ORGANIZATIONAL EFICIENCY OF CONSULTING ENGINEERING FIRMS: PROPOSAL OF A PERFORMANCE INDICATOR

LA EFICIENCIA ORGANIZATIVA DE LAS EMPRESAS CONSULTORAS DE INGENIERÍA: PROPUESTA DE UN INDICADOR DE MEDICIÓN

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ABSTRACT: At the present global economy, the main concern of the entrepreneurs is to survive in a growingly competitive market that works worldwide, does not have borders anymore, and does not inhibit competition. Companies, which are not able to adapt to this environment, are at risk of collapse. In this paper, we propose a model that allows the calculation of a performance indicator for the organizational efficiency as a measure of competitiveness, applied to consulting engineering firms. This indicator aims to offer a comparative framework of the organizational efficiency of a company, having as references, on the one hand, the environment where the activities of the company are developed and, on the other, a virtual competitor achieved by the optimization of the resources of the initial sample of data of our study. The model estimates that the best adjusted production function for this kind of companies comprises the number of employees, not only technical but also administrative, as explicative variables. Furthermore, taking into consideration the initial data, the companies that display better ratios of organizational efficiency have 90% of technical personnel, approximately, regarding the total number of employees of the company, and an annual turnover around 100.000 Euros per technician.

KEYWORDS: Consulting Firms – Efficiency – Engineering – Indicator – Organization.

RESUMEN: En la economía global de hoy en día, la inquietud prioritaria de los empresarios es sobrevivir en un mercado crecientemente competitivo, que por causa de la internacionalización no conoce fronteras ni restringe la concurrencia. Las empresas que no son capaces de adaptarse a este entorno corren el riesgo de desaparecer. En este artículo se propone un modelo que permite calcular un indicador de la eficiencia organizativa como medida de la competitividad, aplicado a las empresas consultoras de ingeniería. Este indicador se plantea con la idea de ofrecer un marco comparativo de la eficiencia organizativa de una empresa teniendo como referentes, por un lado, el entorno en el que desarrolla su actividad y, por otro, un competidor virtual creado a partir de la optimización de los recursos de la muestra disponible para el estudio. El modelo estima que la función de producción con mejor ajuste para este tipo de empresas, tiene como variables explicativas el número de empleados, tanto técnicos como administrativos. Asimismo, basándose en los datos de partida, las empresas que mostraron un mejor índice de eficiencia organizativa cuentan con un 90% de personal técnico, aproximadamente, respecto al total de la plantilla, y una producción anual cercana a los 100.000 euros por técnico.

PALABRAS CLAVE: Eficiencia – Empresas Consultoras – Ingeniería – Indicador – Organización.

1. INTRODUCTION

The most widespread theories on market liberalization establish, as an initial hypothesis, that the main consequence of the existence of competition is efficiency improvement [1-3]. Efficiency measurement usually employs productivity as the most noteworthy indicator, especially in the case of firms in the services sector [4]. This macro-sector also incorporates consulting firms, both general (organization and management) and technical ones (engineering and architecture).

From a company standpoint, consulting firms are economic units whose main input is a highly qualified workforce of professionals and whose outputs are contracted services by commission. These firms, together with others in the service sector, present some outstanding features [5-6]: they are based on intensive knowledge; they develop strong relationships with the client; and they are governed by single contracts. Furthermore, in these firms the qualified professionals are essential for developing entrepreneurial activities [7-9]. In the specific case of consulting engineering firms, competition is very fierce, with low profit margins which force costs to be tightly controlled [9-12].

This scenario highlights the need to improve the efficiency and competitiveness of these firms. For this reason, this work seeks to contribute a methodology that evaluates the efficiency level that consulting firms have, internally or in relation to their competitors. Efficiency is mainly linked to technical human resources, as an essential part of the output of these firms, given that there is little consumption of raw materials, and technology and layout are not important [9,12-13].

This research attempts to set up a comparative model of the organizational efficiency of a company. Thus, it is possible to provide some indicators on the current situation which may serve to guide tactical and strategic planning in companies. In no way it is an attempt to provide an exhaustive analysis of each and every one of the resources which come into play in company organization but just in those with the greatest weight within consulting engineering firms.

