Performance Evaluation of Faculties of the Lebanese University: A Data Envelopment Analysis

Dr. Rawda Chebbo, Pr.Wadad Saad

ملخص

تستخدم هذه الدراسة تحليل مغلف البيانات (DEA) من أجل تقييم مستويات الأداء في ١٦ كلية في الجامعة اللبنانية وذلك باستخدام بيانات السنوات الدراسية ٢٠٠٨-٢٠١٣. لقد تم تطبيق نموذج (CRS) الذي يستند إلى فرضية ثبات غلة الحجم والذي يقوم على نهج المدخلات ، وذلك من أجل تحديد الكفاءة النسبية لكل كلية. وأظهرت النتائج أن ٤ من أصل ١٦ كلية تتسم بالكفاءة. هذه الكليات هي: كلية العلوم السياسية والإدارية، معهد العلوم الاجتماعية، كلية الآداب والعلوم الإنسانية وكلية الاقتصاد وإدارة الأعمال. وعلاوة على ذلك، تم استخدام مؤشر الإنتاجية الكلية Mamlquist لدراسة التغيرات الإنتاجية للكليات من العام ٢٠٠٨ إلى العام ٢٠١٣. والمعدلات السنوية لMamlquist تظهر تحسنا في الإنتاجية خلال مدة الدراسة ويرجع ذلك بشكل اساسي إلى تحسن في التغير التكنولوجي اكثر مما هو تغير بالكفاءة.

Abstract

This study uses Data Envelopment Analysis (DEA) in order to assess the performance levels of 16 faculties of the Lebanese University using data from academic years 2008-2013. The Constant Return to Scale (CRS) model based on input oriented approach has been applied in order to determine the relative and scale efficiency of each faculty. The results show that, under Constant Return to Scale, 4 out of 16 faculties are efficient. These faculties are: Faculty of Political and Administrative Sciences, Institute of Social Sciences, Faculty of Letters and Human Sciences and Faculty of Economics and Business Administration. Moreover, the Mamlquist total productivity index is used to study the

productivity change of faculties from 2008 to 2013. The annual Malmquist means show an improvement in total productivity of this period which is mainly due to improvement in technological change rather than in efficiency.

Introduction

Nowadays, we notice an increasing interest in the measurement of performance and efficiency in non-profit organizations such as publicly owned universities, schools and hospital. In fact, the increasing demand for evaluation of the public entities is a result of the governmental desire for accountability. Governments demand from the public organizations to operate efficiently and achieve their targets consuming the least possible resources.

This study uses Data Envelopment Analysis (DEA) in order to assess the performance levels of 16 faculties of the Lebanese University using data from academic years 2008-2013. The Constant Return to Scale (CRS) and the Variable Return to Scale (VRS) models have been applied in order to determine accurate performance estimates (Charnes et al., 1978; Coelli, T.J et al 2005; Banker et al. 1984).

The Malmquist total factor productivity index is used to study the productivity change of faculties from 2008-2013 (Benli Y.K et al, 2013; Coelli T.J et al 2005). The study shows how the advanced techniques in efficiency analysis can be used to assess institutional performance issues. The results reveal the misallocation of resources if any.

This research is organized as follows:

Section 2: In this section we give a brief history of the Lebanese University, subject of our study.

Section 3: A brief literature review of similar studies is presented in this section.

Section 4: The illustration of different DEA models, and the Malmquist total productivity index, which are used in our study, is given in this section.

Section 5: Data and results are presented in this section.

Section 6: Summary of our study is provided.

Section 2: Lebanese University

Higher education in Lebanon has been initially established in 1951 following the vast popular demand and protest held early that year which called for a true independence of the country through an official high-level educational institution that preserves its culture and heritage (29). By December 1951, the first department of the Lebanese University, the high house of teachers and the statistics center were ready to welcome the first class of 68 students (29). No major changes in the university took place from that time up to 1959 when an official decree No. 2883 defined the Lebanese University as “an official institution that provides higher education in its various branches and levels”. This was followed by the other regulating decree that served in structuring and expanding the University which now consists of 19 different faculties (29).

Until 1975, the university was located solely in Beirut and its suburbs. But following the civil war and the resulting difficulties in transportation between different areas, most of the faculties were extended to the other areas through the establishment of new branches sharing the same curricula.

The main administration remained centralized in Beirut. After this expansion, the university experienced remarkable growth in enrolment, about 70546 students in 2013 (29), and significant expansion in faculty and administrative staff. In fact, it has become one of the biggest and most prestigious universities in the Middle East which provides degrees in three different levels: English, French and Arabic and various fields represented in its faculties. The university has become known not only for its rich academic program but for its unique and rich mix of cultural, religious and social backgrounds.

Finally, this rapid expansion of the Lebanese University should be accompanied by relevant studies as to raise the performance indicators and determine the appropriate levels of doctors and staff needed in order to eliminate the unnecessary wastage of human resources. The Data Envelopment Analysis technique used allows us to measure the performance of the faculties of the Lebanese University and to reveal their strengths and weaknesses. It should be noted that even though there are numerous studies estimating the efficiency of departments or faculties within universities or universities as a whole in different countries, very few similar studies exist in Arab countries.

Section 3: Literature review

The Data Envelopment Analysis (DEA) has been used for higher education institutes in many countries around the world (Abdelrazek S., 2014; Athanassopoulos A. et al 1997; Flegg A.T. et al 2004; Johnes J. et al 2008). Each study differs in the way it chooses the decision making units (DMUs), that is the units to be analyzed, and the variables. Many studies evaluated the efficiency of universities, the university as a whole being the DMU, such as the studies done by Carrington R. et al 2005, Abbott and Doucouliagos (2003), Johnes and YUL. (2008), Fandel G. (2007), Agasisti, T. and Johnes G.(2010) and Srairi S.A.(2014). Another kind of studies assessed the performance of academic departments or faculties in a given university, such as the studies done by: Tyagi P. et al (2009), Kao, and Hung H. T. (2008), Moreno A. and TadPalliR. (2002), Agha et al (2011) and Alshayea A. and Battal A. H. (2013).

As stated earlier, each study differs in the way it chooses the variables. In fact, there is no definitive rule to guide the inputs and outputs selection in higher education efficiency evaluation. The table below, will present some of the input and output variables chosen by the aforementioned studies.

Table 1: Inputs and outputs used by some researchers

Author(s)	Inputs	Outputs
Moreno and Tapedalli (2002).	Faculty salaries. Staff salaries. Operational budget Equipment budget. Space allocated in square feet.	Graduates. Under-graduates. Full time equivalent produced. Amount of grants evaluated.
Abbott and Doucouliagos (2002)	Total number of academic staff. Total number of non-academic staff. Expenditure on all other inputs.	Number of equivalent full-time students. Number of post-graduates. Under graduate degrees enrolled. Number of post-graduate degrees conferred. Number of under graduate degrees conferred.
Kao and Hung (2006)	Personal Operating expenses. Floor space.	Credit hours. Publications. External grants.
Agha et al. (2011)	Operating expenses. Credit hours. Training resources.	Graduates. Number of promotions. Public service activities.
Al-Shayea and Battal (2013)	Student enrolled. Staff. Teachers.	Bachelor's degree. Research.
Srairi S. A. (2014)	Number of non-academic staff. Number of academic staff. Non labor expenditures. Number of students.	Number of graduates Total amount of research grant.

