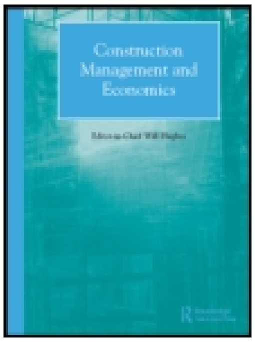


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# Modelling profitability and effectiveness of Greek-listed construction firms: an integrated DEA and ratio analysis

Ioannis E. Tsolas

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# Modelling profitability and effectiveness of Greek-listed construction firms: an integrated DEA and ratio analysis

IOANNIS E. TSOLAS*

*National Technical University of Athens, Greece*

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Existing research on construction performance measurement is dominated by project level studies, and the firm stakeholders require the development of models that compare performance in terms of efficiency. A new framework that integrates data envelopment analysis (DEA) and ratio analysis using a two-step approach is described to evaluate performance in terms of profitability and effectiveness of a sample of construction firms listed on the Athens Exchange. In the first step, profitability and effectiveness are assessed by employing DEA and by using the profit margin (i.e. income-to-sales ratio), respectively. In the second step, a Tobit and an ordinary least squares model are used in order to identify the drivers of profitability efficiency and effectiveness, respectively. Results do point out positive links between profitability efficiency and effectiveness. Profitability inefficiency can be explained by the size and expenses-to-total revenue ratio, whereas effectiveness can be explained only by the latter explanatory variable. The research framework may benefit not only Greek construction firms, but also firms in other countries to quantify their performance and improve their competitive advantages.

*Keywords:* Construction firms, profitability efficiency, effectiveness, data envelopment analysis, Greece.

## Introduction

Performance measurement is fundamental to management planning and control and has accordingly received considerable attention from both academicians and practitioners. The construction industry has been criticized for its underperformance (for a recent critical review, see Yang *et al.*, 2010), and performance measurement has gained more attention as many researchers have placed considerable emphasis on the importance of developing and implementing performance measurement methods.

Existing research on performance measurement and evaluation at the company level offers limited literature as compared to the research at the project level. This limitation calls for new performance frameworks that could be used to establish a baseline for firm performance and benchmark best-in-class firms. Moreover, the construction firm stakeholders require the development of models that compare firm performance in terms of efficiency. In response to that, Pilateris and McCabe (2003) employed data envelopment analysis (DEA) on financial data of Canadian contractors. Elsewhere, Chau and Wang (2003), in their work on the efficiency of construction firms in Hong Kong, argue that important unresolved issues for the construction industry are the scale of operation and the drivers of performance. An effort is made to fill this research gap through initial analysis of Greek-listed construction firms, an area where there has been virtually no previous research by integrating DEA with ratio analysis. In a first step, profitability and effectiveness are assessed as two performance dimensions; whereas in a second step, regression techniques are used to identify the drivers of performance that are sought in the operational and financial spaces of the firm.

DEA, first introduced by Charnes *et al.* (1978), is a deterministic non-parametric efficiency measurement

*E-mail: itsolas@central.ntua.gr

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method that empirically derives an efficient frontier that follows the peak performers and envelops the remainder using sample firm data on inputs and outputs. The estimated frontier characterizes the efficiency of firms (or decision-making units (DMUs)) and identifies inefficiencies. For each DMU, an efficiency measure is defined by its position relative to the frontier.

Accounting-based traditional ratio analysis that predates DEA involves the calculation of single ratio values by employing two figures from either the balance sheet or income statement or both. In Smith's (1990) discussion on the use of performance indicators it is argued that DEA represents the extension of one performance dimension covered under the assumption of constant returns to scale (CRS) by a simple ratio to multiple dimensions.

As described in the 'Research methods' section herein, the focus is on the development of a two-stage framework of performance assessment at the company level that comprises both a multi-input/one-output assessment (Stage 1) and a one-input/one-output (Stage 2) assessment. To conduct such a two-stage evaluation, we integrate data envelopment analysis (Stage 1) and ratio analysis (Stage 2). More specifically, the research objectives are: (1) to establish a new accounting-based general framework for firm performance measurement, integrating DEA and ratio analysis; and (2) to derive a set of performance metrics by which a comparison of construction company performance could be made, and moreover, to identify the drivers of performance.

For ease of reference with the numerous abbreviations found herein, a glossary is provided in Appendix 1.

## Literature review

### Performance measurement in construction

The main performance measurement frameworks applied in construction include the business performance measurement (BPM), which relies on accounting (bottom-line) performance measures, and its alternative 'stakeholder perspective measurement' (SPM), introduced by Love and Holt (2000); the performance measurement process framework (PMPF) proposed by Kagioglou *et al.* (2001) as an extension of the balanced scorecard (BSC) model of Kaplan and Norton (1992); the European Foundation for Quality Management (EFQM) excellence model and some benchmarking programmes such as the CII Benchmarking & Metrics Program developed by the Construction Industry Institute (CII) and the Construction Best Practice Program (CBPP). Another framework based on the principles of the BSC and the EFQM excellence model is that developed by Bassioni *et al.* (2005); this is utilized to assess the performance of UK contractors (for a recent critical review, see Yang *et al.*, 2010).

The SPM proposed by Love and Holt (2000) is based on multi-dimensional firm performance measures. In the PMPF of Kagioglou *et al.* (2001) the performance measures are founded on the four BSC perspectives (financial, customer, internal business, and innovation and process improvement perspective) and two more perspectives: project and supplier. The EFQM excellence model, a framework based on various criteria, can be used to assess an organization's progress towards excellence. In their discussion of the pros and cons of the BSC and EFQM excellence model, Wongrassamee *et al.* (2003) argue that although the BSC is superior to the EFQM excellence model in assigning strategic measures, both models have a major limitation in target setting. In particular, in the BSC, targets are not addressed, whereas in the EFQM excellence model, targets are not specific.

