Comparing the Efficiency and Productivity of Construction Firms in China, Japan, and Korea Using DEA and DEA-based Malmquist

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Abstract

The competitiveness of construction firms may be achieved by effective decision-making and high productivity. Therefore, it is necessary to analyze the efficiency and productivity of construction firms. This study aims to compare the efficiency and productivity of Chinese, Japanese and Korea construction firms between 2005 and 2011 using Data Envelopment Analysis (DEA) and DEA-based Malmquist methods. The analysis process is as follows: 1) Decision Making Units, input and output variables are selected. 2) Efficiency of Chinese, Japanese and Korean construction firms is analyzed by applying DEA and selected variables. 3) Productivity of construction firms is presented as the Malmquist Productivity Index (MPI) by using DEA-based Malmquist and by dividing the MPIs into Technical Change Index and Technical Efficiency Change Index. The analysis results are: 1) the average efficiency score of Korean construction firms (0.861) is higher than those of Japanese construction firms (0.775) and Chinese construction firms (0.639), 2) the average MPI of Chinese construction firms (5.5%) is higher than those of Korean construction firms (0.9%) and Japanese construction firms (-0.1%). The results show that Korean construction firms need to improve productivity more than efficiency to enhance their competitiveness in the market.

Keywords: construction firms; DEA; DEA-based Malmquist; efficiency; productivity

1. Introduction

Since 1962, the Korean construction industry has grown rapidly due to the new demands for infrastructures and housing according to rapid domestic economic growth (Kim et al., 2003; Lee et al., 2013). With enhanced technical ability and competitive price in the field of infrastructure construction and general building, Korean firms tried to enlarge their share of the global market (Jang et al., 2010; Park et al., 2010). However, according to The Economist (2012), Chinese construction firms have become new challengers in the global construction market, surpassing Japan, which had been one of the dominant powers in the global construction market for the past decade. As a consequence, the number of Japanese firms appearing in the top ten construction firms became nil in 2012 from four in 2003. On the contrary, three Chinese construction firms were ranked 1st, 2nd, and 3rd in the global construction market in 2012. Korean construction firms are caught between Chinese firms with their price competency and Japanese firms with technical excellence. Accordingly, competition among Chinese, Japanese, and Korean construction firms has become severe. The future of the Korean construction firms lies in devising measures to respond to changes in East Asian regions, and in becoming competitive. Competitiveness may be achieved by effective decision-making and improved productivity (Xue et al., 2008). A comparison of the efficiency and productivity of construction firms from three countries must be meaningful because of their geographical proximity and tightly competitive structure. In order to analyze the efficiency and productivity, in general, multiple input and output variables should be considered simultaneously (Martić et al., 2009). However, interpretation of the relations among these variables requires a complicated model consisting of various functions. Unlike traditional analytical methods, Data Envelopment Analysis (DEA) can consider multiple input and output variables in an integrated manner and does not need a function form of a specific model.
This study aims to compare the efficiency and productivity of Chinese, Japanese, and Korean construction firms from 2005 to 2011 using the DEA and DEA-based Malmquist methods. The analysis results are presented as the efficiency score and Malmquist Productivity Index (MPI) changes.

2. Top Chinese, Japanese and Korean Firms

Based on 2006–2012 data on the top 225 global construction firms/contractors from Engineering News-Record, the total revenue portions of the above construction firms were compared by nation (Fig. 1.).

In 2005, the portion of Japanese construction firms was 16.5%, which was higher than that of Korea and China. However, Chinese construction firms’ portion rapidly increased from 2007 onwards. On the other hand, the weights of Japanese and Korean construction firms have remained close to 5% since 2005. Meanwhile, the number of Chinese construction firms increased from 23 in 2005 to 41 in 2011.