Section 4: Data envelopment analysis

Data Envelopment Analysis (DEA) is a non-parametric technique used to assess the efficiency of Decision Making Units (DMUs) through using linear programming method, in order to construct an efficient frontier by enveloping all the observed input and output vectors (Coelli T.J. et al. 2005; Cooper W. et al. 2002; Charnes A. et al. 1978; Banker R.D. et al 1984). The term DEA was first introduced by Charnes, Cooper and Rhodes 1978. Since then many studies have emerged, which used and extended the DEA technique.

4.1. DEA with constant return to scale

This model was put forward by Charnes, Cooper and Rhodes 1978. It is input oriented and assumes a constant return to scale and known as CCR model. The CCR model aims to maximize the relative efficiency which is given by the following ratio:

$$relative\ efficiency = \frac{\sum_{i=1}^{m} u_i y_i}{\sum_{i=1}^{n} v_i x_i}$$

Where:

y and *x* are semi-positive vectors of outputs and inputs.

m is the number of outputs.

n is the number of inputs.

u and *v* are the weighing factors for the outputs and inputs respectively.

Before going any further, it should be stated that the efficiency obtained using the CCR model is relative, as it is computed by referring to a given set of DMUs. This efficiency is also called technical efficiency. The assumption of constant return to scale causes the same propositions of increase or decrease in the output vector (Charnes A. et al" 1978).

The mathematical formulation of the CCR model is represented by

Maximize $\frac{u' y_i}{v' x_i}$

Subject to : $\frac{u' y_i}{v' x_i} \leq 1$ for j = 1,…, L

$u, v \geq 0$

where:

i is the DMU to be analyzed.

L is the number of DMUs.

u, v are the variable (weights) to be computed.

x, y as already stated.

The constraints illustrate the idea that no DMU can be more than 100% efficient. Hence the efficiency of DMU should be less than or equal to one. From the objective function one can realize that if we are going to assess a particular DMU (say for example the i^{th} DMU). The DEA technique will determine the values of u and v such that the efficiency measure for the i^{th} DMU is maximized subject to the constraints that all efficiencies must be less than or equal to one.

The above model is a nonlinear programming. In fact it can be linearized by imposing the following equality constraint $v'x_i = 1$ (Charnes et al. 1978; Cooper W. et al. 2002).

Therefore, the linear programming formulation will be

Maximized $u'y_i$

Subject to ; $v'x_i = 1$

$-v'x_j + u'y_j \leq 0$ for i = 1,…, L

$u, v \geq 0$

Note that the two models have the same optimum solution. The dual problem of the latter problem is:

Minimize θ

Subject to ; $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0$

Where:

θ is the dual variable related to $v'x_i = 1$;

Y and X are two matrices which represent the inputs and outputs respectively.

$\lambda = (\lambda_1, \ldots, \lambda_2)$ dual variables related to $v'x_j + u'y_j \leq 0$.

Almost all DEA software use the dual problem in order to compute the efficiency θ (note that, $Max\ u'y_i = Min\ \theta$ duality rule) as it contains fewer constraints, which is the number of inputs and outputs. However, as a rule of thumb the number of DMUS should be at least three times the number of inputs plus the number of outputs (Coelli T. J. et al. 2005). θ is the technical efficiency score and $0 < \theta \leq 1$. In fact, a DMU is said to be CCR efficient if θ = 1 and has zero slacks. Hence a DMU is CCR efficient if and only if it has no input excesses and no output shortfalls. In addition $\theta^* = 1$ means that the DMU is on the efficient frontier.

Note that the zero slacks are obtained by solving an additional linear programming problem, which is:

Maximize $\omega = \sum_{j=1}^{n} S_j^- + \sum_{j=1}^{m} S_j^+$

Subject to $S^- = \theta^* x_i - X\lambda$

$S^+ = Y\lambda - y_0$

Where λ as defined before ; $S^- = (S_1^-, \dots, S_n^-)$ and $S^+ = (S_1^+, \dots, S_m^+)$

The aim of solving the above problem is to determine a solution that maximizes the sum of input excesses and output shortfalls while keeping $\theta = \theta^*$ (where θ^* is the optimum solution attained by solving the CCR model.

When $\theta^* < 1$ (CCR inefficient), the analyzed DMU is said to be inefficient. However one of the advantage of this model is its ability to specify sources or value of inefficiency in each output and input for each DMU. In addition, the CCR model identifies the reference set (some called it peer) or benchmark member of the efficient set used to effect these assessment and specify the source of inefficiency.

In addition inefficiency is calculated using the distance measure between the given DMU and the most efficient DMUs (reference set). This is the main idea behind the use of DEA technique (Collli T.J. et al. 2005; Charnes A. et al. 1978).

In fact when solving the LP problem, if $\theta^* < 1$, there must be at least one DMU for which the variable (u^*, v^*) produce equality between the left and right hand side, otherwise, θ^* could be increased. These DMUs constitute the reference set for the DMU assessed. The same can be achieved by solving the dual problem where the reference set is the one with $\lambda_j^* > 0$

i.e the reference set for the i^{th} DMU if $\theta_i^* < 1$ is given by

$E_i = \{j/\lambda_j^*$ for j = 1, …, L}

As already stated, the first version of the CCR model is input oriented. The model attempts to minimize inputs while maintaining the same level of outputs. The other type of CCR is output oriented, which aims at maximizing outputs given the same levels of inputs. However the two models provide the same value of efficiency. In many studies, analysts have selected input oriented model. However, the choice of the orientation should be based on variables on which they have most control over.

4.2. DEA with variable return to scale

The CCR model is applicable when the DMUs are operating at an optimal scale, which is not always the case. In fact, many reasons, such as finance limitations and imperfect competition, may cause the DMUs not to operate at an optimal scale. Banker, Charnes and Cooper (Banker R.D et.al. 1984) presented a model which accounts for variable return to scale (VRS) characteristics. They extended the CCR model to account for variable return to scale by adding one constraint to the CCR model which is $\sum_{i=1}^{L} \lambda_i = 1$. Hence, BCC model gives an efficiency value which is greater than or equal to the CCR efficiency. In fact, the BCC model develops a convex hull frontier that envelops the input and output vectors of course more tightly than the CCR model. Note that the convexity constraint $\sum_{i=1}^{L} \lambda_i = 1$ makes sure that an efficient DMU is only benchmarked against DMUs of similar size. The mathematical formulation of the BCC model is represented by:

Minimize θ

Subject to ; $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$\sum_{i=1}^{L} \lambda_i = 1$

$\lambda \geq 0$

4.3. Scale efficiency

A DMU is said to be scale efficient when its size of operations is optimal so that any changes of its size will render the DMU less efficient.

