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ENGLISH VERSION.....

Medición de la eficiencia en la industria de la construcción y su relación con el capital de trabajo

Measurement of efficiency in the construction industry and its relationship with working capital

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Abstract

This investigation seeks to determine the relationship between working capital as a financial measure and the efficiency level of construction companies. The study sample is intentional, with 58 participating companies, from which the financial information was obtained in a time horizon of four years (2011-2014). In the first stage efficiency was assessed using Data Envelopment Analysis (DEA), and in the second stage Tobit regression model was applied in order to identify the relationship between the variables. Efficiency levels evaluated show a reduction in the average efficiency in the construction sector for the years 2012 and 2013, and the regression results do highlight a positive link between efficiency and working capital for all years, which indicates that a common financial strategy based on reducing working capital does not lead to an increase in the efficiency level of construction firms. This research can benefit not only Ecuadorian construction companies, but others who wish to improve their competitive advantage based on their financial information.

Keywords: *Data Envelopment Analysis, working capital, construction, efficiency, financial indices.*

Resumen

La presente investigación busca determinar la relación existente entre el capital de trabajo como medida financiera, y el nivel de eficiencia de las empresas de construcción. La muestra de estudio es intencional, con 58 empresas participantes, de las cuales se obtuvo información financiera en un horizonte temporal de cuatro años (2011-2014). En una primera etapa se evaluó la eficiencia mediante el Análisis Envolvente de Datos (DEA), y en una segunda etapa se aplicó un modelo de regresión Tobit con el fin de identificar la relación entre variables. Los niveles de eficiencia evaluados muestran una reducción en la eficiencia promedio en el sector de la construcción para los años 2012 y 2013, y los resultados de la regresión hacen resaltar un vínculo positivo entre la eficiencia y el capital de trabajo para todos los años, lo que determina que una estrategia financiera común basada en la reducción del capital de trabajo, no conduce a un incremento en el nivel de eficiencia de las firmas constructoras. La investigación puede beneficiar no sólo a las empresas de la construcción ecuatoriana, sino a otras que deseen mejorar su ventaja competitiva en base a su información financiera.

Palabras clave: Análisis Envolvente de Datos, capital de trabajo, construcción, eficiencia, índices financieros.

1. Introduction

The construction industry is one of the main actors in the economy of developing countries. In those countries, a significant housing deficit is evidenced and it is common that their countries create policies including direct budget appropriations or financing through financial institutions that tend to boost the construction industry, thus generating employment sources and an important movement of domestic raw materials.

In Ecuador, the construction industry showed a slowdown from 1995 to the dollarization in 2000, after which, the country began a growth cycle with a significant economic recovery and a decrease of social problems that lead not only to the reduction of the housing deficit but also to the reduction of unemployment.

At present, in Ecuador, the construction industry is an important generator of economic growth and contributes significantly to the gross domestic product (GDP) of the country. From 2003 to 2013, an average participation of 8.6% was determined and after 2013, the participation of the construction industry reaches an average of 10.7% of the total GDP (Central Bank of Ecuador 2014). As a result of its growth perspective, the construction industry has gained notoriety from a business perspective, but the lack of technical and economic tools that allow a proper organizational management has become evident. For this reason, the generation of sectoral and business studies that lead to an efficient management of resources is necessary.

For the maximization of profits in construction companies, there are various strategies used by their managers, such as exploitation of economies of scale, in which the management is focused on the completion of large-scale projects. There are also strategic approaches aimed at reducing costs and others such as optimal financial management of cash flows and cash. Every construction company seeks to have enough money flows in order to cover short-term obligations. This guarantees the opportune technical development of works, that is to say, their execution on schedule. Therefore, the availability of short-time resources must be enough to cover the short-term demands for funds, which is financially known as "Working Capital" or "Revolving Fund". However, financially, every resulting surplus after covering short-term obligations, should be reduced to the minimum since there is a capital cost or

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debt cost behind these funds; therefore, the construction manager would opt for a revolving fund reduction strategy " …keeping much working capital does not lack drawbacks. The working capital must be financed with long-term debts and accounting capital, which are expensive. Consequently, managers prefer minimizing the working capital." (Garrison y Brewer, 2007). As warned by the author, the effective management of resources by reducing the revolving fund to their minimum levels is a common practice. However, the problem lies in the lack of studies that determine the effectiveness of this measure.

The objective of the present work is to determine the existent relationship between working capital and business efficiency levels. Due to the need of clarifying the efficiency of certain practices or business strategies, the following research question arises: ¿Does the management based on the reduction of working capital generate an increase in the business efficiency levels? In order to answer this question, we need to determine an efficiency indicator including internal variables related to resources consumed and products obtained. Initially, the present investigation analyzes previous works in which an efficiency measurement scale was prepared, as well as some studies that determine explanatory factors of efficiency scores. Then, the study describes the methodology and data used in the investigation and continues with an analysis and a discussion of the results. Finally, this study finishes with conclusions, limitations of the study and also suggests future investigation lines.

2. Literature Review

2.1 Concept of efficiency

A company is technically efficient if it does not find another way of producing more with the same number or quantity of productive factors. It is common to define the efficiency as a relationship between the results obtained called (outputs) and the resources used called (inputs).

The beginnings of the theory of efficiency can be attributed to the work of (Debreu, 1951) or (Shepard, 1953), but (Farell, 1957) was the author who promoted and gave substance to the development of the concept of efficiency in the industrial sector, by presenting a production frontier determined by the best practices of the area. The work of Farell influenced Charnes, (Cooper and Rhodes, 1978), who developed the DEA (Data Envelopment Analysis) methodology, as an extension of the works of Farrell. In their studies, productive units called DMU (decision making unit) were determined, as well as input and output variables that determined an efficient frontier.

