Performance Evaluation of the Philippine Cement Industry: Application of DEA-MPI and VRSTE

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Abstract

The increasing investment in infrastructure that fuels construction and cement demand makes it essential for cement manufacturers to assess their performance. This research is a first attempt to measure total productivity performance and efficiency growth pattern of the cement industry in the Philippines over the period of 2008-2012. DEA-MPI: Input Oriented Variable Returns to Scale (VRS) was adapted to measure total factor productivity (TFP) and calculate technical efficiency (TE) of cement manufacturing companies (CMCs) on a yearly basis. The study used asset, salaries and wages and power and fuel expense as input variables and total cement production and revenue as output variables. The calculated MPI result showed a decrease in total factor productivity (TFP) growth throughout the period (1.047). It also reflected that the decrease in TFP was due to the decline in technological change (1.006) and efficiency change (1.041). It can be concluded that even though decrease in the mentioned attributes were experienced the industry is still considered to operate in maximum productivity. Moreover, efficiency summary reported that two of the eight DMUs were technically inefficient. The industry's efficiency mean average score was analyzed to be at .997. The findings indicated that with the use of DEA one can determine that there is a need for a more effective policy to increase TE and maintain productivity of the Philippine cement industry.

Keywords: cement, DEA, Malmquist, VRS, productivity, efficiency

1. Introduction

Cement is known as the world's second most consumed substance after water. It is produced from limestone, shell, and clay and processed in a heated temperature of more than 1000 degree Celsius. Cement is the main ingredient in construction. Without cement, concrete construction of infrastructure is impossible (Selim & Salem, 2010).

The cement industry focuses on economies of scale. Due to its capital intensive nature, only a few number of firms control the market in different regions. This limits rivalry. In contrast, cement products are not differentiated, this creates an avenue for intense competition between existing firms (Noche & Elhasia, 2013).

The Cement Manufactures Association of the Philippines (CeMaP) projected a consistent growth in demand for cement from 2011-2016. This projected growth is seen as the public sector gains momentum for nationwide infrastructure projects and as the private sector is motivated to augment its own construction spending because of improved investment ratings (CeMaP, 2011).
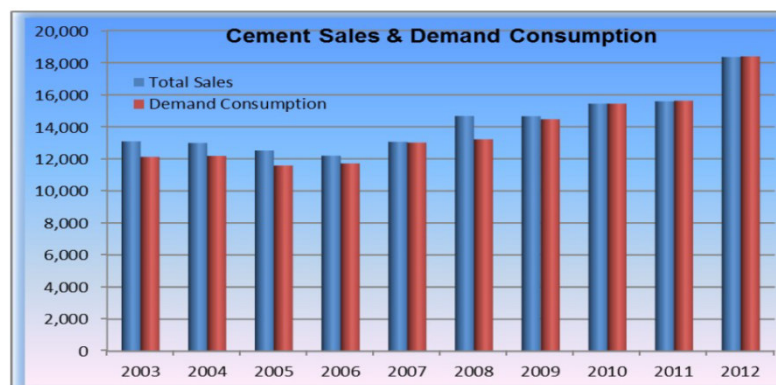
Figure 1.1: Total Sales and Demand Consumption of Cement in '000 MT, 2003-2012 (CeMap, 2012)

Figure 1.1 shows the increasing demand of cement over the period of 2003 to 2012. According to CeMaP (2012), the increasing demand of cement works hand in hand with the industry's ongoing capacity expansion brought by the country's economic progress. The accelerating figure of cement demand (ongoing capacity expansion) and the fierce competition in the local and global market justify the need to assess

productivity and TE performance of the Philippine cement industry.

Globalization brought opportunity to the cement industry. It provided major players a favorable avenue to expand their business and increase investment - increasing production to meet growing demands. On the other hand, cement manufacturers are faced with higher competition level. According to Noche & Elhasia (2013), because of the fierce competition of the international market, it is imperative that business enterprises develop and implement policies to further enhance productivity and efficiency.

Every business entity aims at fully maximizing its output with the use of minimal input. The cement manufacturing companies (CMCs) in the Philippines are faced with the essential issue of efficiently managing its resources while maintaining productivity. By doing so, this study attempted to identify sources of inefficiency and efficiency of CMCs. These practices will serve as a learning paradigm for CMCs to enhance productivity and technical efficiency (TE). Moreover, these practices can be used as a benchmark for less efficient firms. Benchmarks acknowledge best performance that can be imitated by less efficient firms to reach efficiency level.

Productivity and TE performance in this study was measured using Data Envelopment Analysis (DEA). DEA is a non-parametric method fashioned on linear programming system to assess performance among analyzed units **(Mishra, 2012).** Moreover, Malmquist Productivity Index (MPI) was employed to calculate total factor productivity (TFP). Using DEA-Malmquist Productivity Index (MPI), the study decomposed TFP into technological (TECHCH) and efficiency change (EFFCH) and identify other factors that affects productivity performance of the study's decision making units (DMUs). Also, TE of CMCs was measured using Input-Oriented Variable Returns to Scale (VRS).