In order to compute the scale efficiency score of DMU, the CCR model and BCC model should be solved then:

$$scale\ efficiency = \frac{efficiency\ obtained\ using\ CCR\ model}{Efficiency\ obtained\ using\ BCC\ model}$$

The efficiency obtained using BCC model purely reflects managerial performance to organize the inputs in the production process. Hence, it is known as pure technical efficiency. Thus:

Technical efficiency = Scale efficiency × Pure technical efficiency

The measure of scale efficiency allows the management to select the optimum size of resources that is to choose the scale of production that will result in the expected production level. In fact an inappropriate size could be the reason of technical efficiency.

However, the scale efficiency score as already determined does not indicate whether the DMU is operating in an area of decreasing or increasing to scale.

This shortcoming can be overcome by running additional DEA problem with non-increasing return to scale. i.e. in the BCC model the constraint $\sum_{i=1}^{L} \lambda_i = 1$ can be replaced by $\sum_{i=1}^{L} \lambda_i \leq 1$; $\lambda \geq 0$

The non-increasing return to scale (NIRS) DEA problem is given by

min θ

subject to $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$\sum_{i=1}^{L} \lambda_i \leq 1$

$\lambda \geq 0$

After solving the above problem if NIRS efficiency is equal to BCC efficiency then decreasing returns to scale exists for that DMU. Otherwise, increasing return to scale prevails. Finally, the constraint $\sum_{i=1}^{L} \lambda_i \leq 1$, is to make sure that the DMU under assessment is not compared with DMU that is substantially larger than it but could be benchmarked with DMU smaller than it.

4.4. Malmquist productivity index

The Malmquist total factor productivity index will enable analysts to measure the changes in total factor productivity index over years. In fact, the Malmquist factor productivity is calculated based on two different periods say for example t and t+1.

Hence, it is taken as the geometric mean of the two measures. However, Malmquist productivity index uses the distances functions in order to compute the productivity change. Hence, it can be measured using an input or output based distance function, as already stated in calculating the efficiency using CCR or BCC model.

Using Malmquist total factor productivity index, the change in DMU's productivity from period t to t+1 is computed based on constant returns to scale characteristics and input orientation using the following formula (Benly Y.K. et al. 2013; Worthington A., 2000)

$$M_1^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = [\frac{D_1^t(y^{t+1}, x^{t+1})}{D_1^t(y^t, x^t)} \times \frac{D_1^{t+1}(y^{t+1}, x^{t+1})}{D_1^{t+1}(y^t, x^t)}]^{1/2}$$

The above equation is equivalent to:

$$M_1^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D_1^{t+1}(y^{t+1}, x^{t+1})}{D_1^t(y^t, x^t)} \times [\frac{D_1^t(y^{t+1}, x^{t+1})}{D_1^{t+1}(y^{t+1}, x^{t+1})} \times \frac{D_1^t(y^t, x^t)}{D_1^{t+1}(y^t, x^t)}]^{1/2}$$

Hence the Malmquist productivity index is divided into two elements the first one is the technical change in efficiencies = $\frac{D_1^{t+1}(y^{t+1},x^{t+1})}{D_1^t(y^t,x^t)}$ and the second is technological change which equal to: $[\frac{D_1^t(y^{t+1},x^{t+1})}{D_1^{t+1}(y^{t+1},x^{t+1})} \times \frac{D_1^t(y^t,x^t)}{D_1^{t+1}(y^t,x^t)}]^{1/2}$

So the change in Malmquist productivity index is the result of the multiplication of the change in technical efficiency and technological change. If it is greater than one, we have an increase in total factor productivity during period t and t+1; otherwise we have a decrease.

Finally the Malmquist productivity index, is obtained by solving many CCR input based model.

$[D_1^t(y_t, x_t)]^{-1} = \text{Min}_{\theta.\lambda}\theta$

Subject to ; $-y_{it} + Y_t\lambda \geq 0$

$\theta\, x_{it} - X_t\lambda \geq 0$

$\lambda \geq 0$

The same applies to t+1 period instead of using data for t, we used data for t+1.

Note that *i* represents the i^{th} DUM under assessment

$[D_1^{t+1}(y_{t+1}, x_{t+1})]^{-1} = \text{Min}_{\theta.\lambda}\theta$

Subject to ; $-y_{it+1} + Y_{t+1}\lambda \geq 0$

$\theta\, x_{it+1} - X_{t+1}\lambda \geq 0$

$\lambda \geq 0$

$[D_1^{t+1}(y_t, x_t)]^{-1} = \text{Min}_{\theta.\lambda}\theta$

Subject to ; $-y_{it} + Y_{t+1}\,\lambda \geq 0$

$\theta\, x_{it} - Y_{t+1}\,\lambda \geq 0$

$\lambda \geq 0$

The above formulation means you compare the data of t with the efficient limit of time t+1. The same way, we should compare the data of time t+1 with the efficient limit of time t.

$[D_1^t(y_{t+1}, x_{t+1})]^{-1} = \mathrm{Min}_{\theta.\lambda}\theta$

Subject to ; $-y_{it+1} + Y_t\lambda \geq 0$

$\theta x_{it+1} - Y_t\lambda \geq 0$

$\lambda \geq 0$

4.5. DATA

Our objective in this study is the assessment of the performance measures of 16 faculties of the Lebanese University using the DEA technique based on 2012-2013 academic year data. The constant return to scale (CRS) and the variable return to scale (VRS) models-based on input oriented approach, will be applied to compute the relative and scale efficiency of each faculty. The Malmquist total productivity index is used to study the productivity change of faculties over the period 2008-2013.

The input variables are chosen to represent the human resources utilized by the faculties:

Total number of academic staff
Total number of nonacademic staff

The output variables are:

Total number of undergraduate students
Total number of post-graduate students
Total number of research

All the data was gathered from the Lebanese University (29). The total number of research was obtained from the Lebanese University and CNRS (28, 29).

Section 5: Results and discussion

In this study we assess academic faculty efficiency of the only public university in Lebanon which is the Lebanese University. Data Envelopment Analysis is used for evaluating the efficiency of 16 faculties at the Lebanese University. Data Envelopment Analysis (DEA) is concerned with measuring production efficiency for each production unit of a set of decision-making units (DMUs) – faculties in this instance. Comparability means that the set of DMUs has the same objectives and is producing similar outputs using similar inputs with the same technology.

DEA is employed to assess efficiency when there are multiple inputs and outputs in the absence of acceptable weights for aggregating inputs and outputs. If prices of all inputs and outputs exist, then we can use the value of inputs and outputs or their indexes. The existence of prices is possible in the case of private firms. However, in the case of public sector production, prices are not usually available or do not reflect social values; thus the appeal of DEA for the efficiency analysis of public operations.