2.2 DEA (Data Envelopment Analysis)

"Basically, DEA is a mathematical programming technique that allows the construction of an envelopment surface, an efficient frontier or an empirical production function" (Coll y Brasco, 2006). The efficiency is measured or calculated in relation to this surface. Charnes, Cooper and Rhodes proposed a model that assumes constant returns to scale (CRS). Then, some investigations as those of (Banker, Charnes and Cooper, 1984) considered variable returns to scale (VRS). These models could be distinguished by the envelopment surface and its orientation, which can be exemplified in Figure 1, a case of input and output.

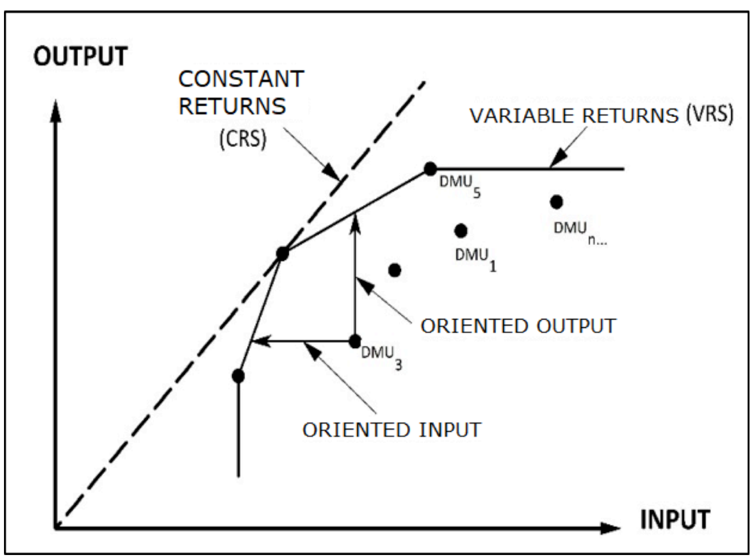

Figure 1. *CRS and VRS model, a case of an input and an output*

The CRS envelopment surface model assumes that an increase in the inputs is translated into a proportional increase of the outputs, while a VRS model proposes a non-proportional increase in the outputs, which entails increasing or decreasing returns to scale.

The efficiency calculation on the same data sample considering both VRS and CRS allows the determination of the so-called scale efficiency (SE), which is the ratio between these two measurements.

Figure 2 shows the case of two inputs (R, S) to produce an output (Q). Each point forms a set of production possibilities, but the C-D curve represents the best practices. The efficiency ratio of a productive unit could be represented as EF DMU3 = OB/OA.

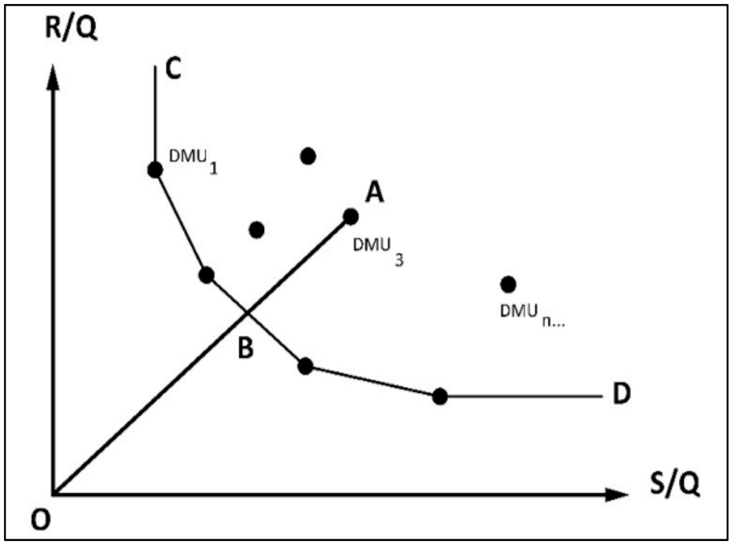

Figure 2. *Efficient frontier. A case of two inputs and one output*

When the technical efficiency measures are determined, it is necessary to choose a direction, that is to say, the path that leads to the frontier must be chosen. "Since all the companies in the frontier are efficient from the technical point of view, the efficiency measurement will depend on the company chosen as a reference" (Álvarez, 2013). The technical efficiency index is between 1 and 0. In an input-oriented method, value 1 means that it is no longer possible to reduce the number of inputs used; therefore, the production is considered to be efficient. In addition, the values less than 1 correspond to inefficient productions. The model can also be expressed in terms of output, that is to say, to maintain the maximization objective of the same number of outputs, keeping the number of inputs constant. Recent investigations such as that of (Aparicio et al., 2016), explore the inefficiency measurement in models that allow changing the supplies and the products at the same time.

2.3 Variable return model (Banker, Charnes and Cooper)

Carrying out an efficiency analysis to constant returns is only relevant if the DMUs operate at the same scale. (Banker et al., 1984) presented variable returns to scale (VRS) where it is possible that a company be efficient, but without showing an optimal operation scale.

Let us suppose that the company is using a set of variables to scale (VRS). Then the company involved could be too small in its operation scale, and part of the production function could fall under the increasing returns to scale (IRS). Similarly, a company could be too big and it can operate within the decreasing returns. In both cases, the efficiency of the companies could improve by changing its operating scale, that is to say, by keeping the same combination of supplies, but changing the size of the operations. If the underlying production technology is a globally constant return to scale (CRS) technology, then the company is automatically efficient in scale (Coelli et al., 2005).

In Figure 3, which is represented through an input and an output, unit 2 can be analyzed, for which the VRS frontier (marked by the best practices 1, 3 and 5) is closer than the CRS frontier. For this reason, the pure Input/Output technical efficiency estimated through the DEA VRS model of variable returns is higher than the Input/Output technical efficiency estimated through the DEA CRS model that considers constant returns.