In order to achieve this end, the work is structured as follows. Firstly, a bibliographical analysis of the different models proposed by several authors in search of efficiency measurement is developed. Next, the aims and methodology of this research are stated. Later, the preliminary data obtained in order to carry out this study, from 21 Spanish consulting engineering firms, are included. Subsequently, an empirical application of the proposed methodology based on parametric statistical methods is presented. Finally, the conclusions are highlighted.

2. THEORY REVIEW

The notion of efficiency has been implicitly present from the outset of economic literature [14], but it was with Marshall [15] when the theoretical tools for the formal development of this concept became available. However, the lack of a suitable methodology for measuring is still latent, which requires another term added to efficiency which would give greater focus to its meaning, for example: technical, of scale, organizational, allocative, etc.

The concept of efficiency, as stated by Pareto [16], is the impossibility of achieving a greater combination of products for a certain level of resources; according to this definition, it is possible to be efficient without being effective, given the fact that goods are produced in efficient circumstances in Pareto terms does not guarantee that the combination of goods obtained is useful for meeting targets. In the Koopmans [17] sense, efficiency is the impossibility of achieving a particular combination of products using fewer than, at least, one of the resources.

On the other hand, Farrell [18] identifies the existence of global efficiency in a company or industry and defines it as the result of its technical efficiency and its allocative efficiency [19].

More recently, Álvarez [20] has proposed three types of efficiency:

- Technical efficiency: it refers to the company process which seeks the maximum output possible with the combination of inputs employed.
- Efficiency of scale: it is achieved when a company produces on an optimal size scale, which is the one that permits maximization of profits.
- Allocative efficiency: it is accomplished when a company combines inputs proportional to production cost reductions.

A previous work [21], identifies additional types of efficiency, defining it as “the degree of competitiveness, performance, profitability or results obtained by the economic activity in relation to other reference magnitudes”. This study recognizes eight types of efficiency and provides a mathematical approach for their measurement by calculating partial productivity ratios.

The efficiency measure is a useful tool for analyzing companies with multiple business outlets, such as restaurant or hotel chains within the tourist sector [22-23]. Control of these outlets has been usually undertaken based on monitoring absolute variables such as turnover, costs grouped according to type, expense or performance [22].

These variables have been complemented with others of a relative nature (ratios) associated with the concepts of profitability or productivity [24]. In this latter case, the numerator which appears in the ratios is an output, for example: the units produced or sold of a particular product or service; although, the denominator is an input, for example: the number of employees. This way the partial productivity measure is attained [25].

In order to obtain a clear idea of the business operation, instruments appeared such as integrated management or additive calculations of several variables. However, partial analyses are achieved which come from accounting and not global ones which involve other variables such as intangibles. This prevents accurate evaluation of the actions carried out and setting specific objectives for the inputs and outputs used. This situation, doubtless, makes difficult to advance in the search for global efficiency of the analyzed units [26].

On the other hand, countless articles have been published dealing with efficiency or administration. However, works focused specifically on measuring business efficiency are not so abundant and the ones found are aimed at other economic sectors. Nevertheless, it is helpful to have an overview of these works; for this reason we summarize the most important ones now.

Efficiency, according to the pioneering work of Farrell [18], includes two components: technical efficiency, which reflects the ability to obtain the maximum output for a specific level of inputs; and allocative efficiency, which reflects the ability of a company to use the inputs in an optimal proportion, considering the prices of the inputs. These two combined concepts constitute economic efficiency.

The estimate of the efficiency frontier can be achieved by parametric or non-parametric methods [27]. The first type (parametric) uses mathematical programming or econometric techniques. This approach has the disadvantage of having to impose a specific functional shape on the frontier and does not allow an analysis using multiple outputs. The second method (the non-parametric approach) is based on the resolution of the model by linear programming; the statement of production assumptions, together with data of actually observed activity, allow us to define possible production processes which can be achieved for attaining maximum productivity. Using this second method of estimating it is not necessary to assume a specific functional shape for the frontier.