3. Literature Review

3.1 DEA and DEA-based Malmquist

Efficiency is often used to mean the ratio of input to output, and signifies evaluation of the internal operation of a firm (Park, 2008). Existing efficiency analysis methods include the function approach and ratio analysis. Nonetheless, it is difficult to consider multiple input and output variables in such an analysis; moreover, it is a parametric method. Therefore, a specific function form for the analysis model should be assumed (Sueyoshi and Goto, 2009). On the other hand, the advantages of DEA are that it can consider multiple input and output variables in an analysis, and does not need to assume a specific function for the analysis model because it is a non-parametric method (Park, 2008). DEA was first introduced by Charnes et al. (1978) to assess the relative efficiency of organizational units with multiple input variables to produce multiple output variables.

Productivity refers to the ratio of production element amount input in order to produce some performance to output amount. The Malmquist Index, which can measure productivity, was defined by Malmquist (1953). Fare et al. (1994a) developed DEA-based Malmquist, a method to measure MPI. MPI is a relative index that can compare performance among businesses for the same or different periods. With MPI, the causes of firms’ changes in productivity over time also can be determined. MPI is classified into technical efficiency change index (TECI) and technical change index (TCI). The causes of firms’ productivity changes can be explained by TECI and TCI through such classification (Xue et al., 2008).

3.2 Previous Studies

DEA has often been used to analyze the efficiency of construction firms at the level of nation. Chau and Wang (2003) first applied DEA to Hong Kong construction firms to measure their production efficiency and analyze the factors affecting efficiency. After Chau and Wang’s initial exploratory study, Chau et al. (2005) analyzed the efficiency of construction firms in Hong Kong. McCabe et al. (2005) developed an enhanced contractor prequalification model using DEA together with a methodology for determining a “practical frontier” of best contractors. El-Mashaleh et al. (2007) proposed a benchmarking model for construction firms using DEA. Sueyoshi and Goto (2009) proposed the practical use of DEA-discriminant analysis (DEA-DA) for bankruptcy-based performance assessment. Horta et al. (2010) suggested models for performance assessment of Portuguese construction firms using key performance indicators and DEA. Seo and Choi (2011) analyzed the efficiency of construction firms in Korea using a combined AHP and DEA model. Tsolas (2011) proposed a framework to evaluate the profitability and effectiveness of Greek construction firms using DEA and Tobit.

Several applications using the DEA-based Malmquist to evaluate productivity change over time have been explored in various industries. Fare et al. (1994b) studied productivity development in Swedish hospitals operating in a nonmarket environment, where radial DEA efficiency scores are used. Mahadevan (2002) used DEA to calculate MPI, dividing it into TCI, TECI, and change in scale efficiency to explain the 1981–1996 productivity growth performance of Malaysia’s 28 manufacturing industries. Camanho and Dyson (2006) used DEA and Malmquist indices to develop measures for comparing groups of DMUs, illustrating the approach with an application to assess the performance of commercial bank branches in Portugal. Chen and Yang (2011) compared the productivity growth of banking industries in Taiwan and China using the generalized meta-frontier MPI.

This study focused on comparing the efficiency and productivity of construction firms in different nations. Previous studies analyzed the efficiency of construction firms of a specific country, or analyzed productivity by applying DEA-based Malmquist to diverse areas. Therefore, this study intends to compare the efficiency and productivity of construction firms in
China, Japan, and Korea using DEA and DEA-based Malmquist, which are judged appropriate for efficiency and productivity analysis of firms in different nations.