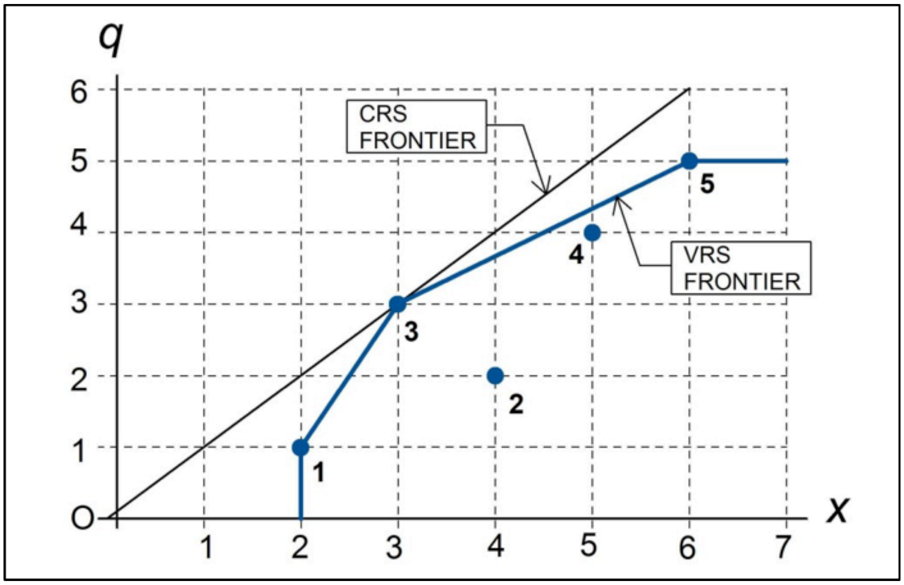

Figure 3. *VRS oriented input. Sources: (Coelli et al., 2005)*

In the variable return model, the inefficient units are only compared with those with similar size, while in constant returns the comparison is produced regardless of the size.

The mathematical approach of the DEA model in fractional form and input-oriented version can be expressed as follows:

$$\boldsymbol{Max}_{\ (u,v,k)} \qquad \boldsymbol{h_0 = \frac{u^T y_0 + k_0}{v^T x_0}} \qquad (1)$$

$$\boldsymbol{Subject\ to}: \qquad \boldsymbol{\frac{u^T Y_j + k_0}{v^T X_j} \le 1} \qquad (2)$$

$$\boldsymbol{j = 1, 2, \ldots \ldots \ldots .., \qquad n}$$

$$\boldsymbol{u^T, v^T > I\varepsilon}$$

$$\boldsymbol{k_0 \quad unrestricted}$$

x_j $(x_j \ge 0)$ *represents the input quantities consumed by the* j^{th} *unit.*

x_0 *represents the input quantities consumed by the assessed unit.*

y_j $(y_j \ge 0)$ *represents the output quantities produced by the* j^{th} *unit.*

y_0 *represents the output amounts produced by the assessed unit.*

u^T *y* v^T *represents the weights of inputs and outputs respectively.*

In the variable return model, the scale could be analyzed according to the sign of the k constant. See figure 4.

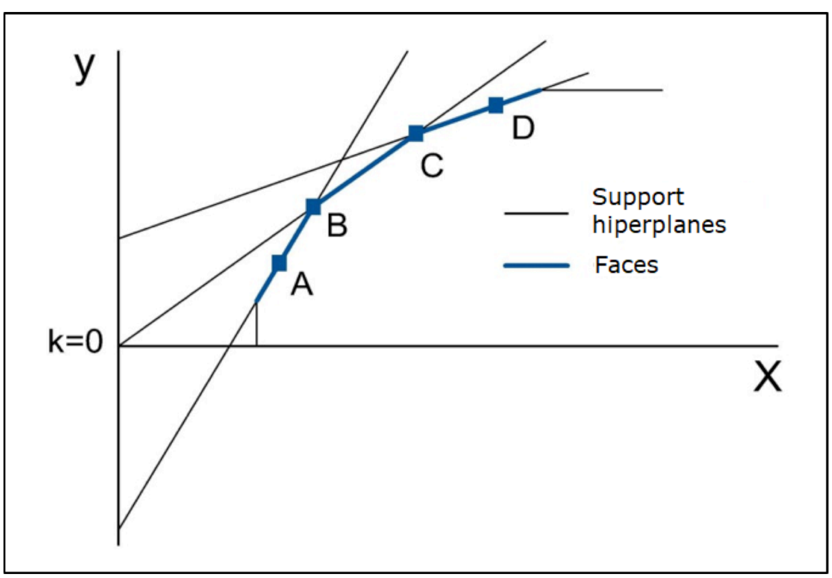

Figure 4. *Returns to Scale. Source: (Coll & Blasco, 2006)*

If $k_0 < 0$, then the DMU presents an increasing returns to scale situation.

If $k_0 > 0$, then the DMU presents a decreasing returns to scale situation.

If $k_0 = 0$, then the DMU presents a constant returns to scale situation.

In models of various inputs and outputs, it is important to reformulate the fractional model for its resolution. "Professor Charnes made an important contribution by transforming the fractional model into an equivalent linear programming model" (Sueyoshi & Goto, 2017). At present, and through the use of software, this transformation has permitted the resolution of more complex models.

2.4 DEA methodology applications

"The DEA has been recognized as a modern tool to measure returns" (Emrouznejad y Liang Yan, 2017). A great number of articles including important advances in the theory have been published, as well as DEA applications, both in the public and the private sector.

Some studies show a series of applications and uses of the efficiency measurement in different productive and business sectors such as the case of (Schuschny, 2007), who performs a measurement of the efficiency applied to the energy sector; (Coll and Blasco, 2007), who perform an application in the textile sector; (Quintanilha & Correia, 2012), who apply an efficiency measurement methodology to the aviation industry, and (Castro, 2015), who performs an application in the mining sector, among other authors.

2.5 DEA in the construction industry

The DEA analysis has had many applications in different industrial sectors. Specifically, in the construction sector, there are important contributions that have considered several variables for efficiency assessment and the creation of a business ranking. Many studies have worked with data from the Asian region, where there is a close relationship between the domestic product and the growth of the construction sector (Chau et al., 2005); (Chen & Tang, 2014); (Dzeng & Wu, 2012); (Devicenzi et al,. 2015). Other important studies were developed in Italy, Greece, Portugal, and Jordan (Guerrini et al., 2013); (Tsolas, 2011); (Horta et al., 2010); (El-Mashaleh et al., 2006).