The Construction Industry Institute (CII) (2011) developed the 'CII Benchmarking & Metrics Program', which is composed of cost, schedule, safety, change, and rework. The Construction Best Practice Program (CBPP) benchmarking model is identical to a set of key performance indicators (KPIs) developed and implemented in the UK construction industry to benchmark a project or a firm against the range of performance across the industry. The two reviewed construction benchmarking models have some limitations. Since they are mainly project specific, they provide single measures of performance that capture a limited perspective of a firm's activities and moreover do not account for the cost associated with the resources used to achieve a particular measure of performance.

The research implies that the limitations of reviewed frameworks call for further research on the development of a framework that, while accounting-based, can be integrated within the existing frameworks. The proposed framework as described in the 'Research methods' section improves upon the BPM, providing a consolidated DEA-efficiency metric and the profit margin that reflect performance in the operational and financial spaces of the firm, respectively. Moreover, it can be easily integrated within the existing frameworks such as the SPM and BSC; the DEA-efficiency metric and the profit margin can serve as the accounting-based measures of the SPM and BSC financial perspective.

The deployment of the proposed framework in a first step provides to construction research and practice a more robust tool, both for performance measurement and benchmarking. Moreover, in a second step, the regression of the derived metrics on a set of firm-specific factors contributes to the identification of performance drivers.

### Research techniques for performance measurement in construction

From recent reviews, such as Yang *et al.* (2010), it appears there are a number of tools available for performance measurement, including: graphical approaches; index approaches based on (financial) ratio analysis; statistical methods; the BSC; subjective-based methods such as analytic hierarchy process (AHP) and principal components analysis (PCA) used for the construction of integrated performance indicators; and DEA. Approaches that are graphical in nature are based on multi-factor gap analysis techniques (e.g. 'spider' or 'radar' diagrams). In his DEA textbook, Zhu (2003) argues that gap analysis a method used in performance evaluation, and benchmarking deals only with one measure at a time. As a result, gaps can be identified with respect to individual measures of performance.

Ratios represent measures of performance of a system as they compute the relative efficiencies of the outputs versus the inputs, and these can express many different aspects of performance. Ratio analysis as an *ex post* evaluation tool is an alternative to DEA. However, unlike DEA ratio analysis, it does not involve any optimization process to provide a consolidated measure of performance in the case of multiple inputs and outputs. As a result, if a firm ranks highly on some metrics (i.e. single input-output ratios) and low on others, the performance assessment becomes difficult.

Statistical methods such as ordinary least squares (OLS) regression can be used to evaluate firm efficiency. However, the use of OLS as a performance evaluation tool has some limitations. First, it is implicitly assumed that all the observed firms combine their input factors in the same way. Second, in their DEA textbook, Cooper *et al.* (2007) purport that OLS reflects 'average' or 'central tendency' behaviour of the observations. Moreover, Rickards (2003), in his work on DEA and BSC benchmark setting, states that OLS results can hardly serve as benchmarks.

The BSC has a major limitation in target setting and can provide a consolidated metric of performance only when combined with other methods.

Since there are indicators that could measure the performance of a construction project or firm in respect of different aspects, there is a need to aggregate these into an integrated performance index. In some cases, the weights of indicators are developed via empirical questionnaire surveys, whereas techniques such as AHP and PCA can also be used for the development of indicator weights.

DEA is a linear programming-based, non-parametric efficiency measurement method. Ramanathan's DEA textbook (2003) states that the main strengths of DEA are its objectivity, the handling of multiple inputs and outputs, its non-parametric nature (i.e. it does not require an assumption of a functional form relating inputs and outputs), the provision of a consolidated performance measure, and the detailed target setting. For a review on DEA past research in the construction industry, the interested reader is referred to a recent safety benchmarking study of construction contractors by El-Mashaleh *et al.* (2010).

Research implies that the DEA is superior to the reviewed performance measurement methods. In addition, DEA has proved to be an accounting-based performance measurement tool of contractors in conjunction with ratio analysis (Pilateris and McCabe, 2003). As described in the following section, current research improves upon the contractor financial evaluation model (CFEM) of Pilateris and McCabe (2003) through the deployment of a proposed two-stage framework that integrates DEA and ratio analysis.

## Research methods

The conceptual framework and definitions relevant to the proposed framework are presented herein, and the logic behind the study hypotheses is developed.

### Definitions and conceptual framework

Past reviews (e.g. Neely *et al.*, 1995; Tangen, 2004), define performance measurement as the process of quantifying the efficiency and effectiveness of firm operation. The performance measures employed are the metrics used to quantify the efficiency and effectiveness of firm operation, as two performance dimensions.

Asmild *et al.* (2007) provide the links between management and DEA literature in terms of efficiency (i.e. 'doing things right' in performing work activities as well as possible without wasting resources) and effectiveness (i.e. 'doing the right things' in the selection of the activities that will help the organization reach its goals). Thus, an organization or DMU is efficient where it attains high levels of output in terms of revenues without excessive investments in inputs and is effective to the degree to which it achieves its goals.

The construction firms might be using their resources with different levels of managerial competence, and this is reflected by what is referred to by Farrell (1957) as technical efficiency in his seminal work on the productive efficiency measurement. Construction firms may operate in adverse conditions, and the extent to which they are successful should be reflected in the financial statements. On the one hand, a direct concern of the management of firms is the extent to which managers use resources efficiently. On the other hand, management's effectiveness in generating profits is also of great interest.

The proposed framework encompasses the two performance dimensions of profitability efficiency (first performance dimension) and effectiveness (second performance dimension) as depicted in Figure 1. The framework specifically incorporates a DEA-based measure of profitability efficiency and a measure of effectiveness as the ratio of net income before taxes to total revenue (i.e. a profit margin).