The data envelopment analysis method is of the non-parametric type, allowing us to work with multiple inputs and outputs. Using linear programming algorithms the efficiency frontier and the estimate of inefficiency can be determined. The efficiency frontier is calculated by maximizing the output given the level of inputs, or minimizing the input given the level of outputs. The second process (inefficiency estimate), which can be calculated using this method, will depend on the orientation used; it is the distance of each firm to the frontier, resulting from comparing it with another technologically similar company [28].

This type of non-parametric analysis may be carried out using the CCR model [28] or the BCC model [29]. The CCR model enables us to compare a company with other substantially larger or smaller ones. The BCC model compares a company with other ones of similar size measuring only inefficiencies caused by production management.

For Knox [30], efficiency measurement, relating to the frontiers of production, cost and other variables, historically has had a strong political orientation. The author examines the econometric approach in the analysis of efficiency and illustrates its application by choosing some empirical studies referring to public policy for which efficiency measurement is of vital importance: agricultural productivity, labor market, standard of living, service standards and environmental assessment.

Subsequently, Horrace and Schmidt [31] apply theoretical statistical techniques known as multiple comparisons with a control (MCC) and multiple comparisons with the best (MCB) in order to classify efficiency. In greater detail, they deal with the practical construction of confidence intervals for the efficiency measures in stochastic frontier models using panel data. They also consider an application for the analysis of salaries in the labor market.

Zofio and Knox [32] define hyperbolic performance measures on a graph representation of production technology. They present a formula for calculating using data envelopment analysis. The authors illustrate their ideas by calculating the hyperbolic efficiency and Malmquist indices for a sample of panel data for United States farming.

Knox *et al.* [33] analyze organizational efficiency compared to quality of service provided in Texas nursing facilities, both private and not-for-profit. They found that there are significant differences between these two types of entities as a result of structural operational differences or differences in the quality of the care provided. Using a quality index measure, the authors arrive at the conclusion that quality does have an influence on costs.

Heshmati [34] provides an overview of recent contributions on the relationship existing between subcontracting, efficiency and productivity growth in industrial and service sectors using a survey which questions the data and methods for measuring efficiency and productivity. Firstly, he tackles issues of measurement of partial and total productivity growth. Secondly, he engages in parametric and non-parametric approaches to the measurement of productivity in static and dynamic contexts. Then, he analyzes the econometric approach for efficiency analysis. Fourthly, he examines the relationship between subcontracting and the increase in productivity, presenting several examples of empirical applications and their implications. Finally, the author analyzes the measurement of inputs and outputs both for industry and the service sector.

As an alternative to the previous works, Atkinson and Dorfman [35] put forward a Bayesian multiple comparison procedure, which is simple to implement and provides the researcher greater flexibility over the types of comparison to be carried out. They also present more information, especially of an intuitive type. The authors make multiple comparisons for ranking technical efficiency for a sample of American electricity generating companies. They conclude that the Bayesian method provides more accurate results than those obtained using MCC and MCB methods proposed by Horrace and Schmidt [31].

Jessop [36] analyzes the performance differences between organizations. Because many of them prefer to monitor their performance using various measures, the author assumes this approach for the analysis instead of a single efficiency measure. Using the multi-criteria additive model a general measure is provided. On the other hand, given the inevitable inaccuracy of the weightings, the latter are obtained by probabilistic estimates of the difference which exist between pairs of organizations. The most important differences are identified; a binary network of relationships puts together pairs so that performance is not significantly different between them. Similarly, a second network shows correlations between groups of measures. The models are constructed to illustrate the important differences to be found between organizations. The data used by the author in the example describe performance at 14 airports over a period of 9 years.

In a more recent work, Ajibefun [37] analyzes the technical efficiency of micro-companies in the Nigerian economy. To do so he uses cross sectional data collected from micro-enterprises in the metallurgy and sawmill sectors located in the north, southwest and southeast of the country. The data collected was analyzed using the borderline stochastic output function. The results of the analysis show that companies have different levels of technical efficiency which are positively affected by degree of education, level of investment and number of employees. On the contrary, seniority in the company negatively affects the level of technical efficiency.