The lack of prices implies that DEA analysis evaluates technical efficiency, not economic efficiency. In other words, the DEA shows how efficiently inputs are used to produce outputs, but not whether the efficient units could reduce costs or enhance the value of outputs by choosing different combinations of inputs or outputs. In spite of that, information on technical efficiency is valuable for assessing and improving the performance of DMUs when prices are absent or limited.

The DEA is relative in making the technical analysis. It determines an efficient group from the set of analyzed DMUs. However, it still might be possible to improve the technical efficiency of even those efficient DMUs which were the best production possibilities. Moreover, the efficient DMUs in DEA are the most efficient of those observed, not in comparison to some ideal. Hence, The DEA efficient group is that subset demonstrating the “best practices” among a group of operating DMUs. Inefficient DMUs are compared to those units demonstrating superior performance (McMillan, Datta, 1998).

The Data Envelopment Analysis is a linear programming procedure used to construct a frontier or production possibilities curve for a set of units. It is applied on homogenous units with the same production (objective) function. This method assigns a score of 1 to efficient units and less than one to (relatively) inefficient units. The score reflects the radial distance from the estimated production frontier to the DMU under consideration.

Two forms of DEA models are considered: input-oriented and output-oriented forms. In the input-oriented model, a DMU is not efficient if it is possible to decrease without increasing any other input and without decreasing any output. In other words, the question is "By how much can inputs be proportionally reduced without altering outputs?" In an output-oriented model, a DMU is not efficient if it is possible to increase any output without increasing any input and without decreasing any other output.

The concept of "technical efficiency" is understood to imply the maximum possible output from a given set of inputs. In the higher education context, technical efficiency became hence associated to the physical relationship between the resources used (labor, equipment, capital) and some education outcomes.

Thus, to use the DEA technique we apply two input and three output variables for comparing the performance in 16 faculties of the Lebanese University using Data Envelopment Analysis. These faculties are reported in table 2.

The input variables are: number of academic staff, number of nonacademic staff. The output variables are: number of faculty graduates, number of faculty postgraduates, and number of published papers (see table 3). The sample period is the year 2013.

Applying DEA technique supposes using the adequate sample size. The size of the sample utilized in this study is in line with the rules of thumb available in DEA literature. One of these rules stipulates that the number of DMUs (n) should be at least three times the sum of number of input (m) and output (s) variables ($n > (m + s)$. In this study, the sample size is $n = 16$ and $m = 2$ and $s = 3$. It is feasible and exceeds the desirable size.

Table 2: Faculties of the Lebanese University

DMU	Faculty names		
1	Faculty of Sciences	9	Faculty of Agronomy
2	Faculty of Law and Political Administrative Sciences	10	Faculty of Engineering
3	Faculty of Pedagogy	11	Faculty of Public Health
4	Institute of Social Sciences	12	Faculty of Medical Sciences
5	Faculty of Letters and Human Sciences	13	Faculty of Pharmacy
6	Institute of Fine Arts	14	Institute of Technology
7	Faculty of Information	15	Faculty of Tourism and Hospitality Management
8	Faculty of Economics and Business Administration	16	School of Dentistry

We notice that the faculty of letters and human sciences has the highest number of undergraduate and postgraduate students. However, the school of pharmacy has the lowest number of undergraduate students. Moreover, the following faculties do not have postgraduate students: Faculty of Engineering, Faculty of Medical Sciences, Institute of Technology, and School of Dentistry. In addition, Faculty of Economics and Business Administration registers the highest number of researches and the Institute of Arts has no research at all.

Table 3 indicates that the highest number of academic staff is in the Faculty of Sciences and lowest one is in the Faculty of Pharmacy. As to nonacademic staff, the Faculty of Public Health has the highest number and the Institute of Technology has the lowest.

Table 3: Variables used in the study - year: 2013

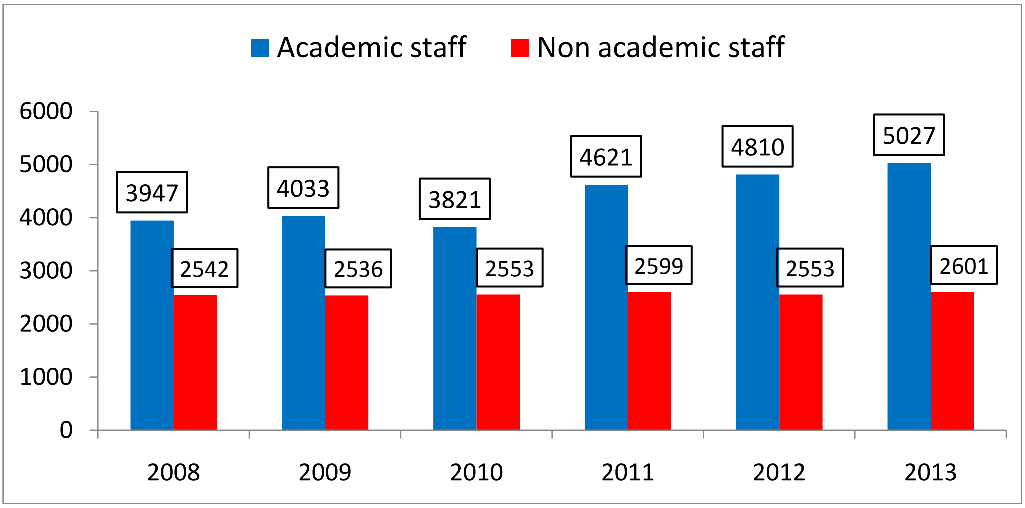
	Variables				
	Inputs		Outputs		
DMU Name	**Total number of academic staff**	**Total number of nonacademic staff**	**Total number of undergraduate students**	**Total number of postgraduate students**	**Total number Of research**
Faculty of Sciences	829	443	11716	2071	27
Faculty of Law & Political Administrative Sciences	262	245	8976	28	3
Faculty of Pedagogy	295	83	1191	406	11
Institute of Social Sciences	151	155	3699	1021	2
Faculty of Letters & Human Sciences	749	295	14955	3210	22
Institute of Fine Arts	489	132	1882	846	0
Faculty of Information	116	106	1463	358	1
Faculty of Economics & Business Administration	493	137	6105	1059	41
Faculty of Agronomy	103	89	490	360	2
Faculty of Engineering	244	183	2334	0	4
Faculty of Public Health	453	549	2513	199	1
Faculty of Medical Sciences	374	44	1210	0	1

	Variables				
	Inputs		Outputs		
DMU Name	Total number of academic staff	Total number of nonacademic staff	Total number of undergraduate students	Total number of postgraduate students	Total number Of research
School of Pharmacy	52	36	341	27	3
Institute of Technology	190	26	901	0	5
Faculty of Tourism & Hospitality Management	67	28	420	40	1
School of Dentistry	160	50	463	0	2
Total	**5027**	**2601**	**58659**	**9625**	**126**
Total number of students			**68284**		

Minimum, Maximum.