In light of global transformation, this study focuses on the Philippine cement industry's efficiency and productivity factors that can guide managers towards sound policy and responsive decision-making.

According to the Department of Environment and Natural Resources (DENR), Mines and Geo-Science Bureau, there are only 9 CMCs operating in the country. These are: Holcim Philippines; Lafarge Republic Inc.; Goodfound Cement Inc.; Apo Corporation (Cemex); Solid Cement Corporation (Cemex); Taiheiyo Cement Corporation; Northern Cement Corporation; Pacific Cement Corporation; and Eagle Cement Corporation. These CMCs operate in a total of seventeen (17) cement manufacturing plants in the Philippines, ten (10) of which are sited in Luzon, three (3) in Visayas and 4 (four) in Mindanao. These CMCs manufacture Portland type of cement.

This research can help company managements recognize inefficient activities in order to deliver recommendations in improving its operations, thus will enable a starting point for prioritizing improvement initiatives. Moreover, this can assist investors in for investment in equity in the industry. The contribution of this study also provides beneficial insights into the use of DEA-MPI: Input-Oriented VRS in measuring productivity and TE performance.

In addition, since cement is the primary ingredient in construction, the efficient manufacturing and productive performance of CMCs will play a significant role in the construction industry's cost minimization (Goudineau, 2012; The New Indian Express, 2013).

At present, there is no study conducted on the productivity and TE peroformance of the Philippine cement Industry.

The primary objective of most efficiency and productivity studies is to analyze and evaluate the performance of the industry. This research specifically investigated on productivity performance and TE of eight (8) CMCs (which account for 89% of the industry) from the start of the industry's capacity expansion in 2008 up to 2012. The study used Financial Statements and annual reports to get 2008-2012 data and realize key areas for financial and production measures. The output variables used in the study are: revenue (in million) and total cement manufactured (in million tons) while the input variables used are: total asset (in million); salaries and wages cost (in million) and energy and fuel cost (in million). Productivity and TE performance were analyzed within DEA-MPI: input-oriented VRS parameters.

2.0 Methodology

For analysis and evaluation of productivity and TE performance, the study used 2008-2012 Financial Statement of Philippine cement manufacturers. Eagle Cement Corp. was excluded from the study since it just entered the market in 2010. The companies that were included in this study are: APO Cement Corporation (CeMex); Solid Cement Corporation (Cemex); Holcim Philippines, Inc.; Northern Cement Philippines, Inc.; Pacific Cement Philippines, Inc.; Taiheiyo Cement Philippines; Northern Cement; Solid Cement Corporation; and Lafarge Republic Inc.

2008-2012 Financial Statements of the CMCs were secured from Securities and Exchange Commission (SEC). In totality, a forty (40) year observation was used for analysis. DEA-MPI: Input-Oriented VRS was employed to achieve the three (3) objectives of the study.

The variables used in this research include financial and production measures. Output variables are revenue (in million) and total cement produced (in million tons). Input variables are total asset (in million), salaries and wages cost (in million) and power and fuel cost (in million).

2.1 DEA

This research employed DEA to evaluate productivity and TE performance. The rationale behind choosing this statistical tool is the characteristics of non-parametric itself. Among the non-parametric and parametric, the former excludes the probability of errors in a specific model that can transpire because of inappropriate functional form. Non-parametric technique of constructing the reference set is less restraining that rests on a set of assumption on the affiliation between the components of statistical observation and constructed set. The components anticipated to belong to the reference set need to fulfill certain characteristics. It is the set of characteristics that defines a non-parametric methodology and distinguishes it from parametric methodology (Ray, 2011).

DEA was first introduced by Charnes, Cooper and Rhodes (1978) and has proven to uncover methods to improve service not present in other techniques, thus a suitable statistical tool to measure performance in a set of DMUs. Generally, DEA calculates the ratio of weighted outputs to weighted inputs and these weighted values are decided according to the best interest of DMUs. The flexible weighting characteristic of DEA unwinds the constraint of a priori value judgment in measuring efficiency scores. This quality enables DEA to evaluate efficiency of DMUs even without the data on price and production.

In this approach, efficiency is considered as the consumption of minimal input for any actual output. According to Färe et al. (1994) DEA is a non-parametric approach to distance estimation. This method utilizes linear programming to arrive at a piecewise linear envelopment frontier over data inputs such that all experiential points is positioned on or below the production frontier.

Linear Programming is the fundamental methodology that makes DEA predominantly powerful among productivity management techniques. DEA is widely used in the field of research by those who understand the methodology of linear programming (Egilmez, 2013).

DEA associates DMUs by considering inputs and outputs and identifies efficient and inefficient firms, giving room for possible improvements. DEA calculates savings that can be realized by making inefficient units efficient as the most efficient. In addition, DEA evaluates the volume of service an inefficient unit can advance on without the requisite of using supplementary resources, thus making DEA a substantial benchmarking system unrecognizable with other techniques.

MPI was employed to examine productivity by which DMUs achieve their objectives as compared to others facing the same condition. MPI showed the sources of productivity (overall efficiency and technical growth). It represents total factor productivity which is a product of two geometric means either input oriented or output oriented (Egilmez, 2013, Samoilenko & Bryson, 2013).