3. RESEARCH OBJECTIVES AND METHODOLOGY

The basic aim of this research is to achieve a method for enabling organizational efficiency of consulting engineering firms to be evaluated as a measure of their competitiveness. The indicator to be developed and its conceptual and computer treatment are set out with the idea of providing a comparative framework for the organizational efficiency of companies. Referents are, on the one hand, the environment in which its activity is undertaken and, on the other hand, an optimal virtual competitor created from the optimization of the resources actually used by the firms analyzed in the study. Thus, it is possible to provide some indicators on the current situation which may serve to guide tactical and strategic planning in companies.

The methodology proposed to obtain the organizational efficiency indicator is based on the parametric statistical analysis. It consists of the following steps:

- To estimate the output function: output is quantified as an estimated multivariant function based on a series of previously identified variables, whether they are endogenous or exogenous.
- To maximize using linear programming: having the estimated output function available, the data is homogenized. Then the function is maximized by applying linear programming. To do so, this function is converted into an objective function (linear function of several variables) subject to a series of restrictions expressed by linear inequations, and obtained from empirical research carried out previously.
- To define and calculate indices: in order to take measurements and make comparisons, standardized indices are calculated which enables all the firms analyzed to be ranked according to a common referent. Once this process is finished, the index for each firm is referred to the maximum obtained thus providing a ranking based on the unit.

4. DATA SOURCES

The information on the companies analyzed is obtained from the results account of the database of the Mercantile and Property Register Association of Spain for 2004. From there, 36 complete audited reports (brief, balance and profit and loss statements) were taken. The size of the sample was determined by the data consistency requirement. Data was not accepted if: (a) they corresponded to another tax year; or (b) the number of administrative staff could not be obtained. This last requirement was a fundamental variable for fulfilling the aims of the study. Having the total number of employees on the staff and the number of administrative staff, the number of technical personnel for each company was calculated. The sample finally obtained (21 firms) are shown in Table 1; all the calculations in this study were made with this sample.

5. ESTIMATION OF PRODUCTION FUNCTION

To obtain the organizational efficiency index for the companies in the study, the output function must be obtained through analysis, regression and estimation of the econometric model. This is set out as a linear function of k-1 explanatory variables and a random disturbance, plus an independent term (equation 1).

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \ldots + u \quad (1)$$

where:

- y is the dependent variable.
- x_n are the explanatory variables.
- α_n are the parameters specified by the model.
- u is the error term.

Table 1. Data series

REF	ADM	TEC	NEP	VNT
1	11	115	126	9,160
2	24	109	133	12,900
4	8	73	81	5,480
7	23	207	230	14,500
12	128	510	638	47,068
13	65	166	231	17,717
14	114	411	525	57,619
15	51	211	262	15,821
16	25	138	163	17,315
17	39	252	291	25,528
20	9	60	69	5,036
21	8	83	91	6,946
25	28	140	168	18,531
26	64	375	439	35,247
27	24	141	165	30,274
30	152	523	675	38,005
34	29	118	147	10,218
37	11	67	78	6,112
38	10	29	39	3,636
39	173	699	872	67,150
43	17	175	192	20,056

REF = Reference number
ADM = Administrative staff
TEC = Technicians
NEP = Total number of staff
VNT = Sales in thousands of Euro

Having established the general econometric model, and previously selected the available data, the production function is estimated using equation 2.

$$Sales(VNT)=0+(\alpha*ADM)+(\beta*TEC) \quad (2)$$

As a preliminary hypothesis, the constant of the previous function is set at equal to 0. In consulting engineering firms the use of technology is limited compared to the intensive use of intellectual work by the technical staff. The results shown in Tables 2 and 3 were obtained. The estimate presents a significance level of 95%, with a coefficient of determination of 0.89.

