crisis period.

However, there are some criticisms about the results of DEA and the Malmquist index in this study. First, the efficiency scores and the Malmquist index are very sensitive to the changes of the input and output data (Talluri, 2000: 10). In this case, we only considered the financial variables from the income statements. Thus, the efficiency scores and the Malmquist might be different if we considered more variables from any other aspects of the construction companies. Second, DEA is the nonparametric method of estimation, thus the normal process in statistics such as hypothesis testing, the confidence interval estimation are out of the question (Talluri, 2000: 10). Finally, the reason why this study cannot include all variables on input and output sides is that some variables have negative number and some are zero, which the traditional DEA method could not be dealing with. Therefore, this is the challenge of the following studies that should consider the problems of negative or zero inputs and outputs in estimating DEA model.

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