A COMPARATIVE ANALYSIS ON EFFICIENCY AND TOTAL FACTOR PRODUCTIVITY IN CONSTRUCTION FIRMS BETWEEN KOREA AND JAPAN

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ABSTRACT: The aim of this study is to compare efficiency and Total Factor Productivity(TFP) between Korean and Japanese construction firms in Korea and Japan over the period of 2005-2011. The results of this study are as follows. Efficiency scores of Korean construction firms are 0.797, and Japanese construction firms are 0.921. Second, annual total factor productivity growth of Korean construction firms is 0.5% and technical progress do much for TFP decrease. However Japanese construction firms marked annual increasing of 2.5% of TFP. Third, technical progress contributed in TFP increase of construction firms in Korea. Korean construction firms, however, relatively lagged behind Japanese construction firms in technical progress. Therefore, Korean construction firms need strategies to achieve technical advances including adopting new technology or process innovation to maintain competitiveness, survive, and develop in the future competition with Japan.

Keywords: Data Envelopment Analysis; Malmquist Productivity Index; Total Factor Productivity; Construction Firm

1. INTRODUCTION

Construction industry is one of important national key industries that forms socially indirect capital, directly and indirectly contributes to the economic development of the country by establishing industrial facilities, and solves residential problems for people by residential construction[1]. Construction industry has been playing an important role in Korea's economic growth for last 60 years. According to the Construction Economy Research Institute Korea, the proportion of domestic construction investment against Korean GDP will maintain current level until 2020, and will continue the maturity stage[2]. Korean construction industry, which entered this maturity stage, is now facing a new change of targeting the global market, the advanced countries of construction industry including the United States and Japan, based on construction technologies and large-scale through M&A of recent global construction firms. The future of Korean construction industry is depended on how it will respond to changes of external environment and secure competitiveness. In order to respond to these changes, it is necessary to analyze efficiency and competitiveness of Korean construction firms.

The policies and systems of Korean construction industry are based on Japan's policies and systems, and few policies enforced in the United States and United Kingdom as well as domestic conditions are reflected, the attention to Japanese construction industry should be continued[3]. Japanese construction industry gives important influences to the survival and development of Korean construction industry as a competitor in the sense of future competitive structure, the comparison of their efficiencies and dynamic analysis of productivity change factors would be meaningful study.

The aim of this study is to compare efficiency and Total Factor Productivity(TFP) between Korean and Japanese construction firms in Korea and Japan over the period of 2005-2011. Data Envelopment Analysis(DEA) and DEA based Malmquist Productivity Index(MPI) model are employed to calculate the efficiency score and TFP of Korean and Japanese construction firms. Through this, it will be the preliminary data to establish strategies to reinforce competitiveness of Korean construction firms by comparing and analyzing changes in relative efficiency and productivity of Korean and Japanese construction firms.

DEA was first introduced in 1978 by Charnes *et al.* (1978). DEA is a data-oriented method for measuring the relative efficiency of Decision-Making Units(DMUs) performing similar tasks in a production system that consumes multiple inputs to produce multiple outputs. It can be applied to analyze multiple inputs and multiple outputs without preassigned weights; it can be used to measure a relative efficiency based on the observed data without knowing information relating to the production function; and it can incorporate decision maker's preferences into DEA models. Because DEA uses linear programming techniques to determine a best practice or efficient frontier of DMUs without prior assumptions on the underlying functional forms. It has been applied to various areas of efficiency evaluation[4].