Table 2. Results of the regression: summary

Multiple correlation coefficient	0.97321831
R2 determination coefficient	0.94715388
R2 adjusted	0.89174093
Number of observations	21

Table 3. Results of the regression: variance analysis

	ADM	TEC
Coefficients	-25.0799731	103.401728
Typical error	97.4195381	23.8694007
Statistic t	-0.25744295	4.33197838
Probability	0.79960441	0.00035924
<95%	178.82146	153.36095
>95%	-228.9814	53.442498

6. DATA HOMOGENIZATION

Before maximizing the production function by linear programming, data is homogenized in order to eliminate noise present in the series. This is achieved by recalculating the figure for turnover or sales of each of the firms in the sample using the regression model described above. Multiplying each of the explanatory variables by the parameter obtained in the regression, the adjusted values for sales (Y') are obtained using equation 3. The results are shown in Table 4.

$$(Y') = A+(\alpha*X1)+(\beta*X2) \quad (3)$$

Table 4. Results of the regression: adjusted values

REF	X1 ADM	X2 TEC	Y VNT	Y’	(Y’-Y)
1	11	115	9,160	11,615	2,455
2	24	109	12,900	10,669	1,436
4	8	73	5,480	7,348	-2,387
7	23	207	14,500	20,827	1,868
12	128	510	47,068	49,525	6,327
13	65	166	17,717	15,534	943
14	114	411	57,619	39,639	-449
15	51	211	15,821	20,539	540
16	25	138	17,315	13,642	-16,297
17	39	252	25,528	25,079	1,924
20	9	60	5,036	5,978	-3,673
21	8	83	6,946	8,382	-4,757
25	28	140	18,531	13,774	-2,231
26	64	375	35,247	37,171	4,718
27	24	141	30,274	13,978	1,256
30	152	523	38,005	50,267	789
34	29	118	10,218	11,474	2,457
37	11	67	6,112	6,652	-17,980
38	10	29	3,636	2,748	12,262
39	173	699	67,150	67,939	-888
43	17	175	20,056	17,669	-2,183

7. MAXIMIZATION OF OBJECTIVE FUNCTION

Solver is an *Excel* tool which solves linear programming problems by seeking to maximize or minimize the result of an equation or objective function. To do so, it takes into account a series of restrictions set on its variables which are translated into equations and inequations. The aim of this approach is to obtain the best possible combination of the administrative and technical resources selected, within the ranges of the companies in the sample, for each variable. This combination gives rise to the maximum turnover or sales of a new optimized company of the sample study; it serves as a milestone or reference point for evaluating actual companies in the market. Sales are maximized to obtain an optimal company (Y_{mx}), using data from the sample, by applying equation 4.

$$VNT_{mx} = (coef\, X1 * X1_{mx}) + (coef\, X2 * X2_{mx}) \quad (4)$$

Table 5 shows the restrictions that seek to obtain variables $X1_{mx}$ and $X2_{mx}$ for the optimal company (Y_{mx}). Input data come from Table 4. The logical reasoning is explained along these lines:

- It is required that the optimal outcomes calculated by *Solver* for variables $X1_{mx}$ y $X2_{mx}$ be integers, because both of them are about people.
- $X1_{mx}$ must be less than or equal to the maximum number of administrative staff in any of the sampled companies (173 ADM).
- $X2_{mx}$ must be less than or equal to the maximum number of technicians in any of the sampled companies (699 TEC).
- $X1_{mx}$ must be greater than or equal to the minimum number of administrative staff in any of the sampled companies (8 ADM).
- $X2_{mx}$ must be greater than or equal to the minimum number of technicians in any of the sampled companies (29 TEC).
- The ratio of $X1_{mx}/X2_{mx}$ must be less than or equal to the maximum ratio of $X1_n/X2_n$ for each of the sampled companies.
- The ratio of $X1_{mx}/X2_{mx}$ must be greater than or equal to the minimum ratio of $X1_n/X2_n$ for each of the sampled companies.
- The ratio of $Y_{mx}/X2_{mx}$ must be greater than or equal to the maximum ratio of $Y_n/X2_n$ for each of the sampled companies.