Figure 1 presents a comparison between the number of academic and nonacademic staff. We notice that the number of academic staff increased progressively from 3947 in 2008 to 5027 in 2013 (except for the year 2010 where the number dropped slightly), while the number of nonacademic staff remained approximately stable between 2500 and 2600.

Figure 1: A comparison between academic and nonacademic staff at the Lebanese University



a) CCR Results

We use three scenarios to deal with the output variables in order to take into account the influence of each scenario on the performance of each faculty. The first scenario consists of taking all the inputs and outputs without any change. In the second scenario we take the research and we merge the graduate students with the postgraduates so that we have only two outputs. The third scenario takes the merged graduates and postgraduates without the research, thus we have only one output.

We employ in this study the constant return to scale (CCR) model that is based on input oriented approach. Due to the fact that in a university environment, it is easier to control the inputs rather than the outputs, the DEA input-oriented model is used to compute the efficiency of these faculties. The purpose of an input-oriented study is to evaluate by how much input quantity can be proportionally reduced without changing the output quantities. We aim at identifying potential cases of waste of resources among faculties at the Lebanese University. We used DEAFrontier software developed by Zhu (2003) and we applied Constant Returns to Scale input oriented.

Figures 2, 3 and 4 present the results of the three scenarios in 2013. The faculties with a score of 1 are efficient and those with a score less than 1 are inefficient. Applying the CCR model, we can observe that four faculties out of 16 are fully efficient in the first scenario while the number of efficient faculties was three units in the second scenario (the Institute of Social Sciences was removed) and two efficient faculties in the third scenario (the Institute of Social Sciences and the Faculty of Economics and Business Administration were discarded). Therefore, this indicates two interesting findings: firstly, research plays an important role in improving the efficiency of faculties (especially, the efficiency of the Institute of Social Sciences and the Faculty of Economics and Business Administration) and secondly, the results show the positive effect of having undergraduate and postgraduate students in the faculties under study (especially, the efficiency of the Institute of Social Sciences).

Since the higher number of best practice units appears in the first scenario,

CCR results in the first scenario will be used in the analysis throughout the rest of the study. Hence, in figure 1, we notice that there is wide variation in efficiency scores and a big gap between lower and higher efficiency scores, The Faculty of Public Health has the smallest score around 18% in CCR model. The number of efficient faculties in the CCR model is four. These faculties are: Faculty of Law and Political Administrative Sciences, Institute of Social Sciences, Faculty of Letters and Human Sciences, and Faculty of Economics and Business Administration. These faculties together define the best practice or efficient frontier and, thus, form the reference set for inefficient faculties. The human resources utilization in these faculties is functioning well. This means that the production process in these faculties does not illustrate any waste of inputs. Therefore, they are characterized by an overall technical efficiency (OTE) and set as an example of good operating practices for inefficient faculties to imitate. In DEA terminology, these faculties are called peers. The remaining 12 faculties are deemed to be relatively inefficient since they have OTE score less than 1.

The results indicate that faculties at the Lebanese University are characterized with large asymmetry with regard to overall technical efficiency (OTE) (in percentage terms). Efficiency scores of the faculties range from 18% to 100%. Four faculties are efficient and 12 are inefficient. The Faculty of Public Health has the lowest efficiency score of 18%. The average of efficiency scores is around 0.63175 which implies that, on average, the 16 faculties in question would be able to achieve the same level of performance and the same output levels by using 37% less resources. In other words, if an average faculty is on the efficient frontier instead of its current (virtual) location, it would need 63% of the inputs currently being used. It has to reduce its physical capital by 37% and still produce the same level of outputs. In addition, faculties need to produce 1.58 (=1/0.63175) times as much as outputs from the same level of inputs. Thus, when a faculty is judged as inefficient, a reasonable reaction might be to reduce its inputs and focus on making internal practices more efficient. However, the potential reduction in inputs from adopting the best practices varies from faculty to faculty. Lastly, the mean of the efficiency scores is 63.32% and the standard deviation is 0.27.

The inefficient faculties can improve their efficiency by decreasing their inputs. For instance, Faculty of Science has an efficiency score of 0.72 which implies that this faculty can potentially reduce its inputs by 28% while keeping their outputs unchanged. This interpretation of the overall technical efficiency can be extended for other inefficient faculties.

CCR model (Total Variables - 2013)