The DEA performance model used herein incorporates a measure of profitability efficiency. That is, a firm is deemed efficient in achieving its objectives as using a minimum of resources (costs) to generate monetary outcomes (total revenue).

The metric of effectiveness (i.e. net income before taxes-to-total revenue ratio) for our purposes is defined as the ability of a firm to achieve the expected level of income generation. In line with Sutton's (2004) textbook on *Corporate Financial Accounting and Reporting*, the components of the profit margin used as an effectiveness metric are based on the DuPont framework, and it can be analysed further by the use of individual cost-to-revenue ratios such as the cost of goods sold to sales and the selling and the administrative expenses to sales. In fact, using DEA modelling, a normalized individual cost-to-revenue ratio is produced.

The specification of inputs and outputs for the profitability and effectiveness assessments are proposed as in Figure 1.

The proposed framework improves upon the existing CFEM introduced by Pilateris and McCabe (2003), as it focuses on a two-stage formulation, since the use of highly correlated outputs such as the selected variables in this study of total revenue and income before taxes in a one-stage formulation is expected to reduce the discriminating power of the DEA. For more on the topic of the discriminating power of the DEA, the interested reader is referred to the DEA book written by Charnes *et al.* (1994). The use of total revenue in the output side in a multi-input/one-output setting (Stage 1) and as input with the income before taxes in the output side in an one-input/one-output setting (Stage 2) addresses the above drawback of the existing model.

## DEA modelling

The specific modelling issues to address when applying DEA are mainly the model selection to account for possible scale effects, the validity of the DEA model specification, and the model orientation.

Regarding DEA assessment, the sample used herein (as described in the next section) includes firms of various sizes; hence, the BCC model of Banker *et al.* (1984) under the assumption of variable returns to scale (VRS), that improves upon the CCR model (Charnes *et al.*, 1978) accounting for possible scale effects, is a natural choice. Firms typically have little or no direct control over the demand required by their customers and therefore, input-orientation was chosen (i.e. BCC input-oriented model).

Given a set of $n$ DMUs (firms, $j = 1, \ldots, n$, utilizing quantities of inputs $X \in \Re^m_+$ to produce quantities of outputs $Y \in \Re^k_+$), we can denote $x_{ij}$ and $y_{rj}$ the amount of the $i^{th}$ input and $r^{th}$ output respectively used by the $j^{th}$ DMU.

The following VRS input-oriented value-based model (Equation 1) can be used to assess the efficiency of firms:

| Inputs | | Output (to be transformed further) | | Final output |
|---|---|---|---|---|
| Total operating cost<br>Selling and administrative cost | Profitability → efficiency (Stage 1) | Total revenue | Effectiveness → (Stage 2) | Net income before taxes |

**Figure 1** Profitability efficiency and effectiveness of construction firms

$$
\begin{aligned}
& Max\ h = \sum_{r=1}^{k} \mu_r y_{rj0} + \omega \\
& s.t \\
& \sum_{i=1}^{m} v_i x_{ij0} = 1 \\
& \sum_{r=1}^{k} \mu_r y_{rj0} - \sum_{i=1}^{m} v_i x_{ij0} + \omega \leq 0 \quad && j = 1, 2, \cdots, n \\
& \mu_r \geq \varepsilon && r = 1, 2, \cdots, k \\
& v_i \geq \varepsilon && i = 1, 2, \cdots, m \\
& \omega \ free\ on\ sign
\end{aligned}
\tag{1}
$$

where:

$\varepsilon > 0$, a convenient small positive number (non-Archimedean)
$\mu_r$ = output weights estimated by the model
$v_i$ = input weights estimated by the model.

For more on Equation 1 and $\varepsilon$, the interested reader is referred to two classic DEA books: Thanassoulis (2001) and Charnes *et al.* (1994), respectively.

The radial efficiency $h$ derived from Equation 1 shows the rate of reduction of the input levels of the firm under evaluation.

The efficiency score obtained from the BCC model is referred to as pure technical efficiency (PTE), representing the ability of management to utilize firms' given resources. The use of VRS decomposes the (overall) technical efficiency (OTE), i.e. the efficiency score obtained from the CCR model, into a product of PTE and scale efficiency (SE). PTE relates to the ability of management to utilize firms' given resources, whereas SE refers to exploiting scale economies by operating at a point where the production frontier exhibits CRS. SE is defined by the ratio of the OTE to PTE, and for BCC-efficient firms with CRS characteristics (in the most productive scale size, MPSS), SE is one.

The classification of return to scale into CRS, increasing returns to scale (IRS), and decreasing returns to scale (DRS) can be obtained by means of the BCC returns to scale method introduced by Banker *et al.* (1984). If in all optimal solutions to Equation 1 $\omega < 0$ ($\omega > 0$), then DRS (IRS) hold locally at DMU$j_o$. In the case that $\omega = 0$ in some optimal solutions, then locally CRS hold where DMU$j_o$ lies within or is projected on the efficient frontier.

It can be shown that in a single input-output assessment, as in the effectiveness performance direction with total revenue as input and net income before taxes as output the employment of DEA coincides to the ratio of output to input multiplied by a normalized constant (Basso and Funari, 2001). For the sake of comparison, net income before taxes to total revenue is standardized using the 'Distance from the best and worst performers' method (Freudenberg, 2003). In this method, standardization is in relation to the global maximum and minimum, and the standardized indicator takes values between 0 (laggard) and 1 (leader). The standardized variables that stem from the following Equation 2 are indicators in which the benchmark is represented by maximum values.

$$
Standardized\ value = \frac{actual\ value\ -\ minimum\ value}{maximum\ value\ -\ minimum\ value} \tag{2}
$$

## Hypothesis development

In the context of this research, profitability efficiency is tightly coupled with effectiveness. In fact, effectiveness also reflects how well the output in the profitability efficiency stage (operational space of firm) meets the requirements in the effectiveness stage (financial space of firm). We expect profitable firms to be more effective than their less profitable counterparts. This leads us to our first hypothesis:

> *Hypothesis 1*: Effectiveness is associated with profitability.