Most aforementioned studies consider sales in their respective currency unit to be a production variable, and the work valued at money or number of employees according to the availability of information, equipment or technology, consumption of materials and certain intermediate resources are mainly considered to be factors or consumed resources. Some studies investigate in the following stage, the explanatory factors of the efficiency indices calculated, which are evaluated through correlations between the efficiency and technical and financial data. This is the case of (Moreno et al., 2014), who applied a three-stage model and established through a Tobit-type regression certain efficiency determinants; or the study of (de Araujo et al., 2012), who related the efficiency calculated with the volume of revenue.

3. Methodology

The present study is performed in two stages: first, a measurement of the efficiency of the different business units is made, and then, its relationship with the working capital is analyzed.

3.1 Investigation hypothesis

In the efficiency study, the hypothesis contrasting through the measurement of internal organizational variables on the efficiency level of the organizations is common. In the construction companies, the economies of scale have been frequently studied and it has been demonstrated that large companies manage low operating and production costs, which leads to the generation of a higher efficiency level (McCabe, 2003); (Dzeng and Wu, 2012). The present study assumes the effect of economies of scale and seeks to analyze the concept of business working capital levels in relation to the efficiency levels previously determined, regardless of the size of the companies. In order to answer the research question, the hypothesis to be tested is:

H1. The practice of working capital reduction is related to a decrease in the efficiency levels of the construction companies.

3.2 Analysis unit

The analysis unit is comprised of a sample of the construction business sector in Ecuador. Those companies involved in the construction of all types of buildings were established as the universe, grouped according to the codification of the Superintendency of Companies as a F41[1] level economic activity, which includes the construction of individual family homes, multifamily buildings, high-rise buildings, charity homes, orphanages, prisons, barracks, convents, religious houses, including remodeling, renovation or restoration of existing structures.

The number of construction companies according to the type of company is detailed in Table 1.

***Table 1.** Number of companies according to their activity. Source: Superintendency of Companies, Securities and Insurance*

Number of Compañías	**2008**	**2009**	**2010**	**2011**	**2012**
F41 - Construction of buildings	*2,122*	*2,251*	*2,477*	*2,491*	*2,111*
F42 - Civil engineering works	*1,331*	*1,506*	*1,730*	*1,769*	*1,419*
F43 - Specialized construction activities	*575*	*611*	*651*	*626*	*540*
Total number of companies	*4,028*	*4,368*	*4,858*	*4,886*	*4,070*

The universe or population is comprised of 2,111 profit-making companies with the F41 category, cut to 2012.

In Ecuador, the companies involved in the construction of civil works are classified as the most important within a general ranking according to their revenue level. Table 2 shows some of them as an example.

Table 2. *The Largest Construction Companies according to Revenue Level. Source: Ekos Magazine, Business Ranking Top 1,000. Taken from Industrial Studies:*

NAME		2013	2014
1	Constructora Norberto Odebrecht S. A.	294.4	651.3
2	Sinohydro Corporation	478.3	430.7
3	Hidalgo e Hidalgo S.A.	328.3	322.0
4	Herdoiza Crespo Construcciones S.A.	270.1	261.2
5	China International Water & Electric Corp-Cwe	130.4	163.4
6	Fopeca S.A	161.0	128.8
7	China Gezhouba Group Company Limited	109.9	109.4
8	Ripconciv Construcciones Civiles Cía. Ltda.	91.6	94.0
9	Harbin Electric International Co. Ltd.	71.7	93.1
10	Sevilla y Martínez Ingenieros CA Semaica	30.9	92.0

Note: Values in millions of dollars

3.3 Data Collection

The determination of a probabilistic sample in this type of study involves much complexity due to the need of having accounting input variables, data that are not often available. The literature on the subject has proven the usefulness of non-probabilistic samples in this type of study such as the case of (Dzeng and Wu, 2012), which includes 26 construction companies; (de Araujo et al, 2012) which includes 57 companies; (Tsola,s 2011) with 16 companies, or (Horta et al., 2010) which includes in its analysis the main 20 construction companies of Portugal. In the aforementioned studies, a business ranking with DEA models could be established, similar to that required in the present investigation. Likewise, these data have served as a basis for subsequent DEA variable ratio stages with sectoral financial information.

Therefore, the present investigation used an intentional non-probabilistic sampling, in which the information of 58 construction companies that belong to the construction of buildings category was collected, according to the following criteria:

Greater participation in the internal property market as per revenue level or asset size.

Greater advertising and positioning.

Quantity and quality of the information, with comprehensive accounting reports of at least 4 years (2011 – 2014).

Records in which the main construction companies of Ecuador according to the aforementioned criteria were used for the formation of the sample. In so doing, institutional lists from the construction chambers and professional architecture and engineering associations were used, as well as industrial studies that present annual rankings of companies in Ecuador.

The financial data were obtained from secondary sources such as financial statements published in the official webpage of the Superintendency of Securities and Insurance of Ecuador, an institution in charge of consolidating and publishing the financial information of institutions and companies, as well as from government databases such as the Internal Revenue Service and the National Statistics and Census Institute of Ecuador.

Even though the companies selected for the study recorded all their financial statements during the years (2011-2014), it was necessary to exclude some data in the year-by-year analysis due to the presence of errors as a result of the improper location of the information in the boxes of the virtual form, and also because the information of some boxes could not be completely displayed.

3.4 Variables and Techniques

In order to determine the efficiency levels, the data envelopment analysis (DEA) was used. This a non-parametric technique widely used in empirical studies to assess efficiency in the construction industry. The analysis is input-oriented type in variable returns. Input and output variables were established. The variables involved were selected from the financial statements and were established as inputs: 1) Work, 2) Materials and intermediate resources, 3) Property, plant and technology, and the variable established as an output is: 4) Production. The statistics of the variables involved are detailed in Table 3.