Previous studies related to the efficiency of construction firms, Chau and Wang (2003) measure the productive efficiency of construction firms in Hong Kong and the rate of change of productive efficiency over time, and to explain the observed variations in productive efficiency across construction firms. Xue *et al*. (2008) measure the Malmquist Productivity Indices of the Chinese construction industry by using the DEA approach, and to analyze the productivity changes of the construction industry in China over the period of 1997-2003. Lee *et al*. (2010) analyzed for their connection between management efficiency evaluation and a ranking of construction capability evaluation in top 100 firms of the ranking. Output factors have a minus in chosen input-output factors for evaluating management efficiency of construction firms in Korea. Chiang *et al*. (2012) explore whether there is significant difference between the productive efficiency of Hong Kong and Mainland contractors. Previous studies applied traditional DEA method for most of cross-sectional data. Like this study, the research that analyzed dynamic productivity using MPI for panel data is Xue *et al*. (2005), however, it was based on Chinese region, not construction firms, and Chau *et al*. (2005) as well as Chiang *et al*. (2012) compared productivities among domestic firms, not among firms.

The rest of the paper is organized as follows. The next section presents how the DEA-based MPI works and visually describe the concepts of MPIs. Then input and calculation variables are selected to analyze efficiencies of Korean and Japanese construction firms. Next, the DEA based MPI is used to measure the changes in TFP. The conclusions are drawn in the last section.

2. DEA BASED MALMQUIST PRODUCTIVITY INDEX

MPI is to estimate distance function, which minimizes factors inserted for certain level of products by estimating TFP changes of organization or company using panel data that integrated cross-sectional and time series data, or distance function of maximum products with fixed inserting factors. MPI can disassemble TFP by Technical Change(TC) and Efficiency Change(EC) factors. Here, EC can be again classified by Pure Efficiency Change(PEC) or Scale Efficiency Change(SEC). Hence, MPI has advantages of estimating productivity changes dividing TC, the progress or regression of changed engineering by DMU based periods, and EC, the progress or regression of efficiency[5, 6].

Input-oriented MPI chosen for this study is as below. D_I^t, the input-based distance function at the specific time t, is the reciprocal of the value that minimized input factor x^t to result the producty^t. M^t, the Malmquist index at t, can be defined as below by the combination of time t, input factors at t+1, and products. M^{t+1}, the Malmquist index at t+1, can also be indicated similarly[6, 7].

$$M^t = \frac{D_I^t(x^{t+1},y^{t+1})}{D_I^t(x^t,y^t)}, \quad M^{t+1} = \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t,y^t)} \quad (1)$$

Meanwhile, when input-oriented total productivity change is deducted, to avoid arbitrariness in time selection, the random selection of evaluation period, it is necessary to get geometric mean of Malmquist indexes at the above two times, t and t+1.

$$M_I(x^{t+1},y^{t+1},x^t,y^t) = [\frac{D_I^t(x^{t+1},y^{t+1})}{D_I^t(x^t,y^t)} \times \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t,y^t)}]^{1/2} \quad (2)$$

If input-oriented MPI value in equation(2) is larger than 1, the corresponding DMU goes from t to t+1 to mean the productivity is enhanced, and if smaller than 1, it means the productivity decreased. In MPI, EC can be subdivided and disassembled to PEC index and SEC index (MPI = EC × TC = PEC × SEC × TC). If these concepts of PEC and SEC are adopted, MPI can be expressed as below.

$$\begin{aligned} M_I(x^{t+1},y^{t+1},x^t,y^t) &= \frac{V_I^{t+1}(x^{t+1},y^{t+1})}{V_I^t(x^t,y^t)} \\ &\times \left[\frac{V_I^t(x^t,y^t)}{D_I^t(x^t,y^t)} \times \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{V_I^{t+1}(x^{t+1},y^{t+1})}\right] \\ &\times [\frac{D_I^t(x^{t+1},y^{t+1})}{D_I^{t+1}(x^{t+1},y^{t+1})} \times \frac{D_I^t(x^t,y^t)}{D_I^{t+1}(x^t,y^t)}]^{\frac{1}{2}} \\ &= PEC \times SEC \times TC \quad (3) \end{aligned}$$

Equation (3), $V_I^t(x^t,y^t), V_I^{t+1}(x^{t+1},y^{t+1})$ presents input-based distance function supposing VRS at the times of t and t+1, $V_I^{t+1}(x^{t+1},y^{t+1})/V_I^t(x^t,y^t)$ shows PEC at t+1 about t, and other sections in braces show SEC and TC.