If effectiveness is associated with profitability, then it is of interest to uncover the characteristics of effective and efficient firms in terms of profitability.

Thus, to facilitate understanding of the key characteristics of effective and efficient construction firms, we offer the following hypotheses:

> *Hypothesis 2a*: Size is related to efficiency.
> *Hypothesis 2b*: Size is related to effectiveness.

As underperformance is present in the construction industry due to complex projects, one would expect that construction firms do not operate at the optimal scale size. This observation leads to the following hypothesis:

> *Hypothesis 2c*: Scale inefficiency is present in the Greek construction industry.

One would also expect that there are some firm-specific factors related to the operational and financial spaces of the firm that are likely to interfere with the determination of performance. Accordingly, we select the expenses-to-total revenue ratio and the equity multiplier as two factors related to the operational and financial spaces of the firm, respectively and we hypothesize that:

*Hypothesis 3a*: The expenses-to-total revenue ratio is related to efficiency.
*Hypothesis 3b*: The expenses-to-total revenue ratio is related to effectiveness.
*Hypothesis 4a*: The equity multiplier is related to efficiency.
*Hypothesis 4b*: The equity multiplier is related to effectiveness.

## Data sources and identification of inputs and outputs

Data on the 16 construction firms listed on Athens Exchange, with total assets greater than €50 million, are used. Financial statement data refer to the year 2007 and have been retrieved from Reuters' database. Details of the sample selection process are presented in Table 1.

The existing legislation framework divides construction companies into seven classes (Classes 1 to 7) in the registry of the so-called Greek Ministry for the 'Infrastructure, Transportation, and Networks'. This classification system of licensure grants different rights to construction companies and serves as an artificial barrier to entry into the public sector market. (For a similar discussion concerning construction firms in Hong Kong, see also Chau and Wang, 2003.) The focus of this study on the three upper-class companies (the Class 7, Class 6 and Class 5 companies) is consistent with the selected firm population of a series of previous studies in Greece. Moreover, the current research is also focused on the greatest heavy construction listed firms because evidence on the performance using financial data will strengthen the understanding of the content of financial statements in the industry. Conveying information about the firm performance would provide useful additional information to investors to improve their portfolio holdings. The selected sample of the greatest heavy construction listed firms is deemed homogeneous, thus avoiding outliers which would bias the results. The use of a smaller sample size (e.g. a sample limited to listed Class 7 firms) may affect the discriminating power of the DEA. The number of DMUs (i.e. firms) and the number of input and output variables are related to the discriminatory power of DEA. The analysis of the number of DMUs to the number of input and output variables is expressed in terms of a ratio value R, where $R = \frac{n}{m+k}$; if R is too small, the ability of DEA to discriminate between the DMUs decreases (Cooper *et al.*, 2007).

The sampled firms are: Aegek S.A. (GCEr.AT), Athena S.A. (ATHr.AT), Atti-Kat S.A. (ATTr.AT), Diekat S.A. (DIEr.AT), Bioter S.A. (VTRr.AT), Domiki Kritis S.A. (DKRr.AT), Edrasis C. Psallidas Technical Co. (EDRr.AT), Ellaktor S.A. (HELr.AT), GEK Holdings Real Estate and Constructions S.A. (HRMr.AT), J. & P. Avax S.A. (AVAr.AT), I. Kloukinas-I. Lappas S.A. (K.L.M) (KLUr.AT), Intracom Constructions S.A. (INCr.AT), Michaniki S.A. (MICm.AT), MOHLOS ATE (MOHr.AT), Proodeftiki S.A. (PROr.AT), and Terna S.A. (TERr.AT).

In the DEA profitability assessment context (first performance dimension), a company is defined as a firm that uses operating costs and selling and administrative expenses to achieve profitability (i.e. a company's ability to generate revenue in terms of its current resources).

Operating costs are a firm's direct costs in producing goods and providing services excluding selling and administrative expenses (i.e. firm costs that combine salaries and expenses for executives and salespersons, as well as advertising expenses). Total revenue (sales or turnover) is the amount of goods or services sold by a company. Net income before taxes includes a company's profits after deducting the charges detailed in the profit and loss account such as total cost of revenue, sales and administrative costs, interest expenses, and depreciation.

Isotonicity, a basic assumption of the DEA (i.e. when an input increases, an output should not decrease, and vice versa) is tested by the calculation of all inter-correlations between inputs and outputs for identifying whether increasing amounts of inputs lead to greater outputs. As positive (and significant) inter-correlations were found for the input and output items, this isotonicity test was passed, and the inclusion of the selected input and output variables was justified.

**Table 1** Construction firms sample selection (various sources)

| Licence class | Number of the sample firms[a] | Listed firms[a] | % of listed firms[a] | Registered firms[b] | % of registered firms[c] |
|---|---|---|---|---|---|
| 7th | 11 | 11 | 100.00 | 12 | 91.67 |
| 6th | 4 | 6 | 66.67 | 45 | 8.89 |
| 5th | 1 | 1 | 100.00 | 60 | 1.67 |
| Total | 16 | 18 | 88.89 | 117 | 13.68 |

*Sources*: [a]This study; [b]Association of Greek Contracting Companies (SATE) (2007); [c]Own calculations based on data from Association of Greek Contracting Companies (SATE) (2007).

In regard to the second performance dimension, the net income before taxes-to-total revenue ratio is treated as a metric of effectiveness and is defined as the ability of a firm to achieve the expected level of income generation.

Descriptive statistics of inputs and outputs used in the analysis are presented in Table 2.