4. Model of DEA and DEA-based Malmquist

DEA is used to derive the most efficient frontier using input and output variables, and then measure relative efficiency with distance from other decision-making units (DMUs). Formula (1) is the expression of DEA.

\[
\text{MAX } \theta, \alpha x_0 - \chi \beta \geq 0, \gamma_0 - \chi \beta \leq 0, \beta \geq 0 \quad (1)
\]

Here, \( \theta \) is the input variable multiplier of \( \text{DMU}_0 \), \( x_0 \) and \( y_0 \) are the input and output variable vectors of \( \text{DMU}_0 \), and \( X \) and \( Y \) are the input and output variable matrices of \( \text{DMU}_t \), and \( \beta \) is a weight vector. The value of \( \text{DMU}_0 \) is 1 or smaller and the efficiency score of \( \text{DMU}_0 \). When the efficiency score of \( \text{DMU}_0 \) is 1, \( \text{DMU}_0 \) is evaluated to be efficient; and when the score is smaller than 1, \( \text{DMU}_0 \) is evaluated to be inefficient. When some DMUs are inefficient, a hypothetical DMU more efficient than the DMU exists, and is composed of a linear combination of DMUs whose \( \beta_j > 0 \) is greater than zero.

DEA-based Malmquist measures movement of the efficient frontier and DMUs by period in the form of an index. In addition, it forms a frontier through DEA; the distance between the formed frontier and DMU is measured to find MPI (Park, 2008). \( D_t \), the input-based distance function at time \( t \), is the reciprocal of the value minimizing input factor \( x^t \) to compute productivity. \( M_t \), the Malmquist index at \( t \), can be defined as shown below by combining time \( t \), input factors at \( t + 1 \), and products. \( M_t \), the Malmquist index at \( t + 1 \), can also be indicated similarly (Fare, 1988).

\[
M_t = \frac{V_t^t(x_t^t, y_t^t)}{V_t^1(x_t^1, y_t^1)} \quad M_{t+1} = \frac{V_{t+1}(x_{t+1}^* y_{t+1}^*)}{V_t^1(x_t^1, y_t^1)} \quad (1)
\]

Meanwhile, when input-oriented total productivity change is deducted, to avoid arbitrariness in time selection—the random selection of an evaluation period, it is necessary to obtain the geometric mean of Malmquist indexes at times \( t \) and \( t + 1 \) (Caves et al., 1982).

\[
M_t(x_t^t, y_t^t, x_t^t, y_t^t) = \left( \frac{\partial V_t^t(x_t^t, y_t^t)}{\partial \{x_t^t, y_t^t\}} \times \frac{\partial V_{t+1}(x_t^* y_{t+1})}{\partial \{x_{t+1}^* y_{t+1}\}} \right)^{1/2} \quad (2)
\]

If the input-oriented MPI value in model (2) is greater than 1, the corresponding DMU goes from \( t \) to \( t + 1 \), indicating an increase in productivity, and a value of smaller than 1 indicates a decrease in productivity. In MPI, TECI can be subdivided and disassembled into Pure Efficiency Change Index (PECI) and Scale Efficiency Change Index (SECI) (MPI = TECI \( \times \) TCI = PECI \( \times \) SECI \( \times \) TCI). PECI is the frontier efficiency approaching the DMU between period \( t \) and \( t + 1 \) and SECI is the extent of economy scale approaching it. (Park, 2008) If these concepts of PECI and SECI are adopted, MPI can be expressed as follows (Sekhri, 2011).

\[
M_{t+(x_{t+1}, y_{t+1}, x_{t+1}, y_{t+1})} = \frac{V_{t+1}(x_{t+1}^* y_{t+1})}{V_t^1(x_t^1, y_t^1)} \times \frac{V_{t+1}(x_{t+1}^* y_{t+1})}{V_{t+1}(x_{t+1}^* y_{t+1})} \times \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}(x_{t+1}, y_{t+1})} \quad (3)
\]

Model (3), \( V_t^1(x_t^1, y_t^1) \), presents an input-based distance function supposing variable return to scale at times of \( t \) and \( t + 1 \), \( V_{t+1}(x_{t+1}^*, y_{t+1}^*)/V_t^1(x_t^1, y_t^1) \) shows PECI at \( t + 1 \) about \( t \), and the other sections in brackets show SECI and TCI.