3. DATA AND VARIABLES

3.1 Data

To analyze the efficiencies and competitiveness changes of Korean and Japanese construction firms in this study, KISVALE DB of Korea Investors Service Inc. and OSIRIS DB of Bureau van Dijk are used. The sample firms are Korean and Japanese construction firms that are mainly dealing with general building among 225 global contractors announced by Engineering News-Record every year[8]. Among them, firms possible for securing time series data of input variables and output variables are

16 construction firms, and the analysis period was 7 years from 2005 to 2011.

The MPI measurement method is usually based on DEA. Because efficiency results changes according to selected variables with DEA, selection of input and output variables are important. Thus this study selected input and output variables and analyzed correlation between input and output variables from the previous study that analyzed the efficiency of construction firms. Table 1 shows input and output variables applied to efficiency analysis if construction firms using DEA model.

This study selected input and calculation variables mostly used in the previous research. Number of Employees, Total Assets, Capital are selected for input variables, and Operating Revenue for the output variable. As inputs, total asset value and number of employees are contractor's main resources of capital and labor. As inputs, total asset value and number of employees are contractor's main resources of capital and labor[9]. Because Capital is the total capital given to firms, proper input variable to judge the operational efficiency was regarded as Capital. The output variable was selected as operating revenue that is commonly included in the previous research. Operating revenue is the representative outcomes of the corporate operation, and is the most common variable used for the efficiency analysis.

Table 1. Input and Output Variables of Previous Studies

Author and year	DMUs	Inputs	Outputs
Chau and Wnag (2003) [10]	Construction firms in Hong Kong	Capital, Number of Employees, Construction Materials, Office overhead expenses	Operating Revenue
Chau *et al.* (2005) [11]	Construction firms in Hong Kong	Total assets, Capital, Construction materials	Operating Revenue
Chiang *et al.* (2012) [9]	Construction firms in China and Hong kong (2004-2010)	Total Assets, Number of employees, Cost of goods sold, Salaries plus expenses	Operating Revenue, Total profit
Lee *et al.* (2012) [12]	Construction firms in Korea	Number of Employees, Total Assets, Net Fixed Assets	Operating Revenue

Table 2 shows the descriptive statistics about input and output variables, and table 3 shows the result of correlation analysis between variables. The correlation analysis proved that variables except capital were regarding in the level of correlation coefficient 0.01, and in the case of correlation index, there is a strong relation of 0.902 ~ 0.958 between input and output variables.

Table 2. Descriptive Statistics of Input and Output Variables(2011)

Variable	Number of Employees (person)	Total Assets (mil $)	Capital (mil $)	Operating Revenue (mil $)
Average	6,843.3	10,181.0	1,830.6	7,932.6
Standard Deviation	5,138.3	7,216.7	2,146.4	5,780.5
Maximum	15,083.0	22,371.0	8,559.0	18,029.0
Minimum	1,294.0	1,460.0	163.0	1,564.0

Table 3. Correlation Analysis of Input and Output Variables

Variable	Number of Employees	Total Assets	Capital	Operating Revenue
Number of Employees	1	0.902**	-0.023	0.958**
Total Assets	0.0902**	1	0.323	0.909**
Capital	-0.023	0.323	1	-0.007
Operating Revenue	0.958**	0.909**	-0.007	1

4. ANALYSIS RESULT

4.1 Analysis result of DEA

Table 4 is the result of the efficiency analysis of Korean and Japanese construction firms using DEA method that includes 3 input variables and 1 output variable. The closer the value of the efficiency analysis is to 1, the more efficient firm it is. The firms with high average efficiency from 2005 to 2011 are J-DMU 8 in Japan with very high efficiency of average 0.992.