## Results

### First-step analysis: profitability efficiency

The distribution of OTE and its components are presented in Figure 2. The median PTE is of the order of 99% and its mean value is about 93%. Out of the 16 firms, seven (44% of the total sample) are relatively efficient (Table 3).

In Figure 3, the SE scores for profitability and size (measured by firm's assets) are provided for the three categories of scale (CRS, IRS, and DRS) within a so-called bubble diagram (i.e. the size of a firm is represented by a circle, with larger circles representing larger firms).

Equation 1 suggests that most of the efficient firms (57%) are operating under DRS, two firms (29%) under CRS, and the rest of the firms (14%) under local IRS. Most of the inefficient firms (89%) are operating under local DRS, and the rest (11%) under IRS; none of the inefficient firms operates under local CRS (Table 4).

### Effectiveness

The results concerning the distribution of the normalized effectiveness metric are presented in Figure 4. As can be seen from the result distribution, the median effectiveness is of the order of 43.54%. The mean value of the normalized ratio of effectiveness is 50% (Table 3).

### Profitability efficiency vs. effectiveness

The efficiency and effectiveness leaders are presented in Table 5.

The comparison between profitability efficiency and effectiveness is illustrated by an efficiency-effectiveness matrix presented by Figure 5. The

**Table 2** Descriptive statistics of inputs-outputs used in the assessments (mil euros)

| | Total operating cost | Selling and administrative expenses | Total revenue | Net income before taxes |
|---|---|---|---|---|
| Mean (SD) | 228.5(228.8) | 15.0 (14.1) | 256.6(253.8) | 23.0(46.9) |
| Median | 168.3 | 10.5 | 180.2 | 6.4 |
| Q1 | 76.0 | 4.9 | 90.0 | 0.4 |
| Q3 | 354.4 | 19.2 | 384.7 | 33.2 |
| Min | 4.2 | 0.8 | 15.7 | –35.2 |
| Max | 812.4 | 46.6 | 914.7 | 165.9 |

*Notes*: SD = standard deviation; Q1 = first quartile; Q3 = third quartile.

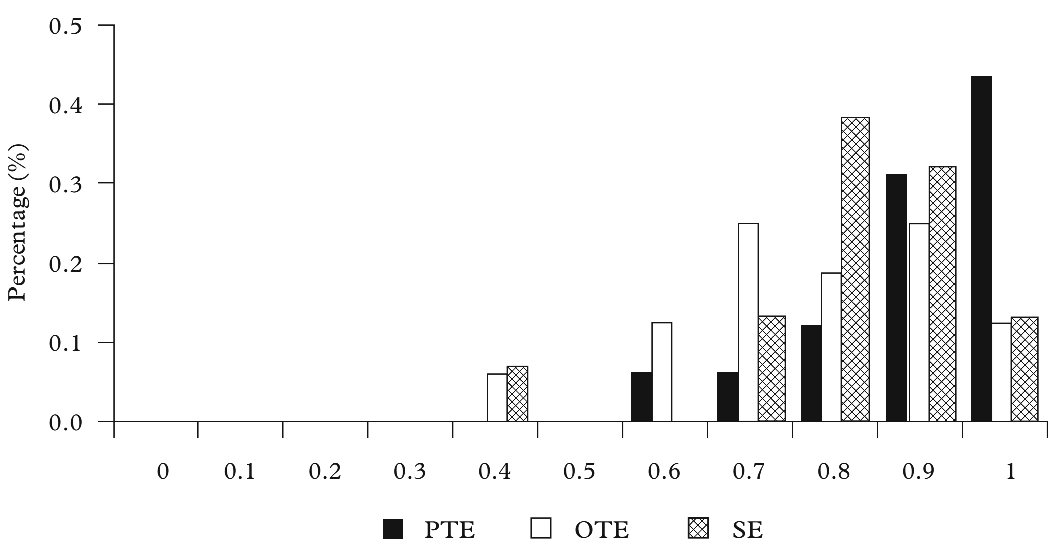


**Figure 2** Distribution of profitability efficiency measures of firms

**Table 3** Mean (standard deviation), median, quartiles (Q1, Q3), min, max values of efficiency and effectiveness measures, number and percentage of efficient firms

| | Mean (SD) | Median | Q1 | Q3 | Min | Max | Efficient firms, number (% of total firms) |
|---|---|---|---|---|---|---|---|
| Panel A: DEA profitability efficiency | | | | | | | |
| Profitability efficiency (%) | 93.13 (10.51) | 98.80 | 91.13 | 100.00 | 63.24 | 100.00 | 7 (44) |
| Panel B: Normalized ratio of effectiveness | | | | | | | |
| Effectiveness (%) | 50.03 (28.91) | 43.54 | 36.50 | 65.65 | 0.00 | 100.00 | |

*Notes*: SD = standard deviation, Q1 = first quartile, Q3 = third quartile.

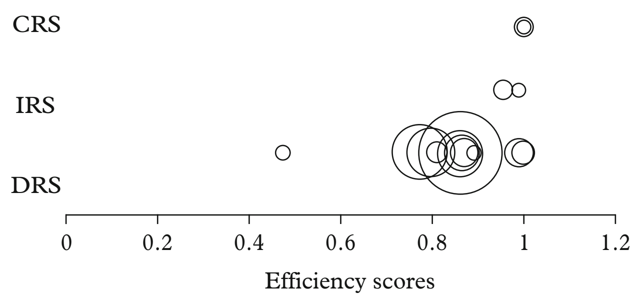


**Figure 3** Scale of operation (profitability efficiency)

matrix utilized herein is drawn from the Product Market Portfolio or Boston Consulting Group (BCG) matrix, which is discussed further by McKiernan (1992) in his book on strategies of growth. Splitting half by the mean value was used to create the four quadrants of the efficiency-effectiveness matrix. For the quadrants, the same names as in a relevant DEA study by Luo (2003) are used: stars, dogs, question marks, and sleepers. Firms that achieve higher levels of both profitability efficiency and effectiveness can be classified as stars. Dogs are those firms that earn higher profitability efficiency but lower effectiveness. Question marks (problematic firms) perform inferiorly in both in profitability efficiency and effectiveness. Finally, sleepers experience a higher level of effectiveness but lower profitability efficiency.