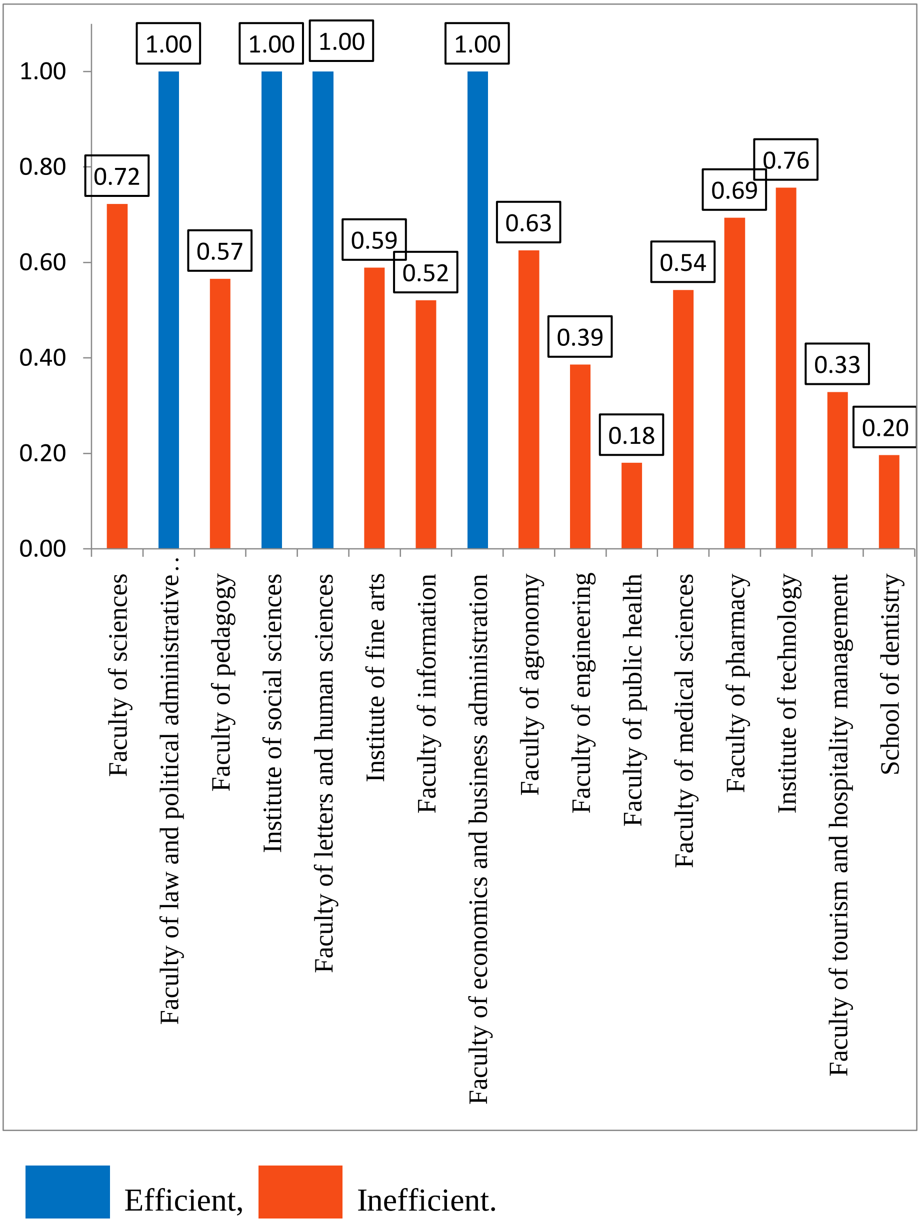


Figure 2: Efficiency of the faculties using all the inputs and outputs (first scenario) during 2013.

-CCR model (Total Students – 2013)

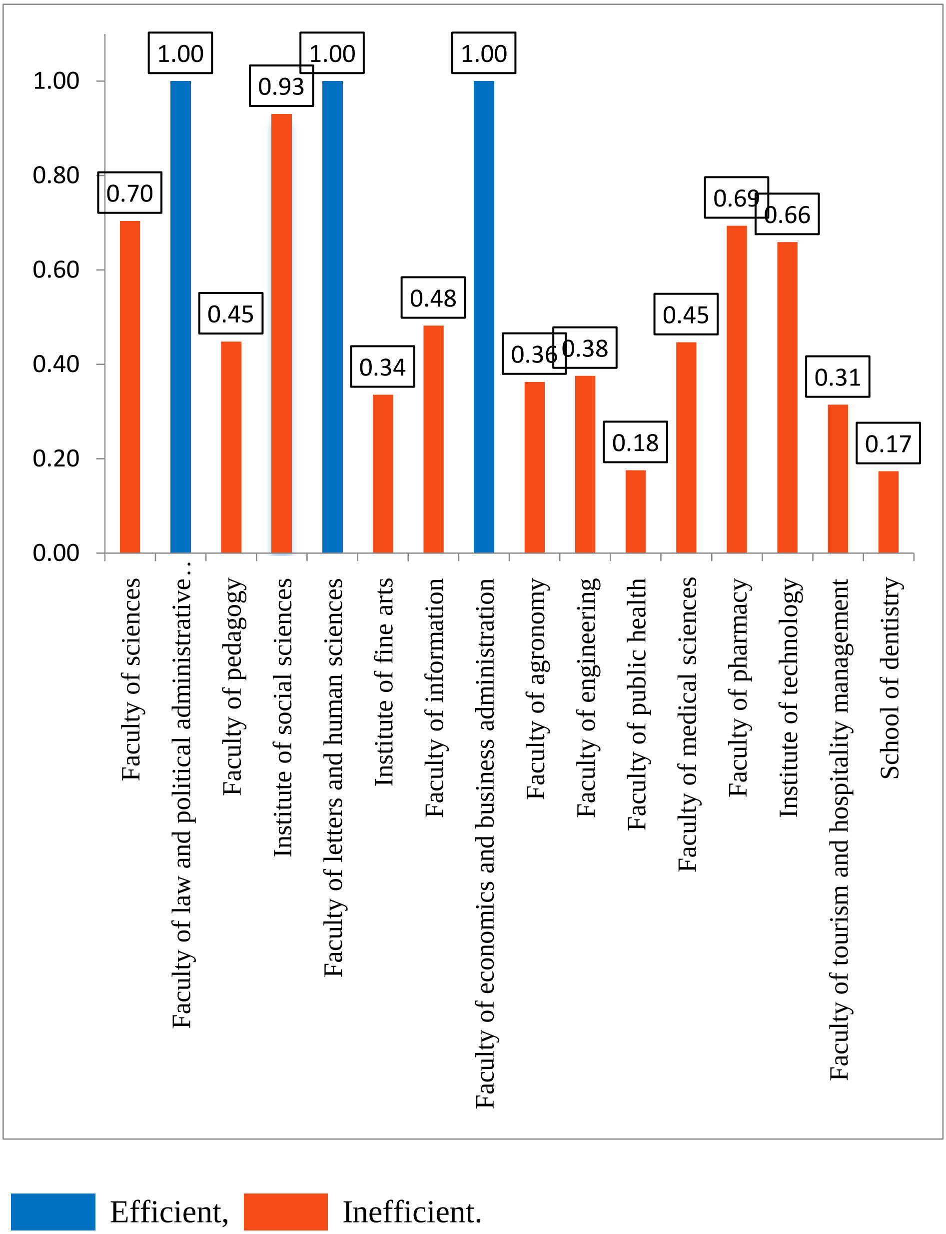


Figure 3: Efficiency of the faculties using 2 outputs: Total Students (undergraduates + postgraduates) and research (second scenario)

CCR model (Total Students without Research – 2013)