2.2 Malmquist Productivity Index

MPI was introduced by Caves et al. (1982), it measures change in efficiency over-time. In the non-parametric framework, the DEA based MPI for time period can be categorized into two modules: one calculates the input technical efficiency change and the other one calculates technological change between specific time periods. This approach does not require production efficiency assumptions, rather, it identifies the best practice industries/firms in every period. Furthermore, it presents efficient production frontier that measures industries/firms' output relative to the frontier. Also it can be disintegrated into technical efficiency and technological efficiency.

In MPI, changes in TFP index differentiate, technical and technological change (Celen, 2013). The value of an index indicating more than 1 denotes an increase from (t) period to (t+1) period, furthermore a value less than 1 reflects its decrease. According to Angelidis and Lyroudi (2005), the calculation of TFP is comprised of multiplication TE change value and technical change value. The decomposition of TFP: EFFCH and TECH indicating a value more than one represents improvement in EFFCH and TECH, on the other hand a value representing less than 1 indicates retrogression. In summation, EFFCH index change depicting more than 1 implies an organization's capability in satisfying production frontier; likewise, TECH index change showing more than 1 represents the organization's success in heaving efficiency level. A negative change value in TECH index describes an output reduction with similar quantity of input in the production process (Benli & Degirmen 2013; Karacabey, 2002). In addition, according to Squires & Raid (2004), TECHCH is captures product development and enhancement of technologies that enables production improvement.

Moreover, EFFCH is decomposed as pure technical efficiency change (PECH) and scale efficiency change (SECH). Competence in PECH reflects whether an organization works within a suitable scale, thus producing in an appropriate scale. Decrease in PECH signifies managerial competence distortion. Also, a decrease in an organization's SECH represents a scale problem. The constitution of Malmquist TFP index play a substantial role in evaluating sources of TFP (Deliktas, 2002).

2.3 Variable Returns to Scale

In relation to returns to scale property, input oriented VRS was used since inputs on production

capability were assumed to have non-constant returns to scale. This acknowledges the conceivable scale of diseconomies in terms of input size among DMUs. VRS recognizes increase and decrease in production over a given set of period which associates efficiency evaluation in this study. Compared with CRS, VRS is more comprehensive (Egilmez, 2013).

Unlike the CCR model, the Banker, Charnes and Cooper (BCC) model acknowledges the restrictive property of CRS and realizes that technologies may exhibit constant, diminishing or increasing returns to scale at dissimilar location on the production frontier.

The output oriented variable returns to scale DEA frontier is defined by the solution to N to linear programs given by:

$$\min_{\Theta,\lambda} \quad \Theta$$

$$\text{subject to} \quad -y_i l \Theta + Y \lambda \geq 0$$
$$x_i + X \lambda \geq 0$$
$$N1' \lambda = 1$$
$$\lambda \geq 0,$$

where $N1$ is an Nx1 vector of 1s, λ is an Nx1 vector of weights, and Θ is the output distance measure. Where note that $0 \leq \Theta \leq 1$ and that $1/\Theta$ is the proportional expansion in inputs that could achieve the ith firm, with input quantities held constant.

Also, the input-oriented VRS DEA frontier is defined by the solution to N linear programs given by:

$$\max_{p,\lambda} p$$

$$\text{subject to} \quad -y_i + Y \lambda \geq 0$$
$$x_i l p + X \lambda \geq 0$$
$$N1' \lambda = 1$$
$$\lambda \geq 0$$

where p is the input distance measure . Note that $1 \leq p \leq \infty$ and that $1/p$ is the proportional reduction in inputs that could be achieved by the ith firm, with output quantities held constant.

The technical efficiency measure under constant returns to scale, sometimes called "overall" technical efficiency measure, is obtained by solving N linear programs given by:

$$\text{Min } \Theta_i^{CRS}$$
$$\Theta_i^{CRS}$$

$$\text{Subject to} \quad - Y \lambda + y_i \leq 0$$
$$\Theta_i^{CRS} x_i - X \lambda \geq 0$$
$$N1' \lambda = 1$$
$$\lambda \geq 0$$

where Θ_i^{CRS} is a technical efficiency quantity of the ith firm under constant returns to scale and $0 \geq \Theta_i^{CRS} \leq 1$. The output and input models were designed to estimate the same frontier surface and identify efficient set of firms. However, efficiency measures may be different input or output orientations. In the concept of constant returns to scale, the estimated frontier and the efficiency measures remain unaffected by the choice of orientation (Coelli et al., 1998).

As technology consents VRS at dissimilar points on a production possibility set frontier, the TE (input or output oriented) of a unit will differ from its SE. TE is calculated by matching firm productivity score with the unit's equivalent average productivity on the VRS frontier. Utilizing DEA Version 2.1 software, efficiency score and productivity level of different CMCs and the Philippine cement industry as a whole were determined. Furthermore, confidentiality of the result was taken into consideration by assigning a code for each firm in the analysis. This was done due to the sensitivity of data as per competitive issue of each CMC.