The distribution included (Figure 5):

(I) Seven stars (44% of the total sample).
(II) Three dogs (19% of the total sample).
(III) Six question marks (37% of the total sample).
(IV) No sleepers.

**Second-step analysis: Tobit and ordinary least square regressions**

The DEA metrics that stem from Equation 1 yield only first-step measures of performance as regards profitability. A second-step analysis is called for, as performance may be affected not only by inadequate firm management, but also by other explanatory variables. Hoff (2007) argues that Tobit regression often encountered in a sequential step that follows DEA, as an alternative to OLS regression, seems to be sufficient in representing second-stage DEA models. The firm DEA profitability measures are regressed using the Tobit regression method to identify the impact of a series of explanatory (control) variables listed in Table 6. The variables related to the firms that might have explanatory power for the efficiency differences were identified as: asset size measured by the natural logarithm of firm's total assets which controls for firm's size; expenses-to-total revenue ratio; and equity multiplier (total assets-to-equity ratio). The first two factors are related to the operational space of the firm, and the third factor is related to firm's financial space.

Between the DEA and Tobit regression, we utilize as dependent variable the transformed variable '*h' = 1-h*', where *h* is the performance metric derived from Equation 1. For computational purposes, Greene (1993), in his classic textbook on econometric

**Table 4** Returns to scale (RTS) classification and DEA-profitability efficiency

| RTS | Efficient, number of firms (% of total sample) | Projected, number of firms (% of total sample) | Total, number of firms (% of total sample) |
|---|---|---|---|
| No. of CRS | 2 (29) | 0 (0) | 2 (12.5) |
| No. of IRS | 1 (14) | 1 (11) | 2 (12.5) |
| No. of DRS | 4 (57) | 8 (89) | 12 (75) |
| Total | 7 (100) | 9 (100) | 16 (100) |

*Notes*: No.: number of firms; IRS: increasing returns to scale; CRS: constant returns to scale; DRS: decreasing returns to scale.

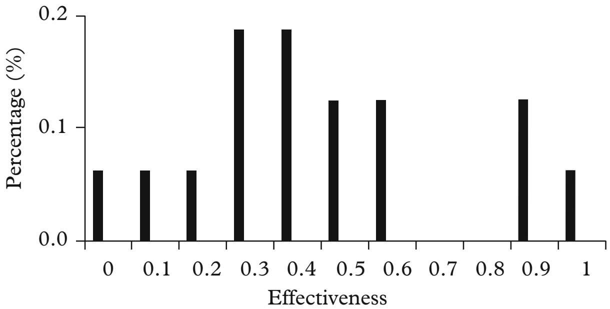


**Figure 4** Distribution of effectiveness measures of firms

**Table 5** Efficiency and effectiveness leaders

| Ticker | Profitability efficiency | Effectiveness* |
|---|---|---|
| DKRr.AT | ✓ | ✓ (2) |
| HELr.AT | ✓ | ✓ (4) |
| HRMr.AT | ✓ | ✓ (5) |
| KLUr.AT | ✓ | ✓ (1) |
| MICm.AT | ✓ | ✓ (3) |
| MOHr.AT | ✓ | ✓ (7) |
| VTRr.AT | ✓ | ✓ (11) |

*Notes*: *Profitability efficient firms as they appeared in the effectiveness ranking. Firm ranking in parentheses.

analysis, suggests the use of censoring at zero for Tobit regression. To uncover the drivers of effectiveness an OLS regression is followed.

The effects of size and expenses-to-total revenue ratio are significant in explaining profitability efficiency at the 0.01 level; the sign of size is negative, and the sign of expenses-to-total revenue ratio is positive, as expected. The effect of expenses-to-total revenue ratio is significant in explaining effectiveness at the 0.01 level; the sign of expenses-to-total revenue ratio is negative, as expected. The results of the analysis explaining the performance scores are given in Tables 7 and 8.

## Discussion

Compared to similar studies for other countries, the average profitability inefficiency of the sample firms (mean estimates of about 7%) is lower than the DEA based financial evaluation estimates of Pilateris and McCabe (2003) in their research sample of Canadian contractors who obtained average inefficiencies that ranged from 38% to 54%. This is perhaps due to the nature and size of the sample of firms assessed herein (i.e. largest heavy contractors) as compared to the large sample of all sizes of the firms of Pilateris and McCabe (2003). With a small number of inputs and outputs in a large sample of firms, it is not surprising to see low efficiencies.

In regard to scale patterns, it is believed that the construction industry is sensitive to the scale of operation (Pilateris and McCabe, 2003) and the sample Greek listed construction firms are no exception. The results indicate that 87.5% of the firms (14 out of 16) do not operate at the most productive scale size (Table 4); 75% of firms operate under DRS; and 12.5% under IRS. These should decrease and increase their scale size of operations, respectively. This finding can be treated as support for future mergers and acquisitions between construction firms. For scale inefficient firms that operate under IRS, performance can be increased by consolidating with other smaller firms to achieve optimal scale.

The previous analysis indicates efficient and inefficient firms on the profitability dimension of performance. Inefficient firms can improve their performance, and the DEA projections provide a prescription for improvement.

The effectiveness findings inevitably signify that only five of seven profitability efficient firms are in the top five effectiveness ranking (Table 5). To fill the gap in effectiveness, low performance firms should increase their profit margin to meet the best-in-class firm in that dimension. The average value of profit margin for the sample firms (about 8%) is deemed very satisfactory since the Associated General Contractors of America (AGCA) recommends a value of 2% or greater for that ratio (Pilateris and McCabe, 2003).