5. Analysis and Findings

In this study, input and output variables for the efficiency and productivity analysis are first selected. Second, based on the selected variables, efficiency is analyzed using DEA, and the average efficiency scores of China, Japan, and Korea are compared. Third, productivity is analyzed using DEA-based Malmquist and the MPIs of the three nations are compared. By dividing the MPIs into TCI and SECI, the causes of MPI changes are analyzed.

5.1 Selection and Descriptive Statistics of Variables

To analyze construction firms in China, Japan, and Korea, firms among the ENR 2012 top 225 global contractors whose time series data on input and output variables could be obtained were chosen: 9 construction firms in China, 12 in Japan, and 11 in Korea. In order to analyze efficiency and productivity changes of construction firms, the data were examined for the seven-year period (2005–2011). The initial monetary data were adjusted to reflect inflation factors using Purchasing Power Parity rates provided by the IMF (International Monetary Fund) and GDP deflator of three nations provided by KSIS (Korean Statistical Information Service). For the DEA and DEA-based Malmquist analyses, EnPAS software developed by Park (2008) was used.

The scores in the efficiency analyses using DEA vary according to input and output variables; therefore, the selection of input and output variables is important. This study chose the input and output variables most frequently used in previous studies, which are shown in Table 1.

Chau and Wang (2003) used capital, number of employees, construction materials, and office overhead expenses; Horta et al. (2010) used number of employees, total assets, and net fixed assets; and
Lee et al. (2012) used capital, number of employees, and selling and administrative expenses. Most studies used total revenues as an output variable. The input variables selected in this study are number of employees, total assets, capital, and selling and administrative expenses. The output variable is total revenues. In an efficiency analysis using DEA, the number of DMUs is restricted by the number of input and output variables. In addition, as the number of input and output variables increases, the number of efficient DMUs goes up; therefore, classification of inefficient DMUs becomes difficult. Thus, analyzing with a minimum number of input and output variables is desirable. Previous researchers have presented different standards for an adequate number of DMUs, input variables and output variables. In this study, the number of DMUs, input variables, and output variables was 32, 4, and 1, respectively, which satisfied all the standards of existing researchers. The authors anticipate that efficient DMUs and inefficient DMUs will be well differentiated.

Table 2 presents the descriptive statistics of selected input and output variables. The mean of input and output variables of Chinese construction firms is higher than Japan, Korea, and the overall nation average. The mean of capital, total assets, selling and administrative expenses, and total revenues of the construction firms in Japan and Korea is similar, and the mean of number of employees of construction firms in Japan is about twice that of Korea.

5.2 Analysis Results of Efficiency

To facilitate comparison, Table 3 presents the efficiency scores of the construction firms in China, Japan, and Korea between 2005 and 2011.

Fig.2 illustrates the average efficiency score of the construction firms from three countries. The average 2005–2011 efficiency score of the Korean firms (0.861) is higher than the 2005–2011 average efficiency score of the Japanese firms (0.775) and Chinese firms (0.639). The average efficiency scores of Japanese and Korean construction firms are greater than 0.83 from 2005–2008, and are less than 0.76 in 2009.

Table 1. Selected Variables in Previous Studies

| Author | Inputs | Outputs |
|--------|--------|---------|
| Chau and Wang (2003) | Capital, Number of employees, Construction materials, Office overhead expenses | Total revenues |
| Chau et al. (2005) | Total assets, Capital, Construction material | Total revenues, Payment to subcontractor |
| El-Mashaleh et al. (2007) | Number of employees, Operating expenses | Total revenues |
| Horta et al. (2010) | Number of employees, Total assets, Net fixed assets | Total revenues |
| Seo and Choi (2011) | Total assets, Selling and administrative expenses, Total debt | Total revenues, Operating profit |
| Tsolias (2011) | Total operating cost, Selling and administrative expenses | Total revenues, Net income before taxes |
| Lee et al. (2012) | Capital, Number of employees, Selling and administrative expenses | Total revenues |