Table 4. Efficiency Result of Construction Firms

	DMU	05	06	07	08	09	10	11	Ave
JAPAN	J-DMU 1	1.000	1.000	1.000	0.972	0.962	0.995	0.957	0.984
	J-DMU 2	1.000	1.000	0.918	1.000	1.000	0.975	0.916	0.973
	J-DMU 3	1.000	0.912	0.958	1.000	1.000	1.000	0.983	0.979
	J-DMU 4	1.000	0.988	1.000	1.000	0.873	0.919	0.935	0.959
	J-DMU 5	0.976	0.900	0.723	0.782	0.788	0.924	1.000	0.870
	J-DMU 6	0.908	0.874	0.621	0.712	0.737	0.669	0.727	0.750
	J-DMU 7	0.874	0.816	0.804	0.799	0.744	1.000	1.000	0.862
	J-DMU 8	0.944	1.000	1.000	1.000	1.000	1.000	1.000	0.992
	Ave.	0.963	0.936	0.878	0.908	0.888	0.935	0.940	0.921
KOREA	K-DMU 1	0.813	0.927	0.965	0.939	1.000	1.000	1.000	0.949
	K-DMU 2	1.000	0.982	1.000	0.762	0.676	0.706	0.735	0.837
	K-DMU 3	0.740	0.676	0.709	0.720	0.448	0.498	0.421	0.602
	K-DMU 4	1.000	1.000	1.000	0.857	0.665	0.621	0.758	0.843
	K-DMU 5	0.790	0.752	0.820	0.680	0.429	0.553	0.720	0.678
	K-DMU 6	0.847	0.808	0.789	0.696	0.644	0.636	0.688	0.730
	K-DMU 7	0.857	1.000	0.985	0.776	0.699	0.542	0.708	0.795
	K-DMU 8	0.993	1.000	0.996	0.831	0.854	0.991	0.947	0.945
	Ave.	0.880	0.893	0.908	0.783	0.677	0.693	0.747	0.797
Total Ave.		0.921	0.915	0.893	0.845	0.782	0.814	0.843	0.859

Next is J-DMU 2 with the efficiency of 0.984. On the other hand, Korean construction firms K-DMU 1(0.949) and K-DMU 8(0.945) had relatively high efficiencies only, when K-DMU 4(0.843), K-DMU 2(0.837), K-DMU 7(0.795), and K-DMU-6(0.730) shows relatively low efficiencies.

Figure 1 shows the comparison of efficiencies between Korean and Japanese construction firms based on outcomes of each firms. the efficiency score of a Japanese construction firms is 0.921 which is close to 1. Whereas, Korean construction firms show 0.797 that is relatively low. However, we need to beware that as DEA is the model to evaluate relative efficiency, the estimated efficiencies are relative, not absolute. Thus, even though a company is evaluated as the most efficient, we cannot consider it with no possible improvement.