Once implemented these restrictions, *Solver* calculates the optimum values for the variables $X1_{mx}$ and $X2_{mx}$ of the optimal company compared with the other companies in the sample. In our case, the computed values for these variables are 66 and 690 respectively; results are obtained solving the last three equations of Table 5. Values obtained for variables $X1_{mx}$, $X2_{mx}$ and Y_{mx} correspond to data of the optimal company (designated with reference number 44), and they are included as part of the sample in Table 6.

Table 5. Linear programming restrictions

$X1_{mx}$	Int	Integer
$X2_{mx}$	Int	Integer
$X1_{mx}$	<=	Max ($X1_0 \ldots X1_{21}$) = 1,173
$X2_{mx}$	<=	Max ($X2_0 \ldots X2_{21}$) = 699
$X1_{mx}$	>=	Min ($X1_0 \ldots X1_{21}$) = 8
$X2_{mx}$	>=	Min ($X2_0 \ldots X2_{21}$) = 29
$X1_{mx}/X2_{mx}$ = 0.09565217	<=	Max ($X1_n/X2_n$) = 0.391566
$X1_{mx}/X2_{mx}$ = 0.09565217	>=	Min ($X1_n/X2_n$) = 0.095652
$Y_{mx}/X2_{mx}$ = 101.002774	>=	Max ($Y_n/X2_n$) = 101.002774

Table 6. Results of recalculation of the turnover

REF	Y’	X1/X2	Y’/X2
1	11,615	0.096	101.003
2	10,669	0.220	97.880
4	7,348	0.110	100.653
7	20,827	0.111	100.615
12	49,525	0.251	97.107
13	15,534	0.392	93.581
14	39,639	0.277	96.445
15	20,539	0.242	97.340
16	13,642	0.181	98.858
17	25,079	0.155	99.520
20	5,978	0.150	99.640
21	8,382	0.096	100.984
25	13,774	0.200	98.386
26	37,171	0.171	99.121
27	13,978	0.170	99.133
30	50,267	0.291	96.113
34	11,474	0.246	97.238
37	6,652	0.164	99.284
38	2,748	0.345	94.753
39	67,939	0.247	97.195
43	17,669	0.097	100.965
44	**69,692**	**0.096**	**101.003**

8. ACHIEVEMENT OF THE RANKING INDICES AND COMPARISON WITH PREVIOUS RESEARCH

To rank the 21 companies taking the optimal company as a reference point, the following procedure is adopted:

- a value of 1 is assigned to the quotient between the volume of sales recalculated for each technical employee of the optimal company $[(y_n/x2_n) / (y_{mx}/x2_{mx})]$.

- The quotients of the remaining companies are related to the one of the optimal company thus obtaining values for each company, which enables them to be ranked.

The resulting indices for each company and their ranking are shown in Table 7 (column: Indices – Proposal).

Table 7. Indices and ranking of companies

Ranking	Indices		REF
	Proposal	According to [37]	
1	**1.0000**	**1.0000**	**44**
1	1.0000	1.0000	1
2	0.9998	0.9998	21
3	0.9996	0.9996	43
4	0.9965	0.9965	4
5	0.9962	0.9961	7
6	0.9865	0.9865	20
7	0.9853	0.9853	17
8	0.9830	0.9829	37
9	0.9815	0.9814	27
10	0.9814	0.9813	26
11	0.9788	0.9787	16
12	0.9741	0.9740	25
13	0.9691	0.9690	2
14	0.9637	0.9637	15
15	0.9627	0.9627	34
16	0.9623	0.9623	39
17	0.9614	0.9614	12
18	0.9549	0.9548	14
19	0.9516	0.9515	30
20	0.9381	0.9381	38
21	0.9265	0.9265	13

These results may be compared with those of the application proposed by Cooper *et al.* [37], based on the data envelopment analysis as a non-parametric statistical analysis. The software used is included in this referred publication. The model applied to perform the calculations is the CCR. In Table 7 the results obtained are attached (column: Indices – According to [38]). It can be seen that the ranking is identical, varying the values of some of the firms at the fourth decimal place.