3.0 Empirical Results

3.1 MPI

This part of the chapter addresses the first objective of the study. It represents the TFP of the Philippine cement industry measured by Malmquist Productivity Index that was also decomposed to TECHCH and EFFCH. Moreover, EFFCH features changes in technical efficiency to PECH and SECH.

Table 3.1: Malmquist Productivity Index

Firm	techch	effch	pech	sech	tfpch
A	1.019	1.000	1.000	1.000	1.019
B	0.976	1.135	1.016	1.117	1.107
C	0.951	1.000	1.000	1.000	0.951
D	1.019	1.096	1.000	1.096	1.117
E	1.016	0.922	0.984	0.937	0.937
F	1.054	1.000	1.000	1.000	1.054
G	1.010	1.102	1.000	1.102	1.113
H	1.004	1.093	1.000	1.093	1.097
mean	**1.006**	**1.041**	**1.000**	**1.041**	**1.047**

Table 3.1 presents the TFPCH of the CMCs. It reveals that over the study period majority of CMCs displayed growth in TFPCH. Taiheiyo Cement Phil. Inc. reported 0.951 TFPCH which indicated that the company showed less productivity due to the decrease in TECHCH (0.951). Also, Northern Cement reported 0.937 TFPCH, its below productivity and efficiency performance score was due to the regressed EFFCH (0.922) which was the result of decreased PECH (0.984) and SECH (0.937). The proposition that follows from regressed TECHCH is that these companies reflected a less benefit from enhanced technology and capital equipment because of the inadequate transfer of technology. MPI highlights that EFFCH is the main driver for the increased in TFPCH of the Philippine cement industry. This finding is similar to the study conducted by Mahmood (2008).

The Philippine cement industry's average TFPCH for the relevant period displayed to be at 1.047. This figure indicates that the industry operated at a maximum productivity. This was the result of the capacity expansion of CMCs to augment of the strong local cement demand and the increased private and government infrastructure project. In fact among different industries, the country's cement sector reported the biggest growth in 2012. Foreign Direct Investments (FDI) also amplified the industry's productivity). Literature indicated the significance of foreign investment as a determinant of growth in TFP (Savvides, 2005). The demand for cement in 2012 rose by 18 percent, recorded as the highest increase in 15 years (CeMaP, 2012).

Among the CMCs that progressed in EFFCH were: Firm B (1.135); Firm G (1.102); Firm D (1.096); and Firm H (1.093). Firms A, C and F reported stagnant scores on EFFCH (1.000). Firm E displayed a regressed EFFCH score of 0.922. This was due to the company's decline in managerial performance efficiency (shown in SECH index) and input combination efficiency (shown in PECH index). Average EFFCH over the study period reflected to be at 1.04. This indicates that overall, the industry is technically efficient.

An annual average on TECHCH has been observed to be at 1.006 . During the observation period, 75% of the industry or 6 CMCs reported to have improved on TECHCH. These were: Firm F (1.054); Firm A (1.019); Firm D (1.019); Firm E (1.016); Firm G (1.010); and Firm H (1.004). Firms B and C regressed in TECHCH with 0.976 and 0.951 TECH score, respectively.

Table 3.2. Malmquist Index Summary of Firm Means

Year	Techch	effch	pech	sech	tfpch
2	1.120	1.052	1.008	1.043	1.177
3	0.981	1.057	0.999	1.057	1.036
4	0.863	1.056	1.001	1.056	0.911
5	1.080	1.001	0.992	1.010	1.081
Mean	**1.041**	**1.041**	**1.000**	**1.041**	**1.047**

Malmquist TFPCH, along with its components takes a preliminary score of 1.000 for year 2008 being the reference and initial year. Figure 3.2 revealed a decline in EFFCH from 1.052 in 2009 to 1.001 in 2012. However, mean EFFCH of the industry was reported to be at 1.041, indicating efficiency over the period. EFFCH is the result of PECH and SECH.

A closer look at the figure revealed that mean SECH (1.041) of the industry is higher than mean PECH (1.000), indicating that input combination is more significant for the source of efficiency in the industry than managerial factor. The study evaluated that there has been no under- utilization of inputs, incorrect selection of input combination or inappropriate returns to scale in the industry.

TECHCH declined from 1.120 in 2009 to 0.981 in 2010 and 0.863 in 2011. TECHCH was reported to be at 1.080 in 2012. Mean TECHCH of the industry was reflected at 1.006. Although there has been some changes in TECH, the industry is still considered to be efficient.

Increased in TFPCH was reported in 2012 (1.081). The full implementation of enormous infrastructure project under the Philippine government's Public-Private-Partnership (Global Cement, 2013) could positively affected the change in TFP from 2011 to 2012 Mean TFPCH of the industry was evaluated to be at 1.047.

3.2 VRSTE

This part of the chapter analyzes technical efficiency of the Philippine cement industry to address the second objective of this research. To achieve this, input oriented Variable-Returns-to-Scale Technical Efficiency (VRSTE) was employed.