1) Work (T), datum obtained from the value expended in salaries and wages reported in the Statement of Income.

2) Materials and intermediate resources (M), this is obtained from the value recorded as cost of sales and additionally includes the administrative expenses and sale expenses reported in the Statement of Income.

3) Property, plant, equipment and technology (P) obtained from the net fixed asset, information contained in the Statement of Financial Position.

4) Production (Q), obtained from the sales and net revenue from ordinary activities recorded in the Statement of Income.

***Table 3.** Statistical description of variables*

Variable	*Observations*	*Median*	*Deviation*	*Min.*	*Max.*
Year	*2011*				
Work (T)	*47*	*469*	*1,346*	*1.28*	*7,780*
Materials (M)	*47*	*3,357*	*6,039*	*0.72*	*32,549*
Equipment (P)	*47*	*1,212*	*2,294*	*0.27*	*13,006*
Production (Q)	*47*	*3,989*	*7,041*	*6.41*	*33,747*
Year	*2012*				
Work (T)	*55*	*506*	*1,560*	*2.97*	*10,491*
Materials (M)	*55*	*3,176*	*6,454*	*19.30*	*39,763*
Equipment (P)	*55*	*1,357*	*2,264*	*0.19*	*11,481*
Production (Q)	*55*	*3,815*	*7,474*	*67.91*	*41,180*
Year	*2013*				
Work (T)	*56*	*591*	*1,421*	*7.63*	*8,818*
Materials (M)	*56*	*3,521*	*8,189*	*26.24*	*59,343*
Equipment (P)	*56*	*1,612*	*3,075*	*0.17*	*15,834*
Production (Q)	*56*	*4,301*	*8,662*	*36.92*	*60,258*
Year	*2014*				
Work (T)	*55*	*420*	*871*	*8.25*	*5,809*
Materials (M)	*55*	*3,569*	*7,960*	*38.05*	*55,757*
Equipment (P)	*55*	*1,596*	*3,198*	*0.14*	*20,195*
Production (Q)	*55*	*4,182*	*8,589*	*12.44*	*59,429*

Note: Values in thousands of dollars

Once the efficiency scores of the companies for each year of study have been defined, a correlation with working capital will be made. The working capital (WC) corresponds to the difference between current assets and current liabilities, which are reflected in the statements of financial position. The working capital of each unit represents the capability of covering the short-term business obligations of the organization, which, in turn, guarantees the appropriate production flow. See Table 4.

***Table 4.** Statistical description of Working Capital*

Variable	*Observations*	*Median*	*Deviation*	*Min.*	*Max.*
CT2011	*47*	*1,669*	*4,563*	*-4,335*	*25,510*
CT2012	*55*	*1,468*	*3,650*	*-4,819*	*16,201*
CT2013	*56*	*1,586*	*3,545*	*-2,775*	*18,937*
CT2014	*55*	*1,509*	*3,264*	*-3,207*	*13,184*

Note: Values in thousands of dollars

Since the efficiency is a truncated variable with its maximum value of 1, the Tobit model is used for the correlation study. The Tobit model solves the truncation problem through Beta estimates that directly represent the marginal effect that each of the x variables has in the median value of y. It should be noted that in this model, the non-normality affects to a greater extent and produces that the Beta estimators are inconsistent. At present, the contrast of the hypotheses of normality is a case of study in these models.

4. Results and discussion

An efficient frontier was initially elaborated by taking the observations of 2011. In the interest of showing a graphical scheme of the information, only two inputs were used for the calculation (Work and Materials), and one output (Production).

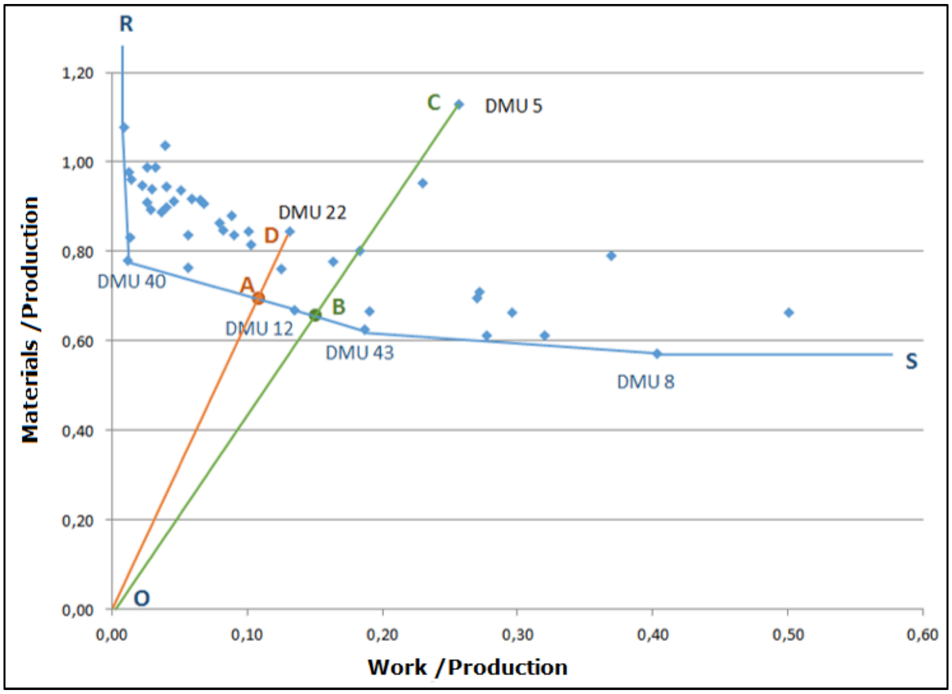

Figure 5. *Efficient frontier, a case of two inputs and one output, 2011*

Figure 5 shows the R-S frontier for the year 2011. The axes indicate the consumption of resources for each production unit, and each point in the space represents a company (DMU). The companies considered to be efficient for showing a lower consumption of resources per production level (DMU 40, 12, 43, 8), mark the efficient frontier. These companies show a score of 1.00 (see Table 5) because they are considered to be the best practices.