The Pearson's correlation coefficients (0.689; p-value = 0.003), as well as Kendall's (0.753; p-value = 0.000) and Spearman's (0.874; p-value = 0.000) rank correlation coefficients between profitability efficiency and effectiveness are statistically significant at the 0.01 level. These results support Hypothesis 1: Effectiveness is associated with profitability.

The second-step results support Hypothesis 2a: Size is related to efficiency (Table 7) but there is no evidence for the association of size with effectiveness. Moreover, as size is related to profitability efficiency, the findings in regard to scale patterns of firms in profitability dimension support Hypothesis 2c: Scale inefficiency is present in the Greek construction industry. These results also confirm the model selection to account for possible scale effects and are in line with those derived by Pilateris and McCabe (2003).

Previous research such as Chau and Wang (2003) suggests that economies of scale exist at the project level, and since large projects are undertaken by large firms, it is expected that economies of scale also exist at the corporate level.

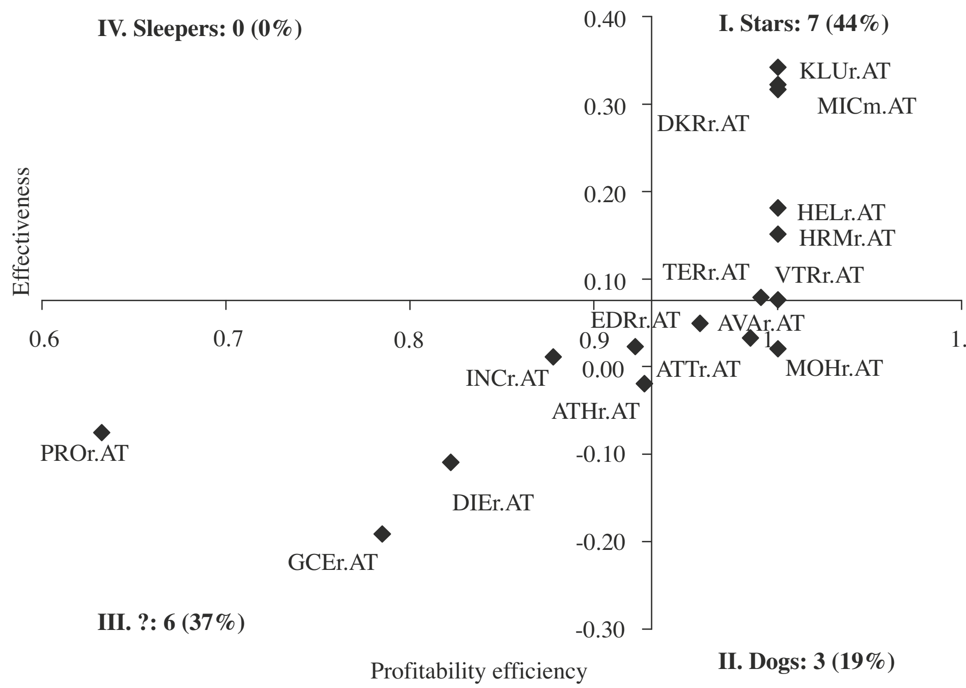


**Figure 5** Profitability efficiency vs. effectiveness

**Table 6** Explanatory variables and descriptive statistics

| | SIZE | EM | ETTR |
|---|---|---|---|
| Min | 3.97 | 1.78 | 0.32 |
| Max | 8.09 | 12.65 | 0.94 |
| Median | 5.73 | 3.55 | 0.95 |
| Mean | 5.45 | 3.01 | 0.99 |
| Standard deviation | 1.13 | 2.50 | 0.96 |

*Notes*: SIZE: asset size (natural logarithm of firm's total assets); EM: equity multiplier; ETTR: expenses-to-total revenue ratio.

**Table 7** Results of Tobit regression for profitability efficiency

| Censored Tobit model (dependent variable = 1-$h$) | | | |
|---|---|---|---|
| Variable | Coefficient | Standard error | t-value |
| Constant | –0.849 | 0.4196 | –2.02 (0.063) |
| SIZE | –0.069 | 0.0254 | –2.71$^{*}$ (0.017) |
| ETTR | 1.357 | 0.3751 | 3.62$^{*}$ (0.003) |
| Sigma | 0.0711 | 0.0167 | |
| Log likelihood = 8.876 | | | |

*Notes*: SIZE: asset size (natural logarithm of firm's total assets); ETTR: expenses-to-total revenue ratio. t-ratios followed by $^{*}$ are significant at a level of 1%. *p*-values in parentheses.

**Table 8** Results of ordinary least squares regression for effectiveness

| Ordinary least squares regression model (dependent variable = effectiveness) | | | |
|---|---|---|---|
| Variable | Coefficient | Standard error | t-value |
| Constant | 0.650 | 0.1519 | 4.28* (0.001) |
| ETTR | –0.635 | 0.1649 | –3.85* (0.002) |
| R-squared = 0.5141 | | | |
| Durbin-Watson = 1.352 | | | |

*Notes*: ETTR: expenses-to-total revenue ratio. T-ratios followed by * are significant at a level of 1%. *p*-values in parentheses.

**Table 9** Hypothesis testing results

| Hypotheses | Confirmed? |
|---|---|
| H1: Effectiveness is associated with profitability | Yes/Strong evidence |
| H2a: Size is related to efficiency | Yes/Strong evidence |
| H2b: Size is related to effectiveness | No evidence |
| H2c: Scale inefficiency is present in the Greek construction industry | Yes/Strong evidence |
| H3a: The expenses-to-total revenue ratio is related to efficiency | Yes/Strong evidence |
| H3b: The expenses-to-total revenue ratio is related to effectiveness | Yes/Strong evidence |
| H4a: The equity multiplier is related to efficiency | No evidence |
| H4b: The equity multiplier is related to effectiveness | No evidence |

The results given in Tables 7 and 8 support Hypothesis 3a: The expenses-to-total revenue ratio is related to efficiency and Hypothesis 3b: The expenses-to-total revenue ratio is related to effectiveness. It should be noted that in contrast to similar studies on listed firms (Mostafa, 2007), the expenses-to-total revenue ratio is statistically significant in explaining profitability efficiency.