Under VRS assumptions, the Philippine cement industry reported an average TE of 0.997 over the observation period. The industry experienced technical inefficiency during: the year 2008 that displayed TE of 0.992; and year 2012 that revealed TE of 0.992 (See Table 3.3). The CMCs that exhibited technical inefficiency over the observation period were Firm B (with TE of 0.988) that reflected excess in number of employees and Firm E (see Table 3.4 and Table 3.5).

Table 3.3: VRSTE Summary

Firm	2008	2009	2010	2011	2012	CMC TE ave.
A	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
B	0.9380	1.0000	1.0000	1.0000	1.0000	0.9880
C	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
D	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
E	1.0000	1.0000	1.0000	1.0000	0.9360	0.9860
F	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
H	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Input Slacks

This part of the chapter evaluates slacks of the CMCs to achieve the third objective of this study. Over the study period, slack values were considered to measure input excess CMCs incurred that have caused

inefficiency. According to Coelli (1998) a firm can only be technically efficient if it operates on the frontier, and furthermore, slack is equivalent to zero.

Over the study period, the Philippine cement industry revealed input slacks only on years 2008 and 2012.

Figure 3.4: 2008 Input Slacks Summary

Firm	Asset	Salaries and wages	Fuel and Energy Cost
A	0.000	0.000	0.000
B	0.000	86.503	0.000
C	0.000	0.000	0.000
D	0.000	0.000	0.000
E	0.000	0.000	0.000
F	0.000	0.000	0.000
G	0.000	0.000	0.000
H	0.000	0.000	0.000
mean	**0.000**	**10.813**	**0.000**

Figure 3.4 shows the summary of input slack values of the DMUs in 2008, the first year of observation. The above figure indicates that Firm B excessed by 86.503 on its salaries and wages. Firm B's input slack may have been brought by its effort in administering alternative fuel using rice husk during this year. The program aimed to reduce CO_2 emission by 25 percent (Abad, 2013). Mean input slack on salaries & wage of the industry is reported to be at 10.813.

Table 3.5 2012 Input Slacks Summary

Firm	Asset	Salaries and wages	Fuel and Energy Cost
A	0.000	0.000	0.000
B	0.000	0.000	0.000
C	0.000	0.000	0.000
D	0.000	0.000	0.000
E	1591.509	0.000	226.755
F	0.000	0.000	0.000
G	0.000	0.000	0.000
H	0.000	0.000	0.000
mean	**198.939**	**0.000**	**28.344**

Table 3.5 represents summary of input slack values of the CMCs during the year 2012, the last year of observation. The figure illustrates the excess amount in asset and fuel & energy cost of Firm E by 1591.509 and 226.755, respectively. The company's over capitalization resulted in excess in asset and fuel and energy cost. This was the year when San Miguel Corporation (SMC) invested P3-billion in Northern Cement Corp. that aimed to double production capacity of its Pangasinan plant (Montealegre, 2013). In addition, SMC officially owned 35 percent of Firm E and still plans to get the majority.

4.0 Conclusions

DEA-MPI: Input-Oriented VRS was employed and was evaluated productivity and efficiency of the Philippine cement industry. Specifically, this study attained its four 3) objectives: (1) Evaluate productivity performance over the period of 2008-2012; (2) Analyze technical efficiency over the observation period; (3) and Examine and compare slacks over the observation period.

The study based its productivity and technical performance of 8 CMCs for a five year period (2008-2012). The results of the empirical study using DEA-MPI showed that 75% or 6 CMCs reported to be productive. During the observation period; a decrease in TECHCH has been reported by Solid Cement Corp. and Taiheiyo Cement Phil. Inc.; and a decrease in EFFCH has been reported by Northern Cement Corp. However, given this decline in different indices the Philippine cement industry was observed to be operating at its maximum productivity with a TFPCH score of 1.047. This productivity level was brought by the industry's capacity expansion and increasing FDI.

The observed decline in TECHCH of the mentioned CMCs may call for the industry to give substantial consideration to technological progress: the improvement of prevailing applications and development of more technology oriented systems and procedures that will enable the industry to be more productive. The EFFCH is the industry's main driver for productivity. The industry reflected 7 CMCs (75% of the industry) to be pure efficient with a mean PECH score of 1.000. Also, in terms of scale efficiency, 7 CMCs (75% of the industry) were found to be scale efficient. The industry's SECH score was reported to be at 1.041. This finding implies that management performance, aside from the efficient allocation of resources should make parallel effort in the enhancement of the industry. These results are congruent with the findings of Mahmood & Afza (2008) which claimed that efficiency should be consistent with technological control.

The Philippine cement industry revealed an input slack on salaries and wages of about 10.8 million; on asset of about 198.9 million; and fuel and energy of about 28.3 million. This indicated that the industry should be cautious in over capitalization and excess in employee for these result to inefficiencies.

The research suggests that although the Philippine cement industry is productive and technically efficient, it still has to augment TFP in attempt to stabilize productivity growth pattern. In this sector, two (2) CMCs reflected the need to improve TE and TECHCH. An enhanced comprehensive plan in attempt for modernization of all CMCs in the country should be a priority to achieve a global standpoint of competitiveness.