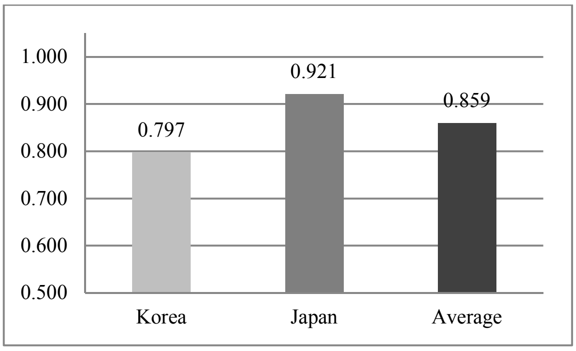


Figure 1. Comparison of Average Efficiency

4.2 Analysis result of DEA based Malmquist Productivity Index

Table 5 shows the analysis of TFP changes by MPI. Because MPI is indicated as compared ratio to previous period, if this number is larger than 1, it means the productivity increased compared to the former, and when it is smaller than 1, it means the productivity fell. During the analysis period from 2005 to 2011, the average MPI of Korean and Japanese construction firms is 0.999 that they are showing the decrease in productivity for average 0.1% every year. When we look at the MPI in the same period, Japan shows 1.025 that indicates productivity increase of 2.5% annually. Especially in the case of J-DMU 8, it shows the highest productivity increase among 16 targets with 9.1%, and other Japanese construction firms excluding J-DMU 1, J-DMU 2, and J-DMU 4 are showing the increases in productivity. On the other hand, in case of Korea, the MPI from 2005 to 2011 is 0.995 that it shows not only lower productivity compared to Japanese construction firms, but also the decrease of 0.5%. As shown in the efficiency analysis, efficiencies of Korean construction firms are inefficient, as TFP of Japanese construction firms is rapidly increasing, it can be interpreted that the TFP relatively decreased.

Figure 2 shows the progress based on 2005 by calculating accumulated index of Korean and Japanese Total Factor Productivity Index(TFPI). In terms of productivity changes, Korea and Japan show very contrasting conditions. In other words, while Japanese construction firms show high productivity increase after 2007, Korean construction firms recorded continuous decrease that the gap between Korean and Japanese productivity increase is widely expanded.

Table 5. Changes of Malmquist Index

	DMU	05-06	06-07	07-08	08-09	09-10	10-11	05-11
JAPAN	J-DMU 1	1.045	0.996	1.017	1.179	0.831	0.804	0.979
	J-DMU 2	1.026	1.034	1.160	1.108	0.805	0.831	0.994
	J-DMU 3	0.924	1.125	1.103	1.296	0.762	0.834	1.007
	J-DMU 4	0.941	0.971	1.284	0.930	0.913	0.874	0.986
	J-DMU 5	0.947	0.919	1.149	1.151	1.006	0.946	1.020
	J-DMU 6	1.068	1.058	1.267	0.96	0.993	0.969	1.053
	J-DMU 7	0.962	1.055	1.078	1.200	1.283	0.850	1.071
	J-DMU 8	1.309	1.217	1.072	1.009	0.996	0.942	1.091
	Avg	1.028	1.047	1.141	1.104	0.949	0.881	1.025
KOREA	K-DMU 1	1.175	1.022	1.078	1.162	1.057	0.912	1.068
	K-DMU 2	0.938	0.950	0.779	0.990	1.050	0.938	0.941
	K-DMU 3	1.091	1.069	1.015	0.728	1.117	0.802	0.970
	K-DMU 4	1.154	1.002	0.881	0.883	0.947	1.086	0.992
	K-DMU 5	1.066	1.085	0.835	0.714	1.309	1.235	1.041
	K-DMU 6	1.039	0.968	0.931	1.043	1.031	0.962	0.996
	K-DMU 7	1.159	0.915	0.834	0.981	0.738	1.164	0.965
	K-DMU 8	1.018	0.844	0.904	1.182	1.093	0.869	0.985
	Avg	1.080	0.982	0.907	0.960	1.043	0.996	0.995
Total Avg		1.049	1.011	1.013	1.019	0.969	0.931	0.999

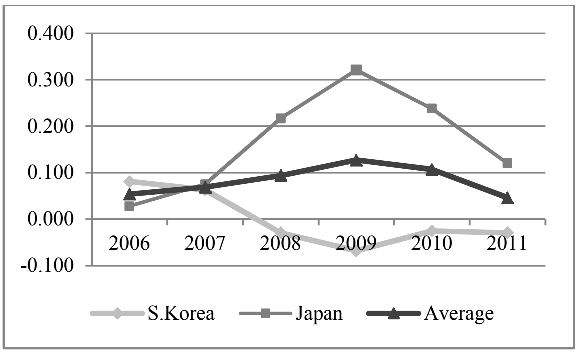


Figure 2. Progress of Accumulated Index of Total Factor Productivity

As TFP is the index that shows comprehensive competitiveness including technical advances, technical efficiency, and economy of scale, if it increases, it means the production ability that can produce with given production factors improves[13]. The useful thing of the MPI analysis is that it can estimate TFP changes, and at the same time it can disassemble productivity change to technical changes and efficiencies, then changes in technical efficiency can be again disassembled to changes in pure technological efficiency and size. Table 6 shows the MPI disassembled to changes of technology, technological efficiency, and size.