Despite the fact that there are some theories on the relationship between leverage and efficiency (see You and Zi (2007) for a similar discussion concerning the Korean construction industry) there is no evidence that the equity multiplier is related to efficiency and effectiveness.

Table 9 summarizes the results identified through testing the hypotheses.

The generalization of results here may be first evaluated from the perspective of construction firms in Greece. It may be argued that issues related to the research questions have potential for generalization in large Greek non-listed construction firms. Although they may be applied in large non-listed firms, generalization to small firms should be made with caution. This is especially true in the case of the research question related to performance and firm size and the presence of scale inefficiency. With regard to other research questions, the potential for generalization should be better. More research is needed in order to better understand the applicability of results in such firms. Second, the factors supporting the development of a new performance measurement in construction and the integration of DEA with ratio analysis should be fairly appropriate to the whole construction industry in Greece and other countries due to their general nature and the similar challenges and needs for construction performance measurement, as indicated by the selected literature reviewed.

## Conclusions

A two-stage analysis has been carried out, integrating the DEA framework with ratio analysis for modelling the profitability efficiency and effectiveness, respectively, of a sample of Greek-listed construction firms. The outcome of this analysis consists of profitability and effectiveness metrics by which a comparison of sample construction companies' performance could be made.

Utilizing DEA a profitability efficiency metric is constructed, whereas effectiveness is measured by the profit margin. The DEA-derived efficiency metric is correlated with effectiveness, which suggests a clear link between the performance in the operational (cost-oriented) and financial (profit-oriented) spaces of the firm.

To gain a deeper understanding of the performance drivers, regression models are employed to explore some firm-specific factors related to the operational and financial spaces of the firm that are likely to interfere with the determination of performance. Both efficiency and effectiveness drivers are related to the operational space of the firm. These findings have important implications for both theory and practice.

These insights illustrate how construction firms can make use of financial statement data to produce performance metrics of both efficiency and effectiveness. The results of this research support the notion that cost-oriented operating policies of a firm are important drivers of its success in the industry. Thus, while much of the current literature focuses on the development of performance improvements at the company level based on questionnaire-based data or other subjective data, this research reinforces the need for the use of available data, such as found in the financial statements, in order to establish baselines for performance, benchmark the best-in-class firms, and set targets for improvement.

The managerial implications are clear. DEA determines the current profitability efficiency level of each firm of the sample and the best-in-class firms. The synthesized baseline establishment of efficiency and effectiveness can provide the targets for improvement using an efficiency-effectiveness matrix. For cost-oriented firms, the main problem seems to be the operation off the MPSS. Those firms sampled that have been found to be operating in a DRS region should reduce their size, whereas firms operating under IRS should investigate the possibility of expanding their operations.

The quest for economies or diseconomies of scale is often given as the rationale behind mergers and acquisitions. Thus, firms that operate in IRS or CRS regions are likely to be viewed as attractive acquisition targets because they have the opportunity to become more efficient through expansion in the case of IRS or because they currently operate in the optimal size range in the case of CRS. On the other hand, firms operating in DRS regions are likely to be viewed as unattractive acquisition targets because they have to reduce their size to achieve optimum scale.

Although the results seem intriguing, they simply represent a first attempt at studying profitability efficiency and effectiveness of the Greek-listed construction firms, and several study limitations must be recognized. To begin with, the focus on listed firms limited the sample to 16 records; this, in turn, limited the statistical power of specific forms of analysis. Future researchers should validate the findings of the current study using a bigger sample. The dataset used prohibited us from assessing (by means of DEA) a particular firm's movement along a profitability efficiency frontier over time. Detailed longitudinal financial statement data are needed in this regard. Future research would benefit from taking this dynamic time-dependent approach to estimate indices of change. Such studies could facilitate a richer discussion of how the policies associated with the proposed metrics may evolve over time.

Finally, there are a number of alternatives to the BCC model that can be used to model profitability. The current work invites further examination by future researchers, as those alternative models may provide additional insights into profitability efficiency estimation.

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## Appendix 1

### Glossary of abbreviations

| | |
|---|---|
| AHP | analytic hierarchy process |
| BCC | Banker, R.D., Charnes, A., Cooper, W.W. |
| BCG | Boston Consulting Group |
| BPM | business performance measurement |
| BSC | balanced scorecard |
| CBPP | Construction Best Practice Program |
| CCR | Charnes, A., Cooper, W.W., Rhodes, E. |
| CFEM | contractor financial evaluation model |
| CII | Construction Industry Institute |
| CRS | constant returns to scale |
| DEA | data envelopment analysis |
| DMU | decision-making units |
| DRS | decreasing returns to scale |
| EFQM | European Foundation for Quality Management |
| EM | equity multiplier |
| ETTR | expenses-to-total revenue ratio |
| IRS | increasing returns to scale |
| KPIs | key performance indicators |
| MPSS | most productive scale size |
| OLS | ordinary least squares |
| OTE | overall technical efficiency |
| PCA | principal components analysis |
| PMPF | performance measurement process framework |
| PTE | pure technical efficiency |
| SATE | Association of Greek Contracting Companies |
| SD | standard deviation |
| SE | scale efficiency |
| SPM | stakeholder perspective measurement |
| Q1 | first quartile |
| Q3 | third quartile |
| VRS | variable returns to scale |