Directions for Future Research

This research is based upon eight (8) CMCs which account for 89 percent of the total players in the industry. This confines the inference of the conclusion for the entire cement industry. Therefore, future researches can work on all CMCs and extend panel data. Also, productivity and efficiency in the study were measured using Financial Statement data, further study may include environmental variables like size and age of each firm in evaluating performance.

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Appendix

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MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

 year   effch  techch   pech    sech   tfpch

     2  1.052  1.120   1.008   1.043   1.177
     3  1.057  0.981   0.999   1.057   1.036
     4  1.056  0.863   1.001   1.056   0.911
     5  1.001  1.080   0.992   1.010   1.081

mean   1.041  1.006   1.000   1.041   1.047


MALMQUIST INDEX SUMMARY OF FIRM MEANS

 firm   effch  techch   pech    sech   tfpch

     1  1.000  1.019   1.000   1.000   1.019
     2  1.135  0.976   1.016   1.117   1.107
     3  1.000  0.951   1.000   1.000   0.951
     4  1.096  1.019   1.000   1.096   1.117
     5  0.922  1.016   0.984   0.937   0.937
     6  1.000  1.054   1.000   1.000   1.054
     7  1.102  1.010   1.000   1.102   1.113
     8  1.093  1.004   1.000   1.093   1.097

mean   1.041  1.006   1.000   1.041   1.047

[Note that all Malmquist index averages are geometric means]
```

```
SUMMARY OF OUTPUT TARGETS:

firm   output:         1             2
   1           7007.980         0.930
   2           5345.670         0.683
   3           3306.530         0.410
   4          18172.400         2.320
   5           3200.800         0.400
   6            854.860         0.240
   7           1016.220         0.130
   8          12819.990         1.610


SUMMARY OF INPUT TARGETS:

firm   input:          1             2            3
   1          15243.220        42.660      981.120
   2           7882.371       121.656      874.639
   3           3099.110        43.230      337.450
   4          27112.000      1063.320     5293.370
   5           5836.720        30.470      755.770
   6            802.000        59.290      238.440
   7           1745.530        33.620      300.310
   8          25516.010       264.070     3076.800


Results from DEAP Version 2.1

Instruction file = te1-ins.txt
Data file        = te1-dta.txt

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  1.000  1.000  1.000  -
    2  0.603  0.938  0.643 drs
    3  1.000  1.000  1.000  -
    4  0.628  1.000  0.628 drs
    5  0.927  1.000  0.927 irs
    6  1.000  1.000  1.000  -
    7  0.546  1.000  0.546 irs
    8  0.577  1.000  0.577 drs

 mean  0.785  0.992  0.790

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste


Note also that all subsequent tables refer to VRS results
```

SUMMARY OF OUTPUT SLACKS:

firm	output:	1	2
1		0.000	0.000
2		0.000	0.003
3		0.000	0.000
4		0.000	0.000
5		0.000	0.000
6		0.000	0.000
7		0.000	0.000
8		0.000	0.000
mean		0.000	0.000

SUMMARY OF INPUT SLACKS:

firm	input:	1	2	3
1		0.000	0.000	0.000
2		0.000	86.503	0.000
3		0.000	0.000	0.000
4		0.000	0.000	0.000
5		0.000	0.000	0.000
6		0.000	0.000	0.000
7		0.000	0.000	0.000
8		0.000	0.000	0.000
mean		0.000	10.813	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	4	1	3	
3	3			
4	4			
5	5			
6	6			
7	7			
8	8			

```
SUMMARY OF PEER WEIGHTS:
  (in same order as above)

 firm  peer weights:
    1   1.000
    2   0.077 0.242 0.681
    3   1.000
    4   1.000
    5   1.000
    6   1.000
    7   1.000
    8   1.000


PEER COUNT SUMMARY:
  (i.e., no. times each firm is a peer for another)

 firm  peer count:
    1        1
    2        0
    3        1
    4        1
    5        0
    6        0
    7        0
    8        0




SUMMARY OF OUTPUT TARGETS:

firm  output:         1            2
    1           7007.980        0.930
    2           5345.670        0.683
    3           3306.530        0.410
    4          18172.400        2.320
    5           3200.800        0.400
    6            854.860        0.240
    7           1016.220        0.130
    8          12819.990        1.610

SUMMARY OF INPUT TARGETS:

firm  input:          1            2            3
    1          15243.220       42.660      981.120
    2           7882.371      121.656      874.639
    3           3099.110       43.230      337.450
    4          27112.000     1063.320     5293.370
    5           5836.720       30.470      755.770
    6            802.000       59.290      238.440
    7           1745.530       33.620      300.310
    8          25516.010      264.070     3076.800
```