Table 2. Descriptive Statistics of Selected Variables

| Author | Input variables | Output variable |
|--------|-----------------|----------------|
| Number of employees | Capital (mil $) | Total assets (mil $) | Selling & admin. expenses (mil $) | Total revenues (mil $) |
| China | Max. 294,761 | 7,216 | 76,891 | 7,083 | 84,554 |
| Min. 485 | 130 | 1,023 | 46 | 362 |
| S.D. 91,763 | 1,888 | 23,879 | 1,552 | 25,253 |
| Mean 84,590 | 2,059 | 27,546 | 1,724 | 25,991 |
| Japan | Max. 16,003 | 1,134 | 17,988 | 1,061 | 17,635 |
| Min. 973 | 50 | 1,081 | 113 | 1,119 |
| S.D. 4,557 | 279 | 5,914 | 328 | 5,252 |
| Mean 7,147 | 87 | 7,510 | 446 | 6,942 |
| Korea | Max. 7,053 | 2,258 | 23,090 | 1,347 | 12,756 |
| Min. 919 | 127 | 1,165 | 90 | 1,308 |
| S.D. 1,330 | 540 | 4,436 | 226 | 3,025 |
| Mean 3,140 | 511 | 7,058 | 407 | 6,034 |
| Nation avg. | Max. 294,761 | 7,216 | 76,891 | 7,083 | 84,554 |
| Min. 485 | 50 | 1,081 | 46 | 362 |
| S.D. 60,413 | 1,284 | 16,212 | 1,038 | 16,423 |
| Mean 27,522 | 885 | 12,977 | 793 | 11,987 |

S.D.: Standard Deviation

The reasons may be the restructuring of and decreases in investment in Korean and Japanese firms due to the global financial crisis in 2008. From 2010–2011, the average efficiency score of Korean construction firms was greater than 0.8, but the average efficiency score of Japanese construction firms was less than 0.75.
efficient, followed by KDMU-7 (0.993), KDMU-4 (0.986), and JDMU-10 (0.951). The average efficiency scores of the Korean firms are greater than 0.8, except for KDMU-8 (0.731), KDMU-9 (0.744), and KDMU-10 (0.696), indicating high average efficiency scores. On the other hand, the average efficiency scores of construction firms in China are less than 0.7, except for CDMU-5 (1.000), CDMU-3 (0.894), and CDMU-2 (0.812), indicating lower average efficiency scores. Specifically, the average efficiency scores of CDMU-8 (0.419) and CDMU-6 (0.376) are less than the other construction firms' scores of all three nations.

### 5.3 Analysis Results of Productivity

In order to compare the MPI of construction firms in China, Japan, and Korea, this study used DEA-based Malmquist. Table 4. shows the firms' MPI in different periods (2005–2011). Fig.3. shows the component shifts in TECI and TCI during each period. The authors first analyze the data of the three nations reported in Table 4.

The values of MPI \(^{15}\) are greater than 1 in the reported period\(^{16}\), except for the periods 2006–2007 and 2009–2011, showing a productivity improvement in the three nations from 2005–2011. Productivity improved to 11.5% from 2005–2006, 2.2% from 2007–2008, and 2.1% from 2008–2009, but declined 2.0% from 2006–2007, 6.2% from 2009–2010, and 1.7% from 2010–2011.

To examine MPI by firms, the productivity of CDMU-6 improved by 28.0% from 2005–2011, exhibiting the largest increase in total productivity among the firms. This was followed by CDMU-7 at 24.7% from 2005–2011. On the other hand, the productivity of CDMU-2 declined by 6.6% from 2005–2011, which is the smallest decrease in productivity among the 32 construction firms.

Comparing the three nations with the construction firm average (Table 4.), the improvement of productivity in Chinese construction firms is larger than the improvement of the three nation average productivity. The productivity improvement in Korean
Productivity of the Chinese construction firms improved during the period from 2005–2009, but not for 2009–2011. The productivity of the construction firms in Japan improved 7.0, 4.2, 3.1, and 0.7% in the period 2005–2009. The productivity of the Japanese construction firms declined 10.9, and 3.9% from 2009–2011, and 0.2% overall in 2005–2011.