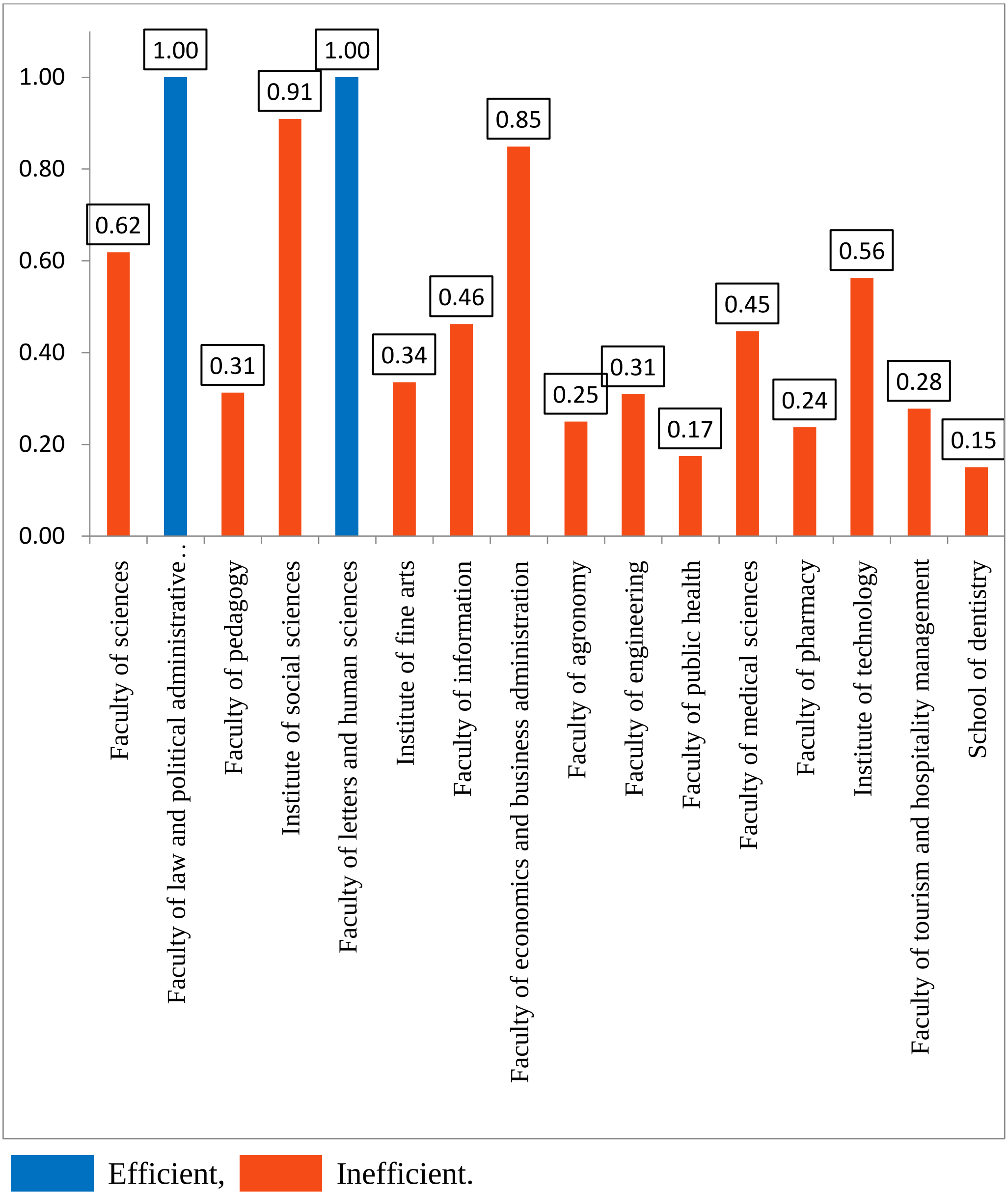


Figure 4: Efficiency of the faculties using 1 output: Total Students (undergraduates + postgraduates) without research (third scenario)

b) Peers of inefficient faculties

DEA also provides information on peers. A peer (or benchmark) is a faculty against which the technically inefficient faculties may be benchmarked.

Table 4 shows all inefficient faculties with their peer units. These inefficient DMUs are asked to learn how to transform their inputs to outputs. We notice that all inefficient faculties have peers (reference sets of benchmarks). In other words, inefficient faculties should adopt their peers' policies and techniques in order to become efficient. They can learn best practices from their peer faculties. The number of peers in CCR model is four. For instance, the faculty of Sciences is an inefficient faculty and its peers in CCR model are Faculty of Law and Political Administrative Sciences, Institute of Social Sciences, Faculty of Letters and Human Sciences, and Faculty of Economics and Business Administration. Therefore, for Faculty of Sciences to become efficient, it can learn best practices from these faculties. However, the other faculties have different combinations of peers. Furthermore, Chen (1997) and Chen and Yeh (1998) use method to discriminate efficient faculties. According to this method, the frequency that an efficient faculty shows up in the reference sets of inefficient faculties represents the extent of robustness of that Faculty relative to other efficient faculties. The higher the frequency, the more robust it is.

It is observed that Faculty of Economics and Business Administration is the most recurring benchmark. It was referred to 10 times, which means that there are 10 faculties which could learn from this faculty best practices and thus become efficient. The same can be said about the other recurring benchmarks like Faculty of Letters and Human Sciences which was referenced for 9 times. In other words, at least 9 inefficient faculties can improve their efficiencies by learning from the methods and techniques adopted by this faculty.

We can use DEA method to investigate the super-efficient faculties. Table 5 provides these scores. The faculty with the highest score is the super-efficient one. The results indicate that Faculty of Economics and Business Administration has the highest score 2.32585. The second one is the Institute of Social Sciences with a score of 1.57770, the third one is

Faculty of Letters and Human Sciences with a score of 1.49705, and the last one is Faculty of Law and Political Administrative Sciences with a score of 1.43692.

Table 4: Peers in the year 2013 using total variables (first scenario), √ indicates the appropriate peer

Inefficient faculty	**Peers (CCR model)**			
	Faculty of Law and Political Administrative Sciences	**Institute of Social Sciences**	**Faculty of Letters and Human Sciences**	**Faculty of Economics and Business Administration**
Faculty of Sciences	√	√	√	√
Faculty of Pedagogy			√	√
Institute of Fine Arts			√	
Faculty of Information	√	√	√	√
Faculty of Agronomy			√	√
Faculty of Engineering	√			√
Faculty of Public Health	√	√		√
Faculty of Medical Sciences			√	
Faculty of Pharmacy				√
Institute of Technology			√	√
Faculty of Tourism and Hospitality Management		√	√	√
School of Dentistry			√	√

Table 5: Super efficiency scores

DMU No.	DMU Name	Super Efficiency
1	Faculty of sciences	0.72286
2	Faculty of law and political administrative sciences	1.43692
3	Faculty of pedagogy	0.56596
4	Institute of social sciences	1.57770
5	Faculty of letters and human sciences	1.49705
6	Institute of fine arts	0.58900
7	Faculty of information	0.52082
8	Faculty of economics and business administration	2.32585
9	Faculty of agronomy	0.62555
10	Faculty of engineering	0.38584
11	Faculty of public health	0.18015
12	Faculty of medical sciences	0.54246
13	Faculty of pharmacy	0.69371
14	Institute of technology	0.75673
15	Faculty of tourism and hospitality management	0.32860
16	School of dentistry	0.19632

c) Scale efficiency

The objective of the faculties is to operate at most productive scale size (or constant returns to scale, CRS) in order to minimize inputs and maximize outputs. In fact, in the short run these faculties may operate in one of the following zones: increasing returns to scale (IRS) or decreasing returns to scale (DRS). However, in the long run, they will move towards CRS by becoming larger or smaller. This involves changing the faculty's operating strategy in terms of size scaling up or scaling down. This information can be used to determine whether a faculty has the appropriate size or not.

The existence of IRS or DRS can be identified by examining the sum of intensity variables (i.e., $\sum_{i=1}^{n} \lambda_i$) in the CCR model. If $\sum_{i=1}^{n} \lambda_i < 1$, then scale inefficiency occurs due to increasing returns to scale. This indicates that particular faculty has sub-optimal scale size. On the other hand, if $\sum_{i=1}^{n} \lambda_i > 1$, then scale inefficiency appears due to decreasing returns to scale. This implies that the faculty in question has supra-optimal scale size.