```
| Results from DEAP Version 2.1

Instruction file = te2-ins.txt
Data file        = te2-dta.txt

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

     1  1.000  1.000  1.000  -
     2  0.778  1.000  0.778 drs
     3  1.000  1.000  1.000  -
     4  0.593  1.000  0.593 drs
     5  0.820  1.000  0.820 irs
     6  1.000  1.000  1.000  -
     7  0.532  1.000  0.532 irs
     8  0.821  1.000  0.821 drs

 mean  0.818  1.000  0.818

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste


Note also that all subsequent tables refer to VRS results


 SUMMARY OF OUTPUT SLACKS:

firm  output:         1         2
     1              0.000     0.000
     2              0.000     0.000
     3              0.000     0.000
     4              0.000     0.000
     5              0.000     0.000
     6              0.000     0.000
     7              0.000     0.000
     8              0.000     0.000

mean                0.000     0.000
```

```
SUMMARY OF INPUT SLACKS:

firm  input:             1          2          3
   1                 0.000      0.000      0.000
   2                 0.000      0.000      0.000
   3                 0.000      0.000      0.000
   4                 0.000      0.000      0.000
   5                 0.000      0.000      0.000
   6                 0.000      0.000      0.000
   7                 0.000      0.000      0.000
   8                 0.000      0.000      0.000

mean                 0.000      0.000      0.000


SUMMARY OF PEERS:

 firm  peers:
   1       1
   2       2
   3       3
   4       4
   5       5
   6       6
   7       7
   8       8


SUMMARY OF PEER WEIGHTS:
  (in same order as above)

 firm  peer weights:
   1    1.000
   2    1.000
   3    1.000
   4    1.000
   5    1.000
   6    1.000
   7    1.000
   8    1.000


PEER COUNT SUMMARY:
  (i.e., no. times each firm is a peer for another)

 firm  peer count:
   1       0
   2       0
   3       0
   4       0
   5       0
   6       0
   7       0
   8       0
```

```
SUMMARY OF OUTPUT TARGETS:

firm  output:          1              2
    1             7976.520          1.000
    2             6237.250          0.790
    3             3751.080          0.470
    4            21861.610          2.790
    5             3500.990          0.440
    6             1263.120          0.310
    7             1039.740          0.130
    8            15339.910          1.940


SUMMARY OF INPUT TARGETS:

firm  input:           1              2              3
    1            15150.980         45.070       1116.710
    2             7564.050        110.150        931.390
    3             3172.290         46.130        433.780
    4            24979.600       1500.830       5661.950
    5             5974.660         37.760        643.020
    6              801.620         60.250        206.580
    7             1510.510         47.770        304.760
    8            24180.440        179.810       3681.580
```

```
 Results from DEAP Version 2.1

Instruction file = te3-ins.txt
Data file        = te3-dta.txt

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  1.000  1.000  1.000    -
    2  1.000  1.000  1.000    -
    3  1.000  1.000  1.000    -
    4  0.712  1.000  0.712  drs
    5  0.885  1.000  0.889  irs
    6  1.000  1.000  1.000    -
    7  0.601  1.000  0.601  irs
    8  0.680  1.000  0.680  drs

 mean  0.860  1.000  0.860

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste


Note also that all subsequent tables refer to VRS results
```

```
SUMMARY OF OUTPUT SLACKS:

firm  output:         1           2
   1              0.000       0.000
   2              0.000       0.000
   3              0.000       0.000
   4              0.000       0.000
   5              0.000       0.000
   6              0.000       0.000
   7              0.000       0.000
   8              0.000       0.000

mean              0.000       0.000


SUMMARY OF INPUT SLACKS:

firm  input:          1           2           3
   1              0.000       0.000       0.000
   2              0.000       0.000       0.000
   3              0.000       0.000       0.000
   4              0.000       0.000       0.000
   5              0.000       0.000       0.000
   6              0.000       0.000       0.000
   7              0.000       0.000       0.000
   8              0.000       0.000       0.000

mean              0.000       0.000       0.000


SUMMARY OF PEERS:

 firm  peers:
   1      1
   2      2
   3      3
   4      4
   5      7     1     2     3
   6      6
   7      7
   8      8


SUMMARY OF PEER WEIGHTS:
  (in same order as above)

 firm  peer weights:
   1    1.000
   2    1.000
   3    1.000
   4    1.000
   5    0.504 0.233 0.170 0.092
   6    1.000
   7    1.000
   8    1.000


PEER COUNT SUMMARY:
  (i.e., no. times each firm is a peer for another)

 firm  peer count:
   1      1
   2      1
   3      1
   4      0
   5      0
   6      0
   7      1
   8      0
```

```
SUMMARY OF OUTPUT TARGETS:

firm   output:            1            2
   1               8789.620        1.100
   2               6673.760        0.850
   3               3507.590        0.440
   4              23674.350        3.020
   5               4022.720        0.507
   6               1254.960        0.300
   7               1018.720        0.130
   8              16502.740        2.080


SUMMARY OF INPUT TARGETS:

firm   input:             1            2            3
   1              14869.450       33.470     1230.550
   2               6654.690       56.830     1411.620
   3               3313.290       60.730      452.990
   4              26127.300     1534.780     5756.080
   5               5697.306       40.623      729.133
   6                929.440       68.130      172.530
   7               1570.290       34.780      317.600
   8              24657.640      311.860     3960.660