It is also possible to measure the efficiency level of the non-frontier units and identify the reference points with which the inefficient units can be compared (Taeb, Hosseinzadeh & Abbasbandy, 2017, p.194).

In the case of two inefficient companies plotted in Figure 5, (DMU 22 and DMU 5), its calculation is detailed as follows:

$$\boldsymbol{Efficiency\ DMU\ 22} = \frac{\boldsymbol{Distance\ OA}}{\boldsymbol{Distance\ OD}} = \frac{\mathbf{0.704}}{\mathbf{0.857}} = \mathbf{0.82} \qquad (4)$$

$$\boldsymbol{Efficiency\ DMU\ 5} = \frac{\boldsymbol{Distance\ OB}}{\boldsymbol{Distance\ OC}} = \frac{\mathbf{0.676}}{\mathbf{1.159}} = \mathbf{0.58} \qquad (5)$$

DMU 5 shows an efficiency value of 0.58 (58%), which means that this year the DMU inputs can be reduced by an average of 42% in order to consolidate itself as efficient.

The geometrical distances to the points A and B are obtained through a simple system of straight-line equations. It is important to mention the superior efficiency score of DMU 22 over DMU 5 since DMU 22 is closer the frontier; therefore, it shows better management or consumption of resources.

Likewise, all efficiency scores are calculated for the study sample. The efficiency scores of the companies 22 and 5, as well as the companies of 2011, are shown in Table 5.

Table 5. *Efficiency scores for the year 2011*

DMU	Score	DMU	Score	DMU	Score	DMU	Score
1	0,78	15	0,81	27	0,82	38	0,74
2	0,83	16	0,91	28	0,86	40	1,00
3	1,00	17	0,82	29	0,81	41	0,97
4	0,76	18	0,81	30	0,86	42	0,89
5	0,58	19	0,83	31	0,91	43	1,00
6	0,86	20	0,68	32	0,81	44	0,81
8	1,00	21	0,85	33	0,86	46	0,78
11	0,97	22	0,82	34	0,87	47	0,99
12	1,00	23	0,85	35	0,86	48	0,87
13	0,82	24	0,85	36	0,94	50	0,86
14	0,88	26	0,86	37	0,82	53	0,95

For the subsequent correlation with the Working Capital, apart from the inputs of Work and Materials, the so-called Equipment input was used in the efficiency calculation in order to include the consumption of technology of each of the firms. When a scheme of three inputs and one output is formed, the graphical representation becomes difficult because of the multidimensional nature of the resulting efficient frontier, and the determination of the score for each DMU requires more complex calculations.

The DEA variable return model in its input-oriented version for 2011 would be:

$$\textbf{Input matrix } X = \begin{pmatrix} Inputs & DMU\,1 & DMU\,2 & \dots & DMU\,n \\ Work & 105 & 17 & \dots & x_{2n} \\ Materials & 4,171 & 356 & \dots & \dots \\ Equipment & 29 & 1,682 & \dots & x_{mn} \end{pmatrix}$$

$$\textbf{Output matrix } Y = \begin{pmatrix} Output & DMU1 & DMU\,2 & \dots & DMU\,n \\ Production & 4,213 & 389 & \dots & y_{2n} \end{pmatrix}$$

Fractional model for the company DMU 1:

$$Max_{u,v,k} = \frac{4213\,u_1 + k}{105v_1 + 4171v_2 + 29v_3} \qquad (6)$$

Subject to:

$$\frac{4213\,u_1 + k}{105v_1 + 4171v_2 + 29v_3} \le 1 \quad \frac{389\,u_1 + k}{17v_1 + 356v_2 + 1682v_3} \le 1 \quad \frac{\dots u_1 + k}{\dots .v_1 + \cdots v_2 + \cdots v_3} \le 1 \qquad (7)$$

$$u_1, v_1, v_2, v_3 \ge 0$$

$$k_0 \quad unrestricted$$

The scale can be analyzed according to the sign of the k constant.

The model can be reformulated and solved by the computer when they pass from its fractional form to its linear programming. The Stata software was used to solve the model and determine the efficiency scores to variable returns posed by Banker, Charnes and Cooper. For the four years of study, apart from the score of each company, the ranking of units (DMU) that are part of the sample can be found in Table 6

Table 6. *Efficiency scores in variable returns to scale*

	2011		2012		2013		2014	
DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	1,00	1	0,70	30	1,00	1	0,69	46
2	0,74	34	0,70	31	0,87	13	1,00	1
3	1,00	1			1,00	1	0,42	52
4	0,67	41	0,73	25	0,76	21	0,97	13
5	0,47	47	0,50	55	0,74	23	0,90	16
6	0,80	25	0,78	22	0,84	15	0,26	55
7	-	-	-	-	0,58	55	0,70	42
8	1,00	1	1,00	1	1,00	1	1,00	1
9	-	-	1,00	1	1,00	1	1,00	1
10	1,00	1	1,00	1	1,00	1	1,00	1
11	1,00	1	0,84	18	-	-	-	-
12	0,80	26	0,64	45	0,66	40	0,83	24
13	0,95	13	0,86	16	0,72	25	0,62	51