9. CONCLUSIONS

The first conclusion to be drawn is the difficulty in finding reliable information on the internal organization of the companies. This also affects the information obtained from the Mercantile and Property Register Association of Spain. Anyway, taking into account the number of explanatory variables (2) and the number of observations accepted (21), it can be assumed that the sample is reasonably representative, albeit not statistically representative.

The estimate of the production function of this type of firm, taking the number of technical and administrative employees as explanatory variables, provides a fair adjustment. Theoretically, this enables the function obtained to be used as a predictive model although this was not the purpose initially sought.

The introduction of two explanatory variables expressed in integers is based on the assumption that the real efficiency of the organizational structure of consulting engineering firms is based on the proportion existing between technical and administrative personnel on the staff. This is possible since the productive processes of this type of firm rests on knowledge management of its own personnel, in particular, of its technical staff. In view of the results obtained, this pair of variables may be considered good estimators for quantifying organizational efficiency of this type of enterprise until other relevant data can be obtained regarding its organizational structure.

Companies which showed a better organizational efficiency index meet two personnel conditions simultaneously:

- Technical personnel comprise around 90% of the total staff.
- The production function estimates that each technician must produce around 100,000 Euros per year.

Subsequent optimization of the estimated function, prior projection of its parameters on the firms, enables to obtain an optimum using mathematical linear programming, which leaves the way open to evaluating other questions. Relating each one of the firms with the optimal objective function, which is incorporated as an optimal virtual company, a ranking of the firms considered may be obtained. The results finally achieved have added value as a quantitative method which, besides ranking the companies among each other, provides a parameterized and optimized mathematical function that can be used as a prediction model.

The results obtained by the proposed method, based on the parametric statistical analysis, are identical to the ones obtained using data envelopment analysis (non-parametric statistical analysis). From our point of view, this latter method should be used when two or more outputs are envisaged since, in this case, parametric methods cannot be used. Nevertheless, the method proposed in this research has greater added value than the data envelopment analysis because it is a quantitative method which ranks the firms, and it also provides an optimized and parameterized mathematical function which can be used as a prediction model.

We consider that the work undertaken opens up a way for research on organizational efficiency of consulting firms and their measurement that can be improved and extended as better data become available and intellectual concerns boost and favor their continuity.

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REFERENCES

[1] COSTAS, A.; BEL, G. (ed.). Los beneficios de la liberalización de los mercados de productos. Barcelona: La Caixa, 11, 1997.

[2] RAYMOND, J.L.; ALONSO, J.O.; ROCA, A. Liberalización de los mercados e inflación. Cuadernos de Información Económica, 160, 17-26, 2001.

[3] BEKAERT, G.; HARVEY, C.R.; LUNDBLAD, C.T. Equity market liberalization in emerging markets. Journal of Financial Research, 26(3), 275-299, 2003.

[4] PICAZO, A.J.; QUIRÓS, C. Liberalización, eficiencia y cambio técnico en telecomunicaciones. Revista de Economía Aplicada, 9(25), 77-113, 2001.

[5] MAISTER, D.H. Managing the professional service firm. New York: Simon & Schuster, 1997.

[6] LØWENDAHL, B.R. Strategic management of professional service firms. Copenhagen: Handelshøjskolens Forlag, 2000.

[7] HECKER, P.A. Human resources strategies for successful consulting engineering firms. Journal of Management in Engineering, 12(5), 32-36, 1996.

[8] HITT, M.A.; BIERMAN, L.; SHIMIZU, K.; KOCHHAR, R. Direct and moderating effects of human capital on strategy and performance in professional service firms: a resource-based perspective. Academy of Management Journal, 44(1), 13-28, 2001.

[9] PELLICER, E. Consulting engineering companies versus building contractors: two different means of adapting to the market. Revista de Obras Públicas, 3483, 7-18, 2007.

[10] MINISTERIO DE FOMENTO. Estudio del sector de las empresas de ingeniería civil en España. Madrid: Ministerio de Fomento, 1998.

[11] HARTLEY, P.M. Consulting engineering: constructing the future. Baldock: Research Studies Press Ltd., 2000.

[12] PELLICER, E. Cost control in consulting engineering firms. Journal of Management in Engineering, 21(4), 189-192, 2005.