 Results from DEAP Version 2.1

 Instruction file = te4-ins.txt
 Data file        = te4-dta.txt

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  1.000  1.000  1.000   -
    2  1.000  1.000  1.000   -
    3  1.000  1.000  1.000   -
    4  0.778  1.000  0.778  drs
    5  0.932  1.000  0.932  irs
    6  1.000  1.000  1.000   -
    7  0.648  1.000  0.648  irs
    8  0.849  1.000  0.849  drs

 mean  0.901  1.000  0.901

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste


Note also that all subsequent tables refer to VRS results
```

```
SUMMARY OF OUTPUT SLACKS:

firm  output:          1          2
   1               0.000      0.000
   2               0.000      0.000
   3               0.000      0.000
   4               0.000      0.000
   5               0.000      0.000
   6               0.000      0.000
   7               0.000      0.000
   8               0.000      0.000

mean                0.000      0.000


SUMMARY OF INPUT SLACKS:

firm   input:          1          2          3
   1               0.000      0.000      0.000
   2               0.000      0.000      0.000
   3               0.000      0.000      0.000
   4               0.000      0.000      0.000
   5               0.000      0.000      0.000
   6               0.000      0.000      0.000
   7               0.000      0.000      0.000
   8               0.000      0.000      0.000

mean                0.000      0.000      0.000

SUMMARY OF PEERS:

 firm  peers:
   1       1
   2       2
   3       3
   4       4
   5       5
   6       6
   7       7
   8       8


SUMMARY OF PEER WEIGHTS:
  (in same order as above)

 firm  peer weights:
   1    1.000
   2    1.000
   3    1.000
   4    1.000
   5    1.000
   6    1.000
   7    1.000
   8    1.000
```

```
PEER COUNT SUMMARY:
  (i.e., no. times each firm is a peer for another)

 firm  peer count:
   1        0
   2        0
   3        0
   4        0
   5        0
   6        0
   7        0
   8        0


SUMMARY OF OUTPUT TARGETS:

firm  output:           1              2
   1              7952.000          1.040
   2              5522.410          0.740
   3              3495.010          0.440
   4             21621.500          2.760
   5              3707.680          0.470
   6              1259.180          0.340
   7              1002.980          0.140
   8             14498.250          1.910


SUMMARY OF INPUT TARGETS:

firm  input:          1              2              3
   1            14905.460         46.600       1113.280
   2             6919.120         72.090        786.200
   3             3266.320         83.770        458.270
   4            26026.250       1156.060       6263.260
   5             5848.280         41.950        808.920
   6             1387.040         69.070        263.760
   7             1642.760         34.550        243.560
   8            25678.650        173.340       3479.580


 Results from DEAP Version 2.1

Instruction file = te5-ins.txt
Data file        = te5-dta.txt

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  1.000  1.000  1.000  -
    2  1.000  1.000  1.000  -
    3  1.000  1.000  1.000  -
    4  0.906  1.000  0.906 drs
    5  0.670  0.936  0.716 irs
    6  1.000  1.000  1.000  -
    7  0.806  1.000  0.806 irs
    8  0.825  1.000  0.825 drs

 mean  0.901  0.992  0.906

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste


Note also that all subsequent tables refer to VRS results
```

```
SUMMARY OF OUTPUT SLACKS:

firm  output:          1          2
   1               0.000      0.000
   2               0.000      0.000
   3               0.000      0.000
   4               0.000      0.000
   5              27.964      0.000
   6               0.000      0.000
   7               0.000      0.000
   8               0.000      0.000

mean                3.495      0.000

SUMMARY OF INPUT SLACKS:

firm  input:           1          2          3
   1               0.000      0.000      0.000
   2               0.000      0.000      0.000
   3               0.000      0.000      0.000
   4               0.000      0.000      0.000
   5            1591.509      0.000    226.755
   6               0.000      0.000      0.000
   7               0.000      0.000      0.000
   8               0.000      0.000      0.000

mean              198.939      0.000     28.344

SUMMARY OF PEERS:

 firm  peers:
   1      1
   2      2
   3      3
   4      4
   5      7      1
   6      6
   7      7
   8      8

 SUMMARY OF PEER WEIGHTS:
   (in same order as above)

 firm  peer weights:
   1   1.000
   2   1.000
   3   1.000
   4   1.000
   5   0.723 0.277
   6   1.000
   7   1.000
   8   1.000


 PEER COUNT SUMMARY:
   (i.e., no. times each firm is a peer for another)

 firm  peer count:
   1        1
   2        0
   3        0
   4        0
   5        0
   6        0
   7        1
   8        0
```

SUMMARY OF OUTPUT TARGETS:

firm	output:	1	2
1		9022.380	1.140
2		6792.540	0.880
3		4427.760	0.550
4		27159.000	3.460
5		3246.454	0.410
6		1284.880	0.360
7		1031.030	0.130
8		16432.880	2.080

SUMMARY OF INPUT TARGETS:

firm	input:	1	2	3
1		13807.460	53.830	1172.910
2		6403.260	113.980	922.430
3		3798.490	103.710	612.940
4		25864.290	1695.110	6686.780
5		4623.887	39.331	495.600
6		1382.750	70.360	238.500
7		1101.420	33.770	235.810
8		26671.900	189.170	3943.890