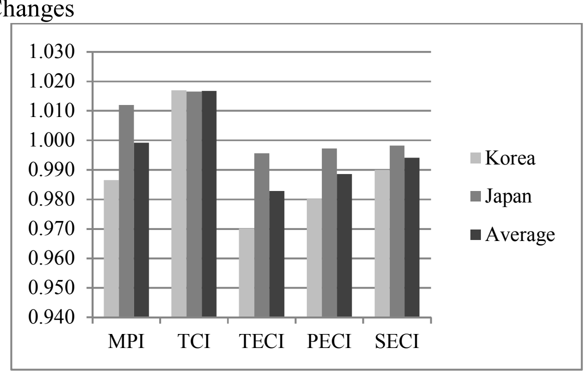
Table 6. Decomposition of Malmquist Index

	TFPI	TCI	TECI	PECI	SECI
JAPAN Avg	1.011	1.016	0.995	0.997	0.997
KOREA Avg	0.986	1.016	0.969	0.979	0.989
Total Avg	0.999	1.016	0.982	0.988	0.994

The average MPI between Korean and Japanese construction firms is 0.999 that shows annual productivity decrease of average 0.1%. Among decrease in this factor productivity, the Technical Change Index(TCI) is 1.016 and Technical Efficiency Change Index(TECI) is 0.982 that technical efficiency decreases average 1.8% annually while technical development was 1.6% annually, thus the technical advances absolutely contributed to the increase of TFP.

When we see the changes in Japan's TFP, MPI is 1.011 that shows 1.1% productivity increase every year. Productivity change from technical advances among them is 1.016, and TECI is 0.995 that Japan's TFP is also caused mainly by technical advances. On the other hand in case of Korea, TFPI in the same period decreases average 1.4% every year that is caused by relatively recessed technical advances despite of no change in technical efficiency.

Table 3. Decomposition of Total Factor Productivity Changes



5. CONCLUSIONS

Using non-parametric inferences DEA and MPI, this study analyzed and compared changes of efficiency and TFP between Korean and Japanese construction firms. Moreover, by disassembling changes in TFP of their steel industries by technical advances and technical efficiency factors, it tried to deduct the current status and directions for future strategy establishment of Korean construction firms.

The summary of this study is as below. First, as a result of efficiency estimation of Korean and Japanese construction firms, Japan is 0.921 that shows relatively high efficiency. On the other hand, efficiency index of Korean construction firms is 0.859 that is relatively lower than that of Japan. Second, as a result of TFP change by MPI, Japan shows annual 2.5% productivity increase rate from 2005 to 2011 while Korea shows productivity decrease with 0.995 MPI. Third, as the result of the disassembly of TFP change to technical and technical efficiency changes, Korean and Japanese construction firms show average 0.1% productivity decrease every year from 2005 to 2011. Among them, because technical advance rate is average 1.6% every year while technical efficiency decreased 1.8%, the TFP increase of Korean and Japanese construction firms in the same period was fully from the technical advances. Fourth, when we see the TFP changes of Korean and Japanese construction firms, in case of Japanese construction firms, the technical advance ratio increase 1.6% and TECI decreased 0.5% that the TFP increase in Japan is also caused mostly by technical advances. On the other hand in case of Korea, TFP during the same period is decreasing average 0.1% annually, because even though technical efficiency increases 1.6%, the technical advance relatively recessed. Therefore, Korean construction firms need strategies to achieve technical advances including adopting new technology or process innovation to maintain competitiveness, survive, and develop in the future competition with Japan.

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