Table 6. *Efficiency scores in variable returns to scale*

14	1,00	1	1,00	1	-	-	0,99	12
15	1,00	1	1,00	1	1,00	1	1,00	1
16	1,00	1	1,00	1	1,00	1	1,00	1
17	1,00	1	0,64	47	0,67	37	0,92	14
18	0,85	20	0,71	29	0,71	28	1,00	1
19	0,65	44	0,50	54	0,71	27	0,66	49
20	0,66	43	0,89	14	0,72	26	1,00	1
21	0,76	30	0,66	39	0,68	33	0,86	20
22	0,74	33	0,69	32	0,85	14	0,73	37
23	0,63	46	0,66	41	0,67	39	0,70	44
24	0,93	15	0,93	12	1,00	1	0,84	23
25	-	-	1,00	1	1,00	1	0,76	32
26	0,79	27	0,65	43	0,63	43	0,89	17
27	0,66	42	0,72	26	0,60	48	0,71	40
28	0,75	31	0,72	27	0,67	36	0,79	28
29	0,88	18	0,64	46	0,60	52	0,88	18
30	0,69	38	1,00	1	0,68	34	0,84	21
31	0,82	23	1,00	1	0,68	35	0,31	54
32	0,71	36	0,69	33	1,00	1	0,66	48
33	0,77	28	0,83	19	0,63	44	0,74	36
34	0,96	12	0,61	51	0,60	51	0,71	41
35	0,67	40	0,64	44	0,57	56	0,72	38
36	0,94	14	0,80	20	0,61	47	0,84	22
37	0,68	39	0,67	38	0,60	50	-	-
38	0,69	37	0,71	28	1,00	1	0,70	43
39	-	-	1,00	1	0,70	29	0,42	53
40	1,00	1	1,00	1	1,00	1	1,00	1
41	0,87	19	0,63	48	0,73	24	0,91	15
42	0,75	32	0,57	53	0,59	54	0,75	34
43	0,83	22	0,69	35	0,77	20	1,00	1
44	0,71	35	0,74	24	0,76	22	0,75	35
45	-	-	0,65	42	0,67	38	1,00	1
46	0,83	21	0,66	40	0,59	53	0,71	39
47	0,90	16	0,61	50	0,60	49	0,83	25
48	0,64	45	0,69	34	0,83	16	-	-
49	-	-	0,77	23	0,64	42	0,76	31
50	0,90	17	0,68	37	0,68	32	0,81	26
51	1,00	1	0,84	17	0,80	18	0,87	19
52	-	-	0,57	52	0,61	46	0,67	47
53	0,77	29	0,88	15	0,78	19	0,81	27
54	-	-	0,90	13	0,70	30	0,79	29
55	0,81	24	0,68	36	0,69	31	0,77	30
56	-	-	0,78	21	0,82	17	0,75	33
57	-	-	0,62	49	0,62	45	0,66	50
58	-	-	-	-	0,66	41	0,69	45

Table 7 shows the descriptive statistics of the model, in which 11 efficient companies are shown (2011, 2012, 2014), and 12 in 2013. In addition, the year 2011 can be analyzed as a relevant fact, with a superior average efficiency (0.82), the value that has a correspondence with the outstanding economic growth of the country this year. The maximum efficiency value is 1.0, while the minimum values are near 0.5, except for the year 2014, where a minimum value of 0.26 can be observed. This means that for this year, the DMU inputs can be reduced by an average of 74%.

Table 7. *Descriptive statistics DEA (VRS)*

Year	**2011**	**2012**	**2013**	**2014**
Number of efficients	11	11	12	11
Averange efficiency	0.82	0.76	0.75	0.79
Median	0.81	0.71	0.70	0.79
Deviation	0.14	0.15	0.15	0.17
Max.	1	1	1	1
Min.	0.47	0.50	0.57	0.26

Figure 6 shows the decrease in the efficiency scores in 2012 and 2013. For this reason, the companies were partially inefficient in terms of consumption of resources during these years.

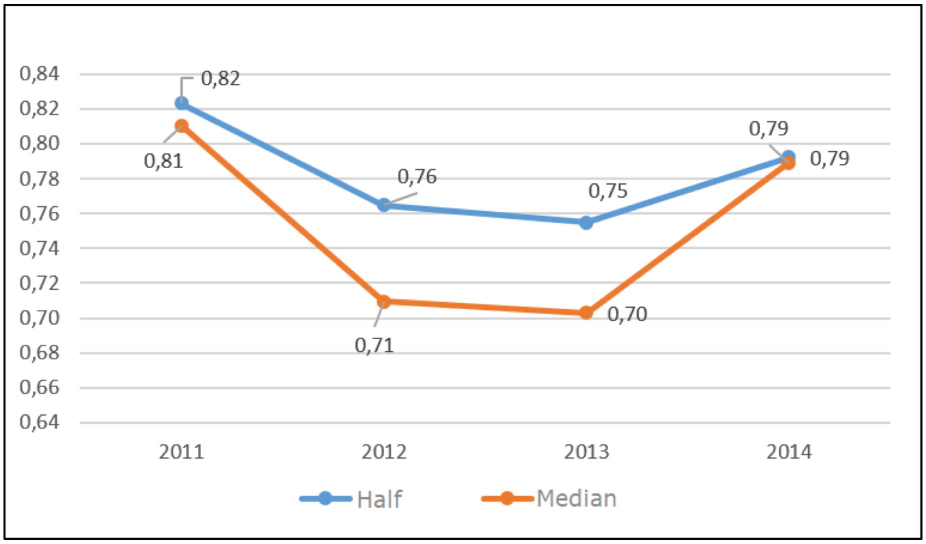

Figure 6. *Evolution of the efficiency per year (VRS)*

*Table 8 shows descriptive statistics of the efficiency of the ES scale, which relates the global technical efficiency GTE (constant return model) and the pure technical efficiency PTE (variable return model). The efficiency of the scale can be interpreted as the inefficiency part present in the global technical efficiency (GTE) that follows the production scale of the different DMUs. Therefore, GTE=PTE * ES. If ES=1, then the analyzed unit would not present scale inefficiencies. On the contrary, if ES<1 there would be scale inefficiencies. Table 8 shows high values of average scale efficiency, which indicates that the units are not far from the optimal operation scale. However, as all years present scale inefficiencies, it is convenient to analyze if the units operate at increasing or decreasing returns.*