Table 4. Results of MPI from 2005–2011

| DMUs | 05-06 | 06-07 | 07-08 | 08-09 | 09-10 | 10-11 | 05-11 |
|------|-------|-------|-------|-------|-------|-------|-------|
| KDMU-1 | 1.050 | 0.796 | 1.089 | 1.196 | 1.070 | 0.822 | 0.998 |
| KDMU-2 | 1.041 | 0.545 | 0.901 | 1.245 | 1.096 | 0.857 | 0.934 |
| KDMU-3 | 0.998 | 1.006 | 0.764 | 1.212 | 1.027 | 1.133 | 1.018 |
| KDMU-4 | 0.949 | 1.028 | 0.917 | 1.080 | 1.027 | 0.940 | 0.989 |
| KDMU-5 | 1.090 | 1.085 | 1.102 | 1.345 | 0.830 | 0.950 | 1.061 |
| KDMU-6 | 2.992 | 0.673 | 1.328 | 1.026 | 1.106 | 1.117 | 1.280 |
| KDMU-7 | 3.411 | 0.974 | 1.090 | 1.018 | 0.723 | 1.035 | 1.247 |
| KDMU-8 | 1.100 | 1.106 | 0.960 | 0.935 | 0.983 | 1.017 | 1.016 |
| CDMU-9 | 0.967 | 0.742 | 1.244 | 1.473 | 1.000 | 0.567 | 0.976 |

Productivity of the Japanese construction firms improved 16.8% from 2008–2009, but the TECI declined 13.4% from 2008–2010 and 11.7% from 2010–2011 (see Fig.3.). Japanese construction firms have enhanced construction technology through technological innovation. The decline of TECI is one of the reasons that extra expenses were increased by multiple participants in projects, such as owners, contractors, architectural design firms, and construction firms. Another reason is that the construction field is subcontracting 4–5 steps due to lack of legal systems to restrict subcontracting.

Aspects of Chinese construction firms

Productivity of the Chinese construction firms improved to 38.3% from 2005–2006, respectively. The 2005–2006 productivity improvement is the highest during the periods and among the three nations in the study. Chinese construction firms' productivity declined 12.6, 1.9, and 7.0% from 2006–2007 and 2009–2011, and improved 3.7, and 16.4% from 2007–2009. The improvement results from the positive shift of TCI and TECI, because the averages of TCI and TECI from 2005–2011 are larger than 0% (see Fig.3.). Although the shifts of TECI and TCI are negative in the periods 2006–2007, and 2009–2011, the TECI improved 33.8% from 2005–2006; TCI improved 14.2% from 2008–2009 (see Fig.3.). Chinese construction firms' productivity increased because of China's abundant domestic construction market, its technological development, and its accumulating experience by focusing on advancing into ODA projects. Another reason is that the work loads of China's major construction firms were comprehensively managed, and thus stable given that the central and local governments own the companies.

Aspects of Japanese construction firms

Productivity of the Japanese construction firms improved during the period from 2005–2009, but not for 2009–2011. The productivity of the construction firms in Japan improved 7.0, 4.2, 3.1, and 0.7% in the period 2005–2009. The productivity of the Japanese construction firms declined 10.9, and 3.9% from 2009–2011, and 0.2% overall in 2005–2011.

Note that the TCI of the Japanese firms improved 16.8% from 2008–2009, but the TECI declined 13.4% from 2008–2009 and 11.7% from 2010–2011 (see Fig.3.). Japanese construction firms have enhanced construction technology through technological innovation. The decline of TECI is one of the reasons that extra expenses were increased by multiple participants in projects, such as owners, contractors, architectural design firms, and construction firms. Another reason is that the construction field is subcontracting 4–5 steps due to lack of legal systems to restrict subcontracting.