[13] OLTRA, V. (coord.). Desarrollo del factor humano. Barcelona: UOC, 2005.

[14] SMITH, A. Indagación acerca de la naturaleza y causas de la riqueza de las naciones. Madrid: Ed. Aguilar, 1961 (original edition from 1776).

[15] MARSHALL, A. Principios de economía: un tratado de introducción. Madrid: Ed. Aguilar, 1963 (original edition from 1898).

[16] LOZANO, J. Economía institucional y ciencia económica. Revista de Economía Institucional, 1, 99-128, 1999.

[17] KOOPMANS, T.C. Activity analysis of production and allocation. New York: Cowles Commission for Research in Economics, 13, 1951.

[18] FARRELL, M.J. The measurement of productive efficiency. Journal of the Royal Statistical Society, 120(3), 253-281, 1957.

[19] LEVITT, M.S.; JOYCE, M.A.S. The growth and efficiency of public spending, Cambridge: Cambridge University Press, 1987.

[20] ÁLVAREZ, A. (ed.). La medición de la eficiencia y la productividad. Madrid: Pirámide, 2001.

[21] AECA. El objetivo de eficiencia de la empresa. Madrid: Asociación Española de Contabilidad y Administración de Empresas, 1991.

[22] BLASCO, R.A.; MOYA, C.I. Diagnóstico financiero de la eficiencia de las empresas del sector turístico español. Valencia: Universidad Politécnica de Valencia, 2002.

[23] CRISTÓBAL, J.M. Fundamentos de financiación de la empresa. Madrid: Ed. Ramón Areces, 1996.

[24] FERRELL, O.C.; HARTLINE, M.D. Estrategia de márketing. Mexico: Ed. Thomson, 2006.

[25] HANSEN, D.R.; MOWEN, M.M. Administración de costos: contabilidad y control. Mexico: Ed. Thomson, 2007.

[26] SALGUEIRO, A. Indicadores de gestión y cuadro de mando. Barcelona: Ed. Díaz de Santos, 2001.

[27] COELLI, T.J. Estimators and hypothesis test for a stochastic frontier function: a Monte Carlo analysis. Journal of Financial Research, 6(4), 247-268, 1995.

[28] CHARNES, A.; COOPER, W.W.; RHODES, E. Measuring the efficiency of decision making units. European Journal of Operational Research, 2, 429-444, 1978.

[29] BANKER, R.D.; CHARNES, A.; COOPER, W.W. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30(9), 1078-1092, 1984.

[30] KNOX, C.A. Econometric efficiency analysis: a policy-oriented review. European Journal of Operational Research, 80, 452-461, 1995.

[31] HORRACE, W.C.; SCHMIDT, P. Multiple comparisons with the best, with economic applications. Journal of Applied Econometrics, 15, 1-26, 2000.

[32] ZOFIO, J.L.; KNOX, C.A. Graph efficiency and productivity measures: an application to US agriculture. Applied Economics, 33(11), 1433-1442, 2001.

[33] KNOX, K.J.; BLANKMEYER, E.C.; STUTZMAN, J.R. Organizational efficiency and quality in Texas nursing facilities. Health Care Management Science, 6(3), 175-188, 2003.

[34] HESHMATI, A. Productivity growth, efficiency and outsourcing in manufacturing and service industries. Journal of Financial Research, 17(1), 79-112, 2003.

[35] ATKINSON, S.E.; DORFMAN, J.H. Multiple comparisons with the best: bayesian precision measures of efficiency rankings. Journal of Productivity Analysis, 23(3), 359-382, 2005.

[36] JESSOP, A. A multicriteria blockmodel for performance assessment. Omega, 37, 204-214, 2009.

[37] AJIBEFUN, I.A. Technical efficiency analysis of micro-enterprises: theoretical and methodological approach of the stochastic frontier production functions applied to Nigerian data. Journal of African Economies, 17(2), 161-206, 2008.

[38] COOPER, W.W.; SEIFORD, L.M.; TONE, K. Introduction to data envelopment analysis and its uses with DEA-Solver software and references. New York: Springer, 2006.