Table 8. *Scale efficiency of descriptive statistics*

Year	***2011***	***2012***	***2013***	***2014***
Number of efficients	*6*	*6*	*5*	*6*
Average efficiency	*0.93*	*0.94*	*0.93*	*0.92*
Median	*0.98*	*0.98*	*0.98*	*0.96*
Deviation	*0.09*	*0.09*	*0.09*	*0.12*
Max.	*1*	*1*	*1*	*1*
Min.	*0.72*	*0.68*	*0.69*	*0.17*
Constant returns	*6*	*6*	*5*	*6*
Increasing returns	*15*	*33*	*42*	*7*
Decreasing returns	*26*	*16*	*9*	*42*

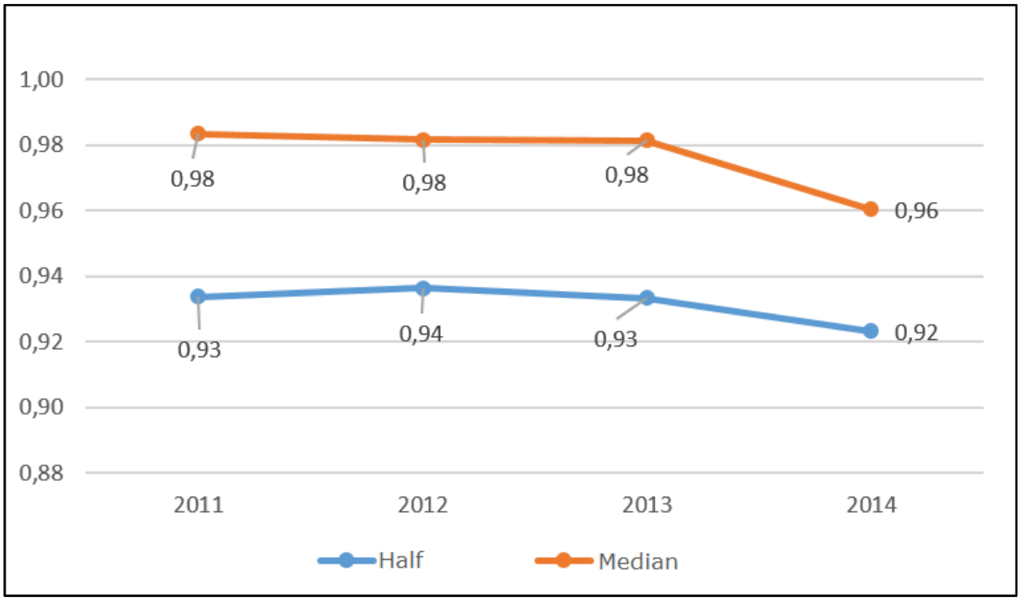

Figure 7. *Scale efficiency evolution per years*

The (increasing or decreasing) returns to scale indicate the proportion the outputs versus the inputs vary, so for the years 2011 and 2014, there are mainly companies that present decreasing returns. This means that in these DMUs, the percentage increase of sales (output) is less than the percentage increase of consumed resources (inputs). In 2012 and 2013, there are mainly increasing returns, which means that the percentage increase of the sales is higher than the percentage increase of the factors consumed during these years.

Table 9 shows the results of the Tobit regression analysis carried out between the efficiency scale and the working capital for each of the years. Positive beta coefficients can be observed for all of the years, which indicate that an increase in the working capital is related to higher efficiency levels. The higher coefficient is shown in 2012, which lead us to interpret that for this year, the increase in the working capital has a greater effect on the efficiency level. The analysis shows the different t-ratios and their respective p-values, with significance values of 99% for all of the years.

Table 9. *Effect of the working capital (WC) on the efficiency (VRS) according to the years*

Tobit regression						
VRS	*Beta Coefficient*	*Average Error*	*t-ratio*	*p > t*	*Obs.*	*Prob>chi2*
CT2011	*0.336*	*0.090*	*3.75*	*0.001**	*43*	*0.0001*
CT2012	*0.415*	*0.156*	*2.66*	*0.011**	*48*	*0.006*
CT2013	*0.339*	*0.127*	*2.67*	*0.01**	*54*	*0.0061*
CT2014	*0.231*	*0.074*	*3.12*	*0.003**	*50*	*0.0018*

5. Conclusions

This investigation pretends to be a support and help for the construction entrepreneurs. Its financial guidance is focused on the analysis of the working capital as an important financial indicator for proper decision making. The investigation also shows the relevance of the use of the DEA technique to value the level of efficiency of the companies, its current positioning and the possibility to properly handle the internal supplies in search of competitive positioning.

Establishing an efficiency valuation in construction companies is a complex task due to the diversity of information available for the comparison of productive units. In the study, the data envelopment analysis that measures the efficiency of a productive unit through multiple inputs and outputs has proven to be a feasible tool to solve the problem of the efficiency level rating in the companies involved in this investigation. The DEA analysis applied to the construction industry in Ecuador indicates a reduction in the efficiency levels in 2012 and 2013, after which the sector experiments an improvement for the year 2014. As this is a supply-oriented model, the study shows the way each DMU can reduce its inputs, keeping the same amount of outputs, up to reaching its efficient frontier.

The resulting DEA valuation, when it is correlated with the working capital, showed a direct link between these two measurements. The regression model used allows corroborating that a lower working capital level is related to lower efficiency variations in all years considered in the study. These results have a significant implication both theoretical and practical. The study allows illustrating how, in the construction firms, the implementation of a working capital reduction strategy does not lead to an increase in its efficiency. On the contrary, higher efficiency indicators are displayed in companies with a higher working capital.

Much current literature is focused on improving the returns and efficiency through the analysis of financial information. The present investigation shows how this information, present in the financial statements, can be the basis for the comparative evaluation between companies, which, in turn, allows determining the best practices of the industrial sector.

Although the results are conclusive with regard to the management of working capital, they only represent an attempt to study the financial information related to the efficiency of construction companies. The sample is comprised of only 58 records, which limits the statistical inference of the analysis. Future investigations will have to validate the results of the present study with a broader sample. It will also be necessary to relate more financial variables, which would allow future investigators to provide additional information on financial indicators and its relationship with the efficiency level of the organizations.

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