Aspects of Korean construction firms

Productivity of the Korean construction firms improved from 2005–2008, 2010–2011, and 2005–2011 overall, but not for 2008–2010. The productivity of the firms in Korea improved 1.8, 2.2, 1.1, 7.0 and 0.9 from 2005–2008, 2010–2011 and 2005–2011, and declined 4.2 and 2.1% in the period 2008–2010. The reason is that the TECI declined 0.5% from 2005–2011, while the TCI improved 1.5% from 2005–2011 (see Fig.3.). This implies that the cause of the productivity improvement in Korean firms was a decrease in the TCI. The Korean firms' productivity is lower than that of the Chinese firms. The authors feel that the reason was that the number and size of construction projects by Korean firms were small relative to Chinese construction firms', and that therefore the former lacked technical experience; in addition, business boundaries in the Korean construction industry made comprehensive management of the participants difficult.

5.4 Discussion

This study presented attitudes to improve the efficiency and productivity of Korean construction firms based on a comparison of efficiency and productivity among construction firms in China, Japan, and Korea. The average efficiency score of Korean firms was higher than that of the Chinese firms. The authors feel that the reason was that the number and size of construction projects by Korean firms were small relative to Chinese construction firms', and that therefore the former lacked technical experience; in addition, business boundaries in the Korean construction industry made comprehensive management of the participants difficult.
Therefore, management in Korean construction firms is more efficient than in Chinese and Japanese construction firms. The MPI of Korean construction firms from 2005–2011 was higher than that of Japanese firms, but very low compared to Chinese firms. In particular, the decrease in TECI was the cause of a productivity decline in Korean construction firms; accumulation of technological experience and improvement in management among firms participating in construction projects are necessary. The authors also estimate that construction plans and management tasks performed by the government and firms, and business boundaries of the construction industry, need to be improved to become competitive. Meanwhile, Korean firms should establish collaborative relationships with Chinese firms that own massive overseas and domestic construction markets, through strategic partnerships and consortiums, not competitive relationships, to accumulate technical experience.

In previous research, efficiency and productivity were analyzed individually at the level of a single nation. In this research, both are analyzed in an integrated manner. In addition, the analysis is expanded to compare those of several countries in competitive situations.

6. Conclusion

Korean construction firms in East Asia are caught between Chinese firms with price competency and Japanese firms with technical competency. This means that Korean construction firms are likely to be countered by China and Japan in terms of price and technology. Accordingly, this study compared the efficiency and productivity of Chinese, Japanese, and Korean construction firms to improve the competitiveness of Korean construction firms by using DEA and DEA-based Malmquist. In order to analyze efficiency and productivity, this study selected input and output variables, and analyzed the efficiency scores of the three nations using DEA. In addition, this study analyzed the three nations' MPI using DEA-based Malmquist and presented the causes of increases and decreases in productivity by nation. Finally, this study defined attitudes to gain competitiveness through enhancement of Korean construction firms' efficiency and productivity. The efficiency of Korean construction firms was higher than Chinese and Japanese firms, whereas the productivity of Korean firms declined compared with Chinese ones. This indicates that Korean construction firms need to improve productivity more than efficiency in order to improve their competitiveness. The findings of this study will contribute to strengthening Korean construction firms' market competitiveness and to devising strategies for its construction industry. Future research should compare the efficiency and productivity of countries beyond East Asia and consider qualitative as well as quantitative variables.

Notes

1. The function approach includes regression analysis and the index approach. Ratio analysis evaluates a business’s financial and management performance (Park, 2008).
2. Productivity includes qualitative concepts such as technical change as well as efficiency and maximal productivity.
3. TECI means optimal technical dissemination in task management, and is determined by investment plans, technical experiences, and the firm's management and organization.
4. TCI signifies technological innovation by adopting new technologies. It also means that investment in the upgrade of new technologies has not been made (Barros and Alves, 2004).
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