A measure of scale efficiency (SE) can be obtained by comparing technical efficiency measures that are computed under the assumptions of constant returns to scale (CRS) and variable returns to scale (VRS). The technical efficiency under the CRS assumption is defined as overall technical efficiency (OTE) which measures the inefficiencies due to the input/output configuration as well as the size of operations. As to efficiency measure related to VRS assumption, it represents the pure technical efficiency (PTE) which measures inefficiencies due only to managerial underperformance. The ratio of overall technical efficiency to the pure technical efficiency (SE = OTE/PTE) provides a measure of scale efficiency. Thus by comparing the two different DEA approaches we express whether a faculty is operating at its "optimal size". If it is not the case, we can use further comparisons of DEA technique (using increasing or decreasing returns to scale) in order to see whether the faculty is "too large" or "too small".

To do so, we need first to compute the efficiency scores under the variable returns to scale. This is called BCC model. Figure 5 presents a depiction of the CCR and BCC models (see figure 5).

Table 5 reports the Score efficiency in both models CCR and BCC and the scale efficiency of the 16 faculties of the Lebanese University. The scale efficiency is 1 for the faculties that are efficient in both models (CCR and BCC).

In both models CCR and BCC, there is a room for improvement in several faculties. The number of faculties with low performance is relatively high in the CCR model. However this number increases remarkably in the BCC model.

Consequently, BCC model yields more efficient faculties than CCR model. After dropping the assumption of constant returns to scale more faculties appear to be efficient. This indicates that these faculties (Faculty of Pharmacy, Institute of Technology, and Faculty of Tourism and Hospitality Management) are technically efficient and the source of inefficiency in the CCR model was due to environmental factors more than technical factors. In other words, these faculties already have the best practices, but the only difference in their productivity is due to economies of scale.

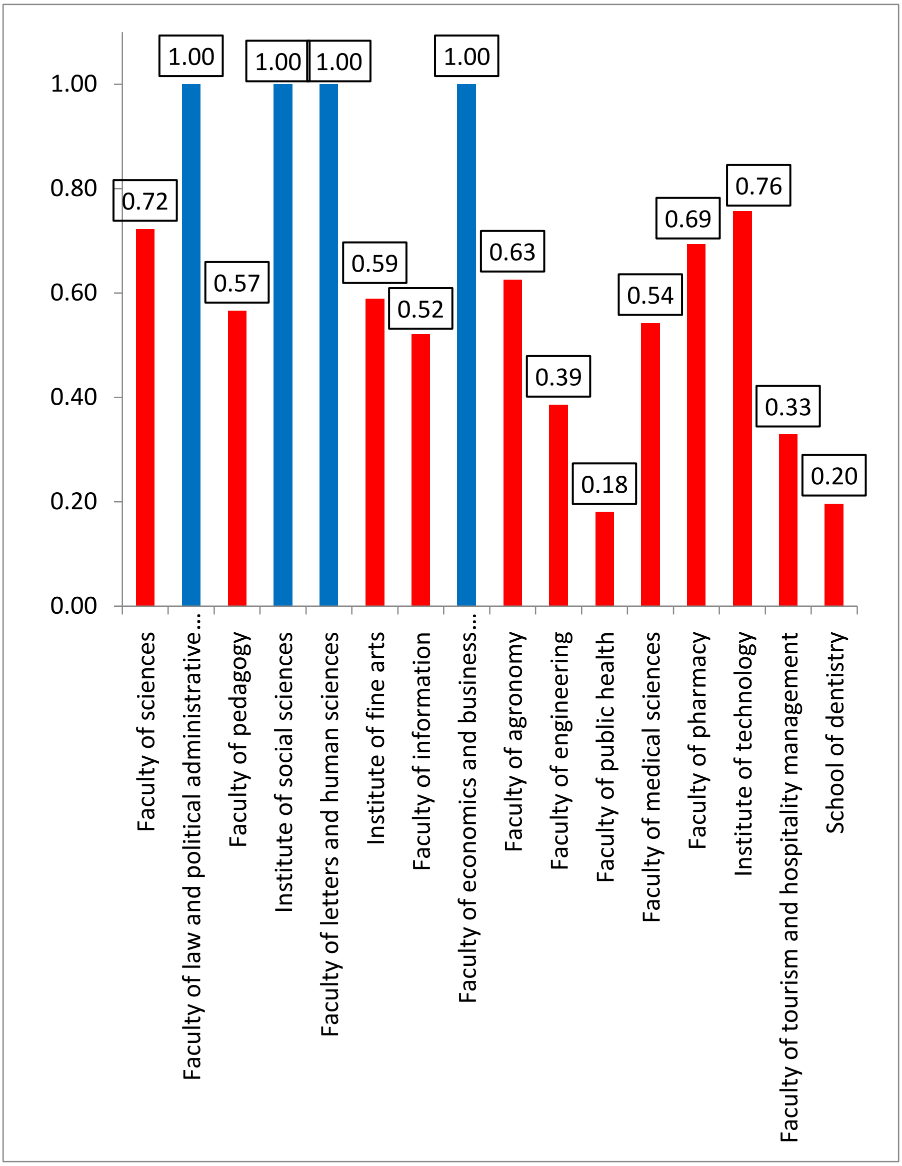
It is possible to increase the productivity of the faculties that are only efficient in the VRS DEA, by using increasing or decreasing returns to scale. For more insights see Appendix A. This letter shows that among all inefficient faculties, the Faculty of Sciences is the only one that should have decreasing returns to scale while other inefficient faculties should have increasing returns to scale. The efficient faculties in VRS DEA model only are already using the best practices. However, because of economies of scale it is not possible to achieve an overall technical efficiency. It is about adjusting the scale and not adopting efficiency measures this time. It is just increasing or decreasing the scale in order to reach the CRS frontier while keeping the best practices they already have.

The four efficient faculties (25%) that are fully efficient in both models are working with the most productive size. Those faculties are Faculty of Law and Political Administrative Sciences, Institute of Social Sciences, Faculty of Letters and Human Sciences, and Faculty of Economics and Business Administration. They are operating at most productive scale size and experiencing CRS. The additional three faculties, which are found to be efficient in the VRS model, have pure technical efficiency but don't have scale efficiency. Other faculties that are inefficient in both models have neither technical nor scale efficiencies.

The 12 inefficient faculties according to CCR model are divided into two groups. The first group consists of 11 faculties (67%) that are experiencing increasing returns to scale. These faculties are operating below their optimal scale size and hence they need to increase their size in order to enhance their OTE. The second group consists of one faculty (Faculty of Science) which experiences decreasing returns to scale and needs to reduce its scale in order to become fully efficient.

All in all, increasing returns to scale is the predominant form of scale inefficiency in the faculties of the Lebanese University.

CCR model (Total Variables - 2013)



Efficient, Inefficient.

BCC model (Total Variables - 2013)

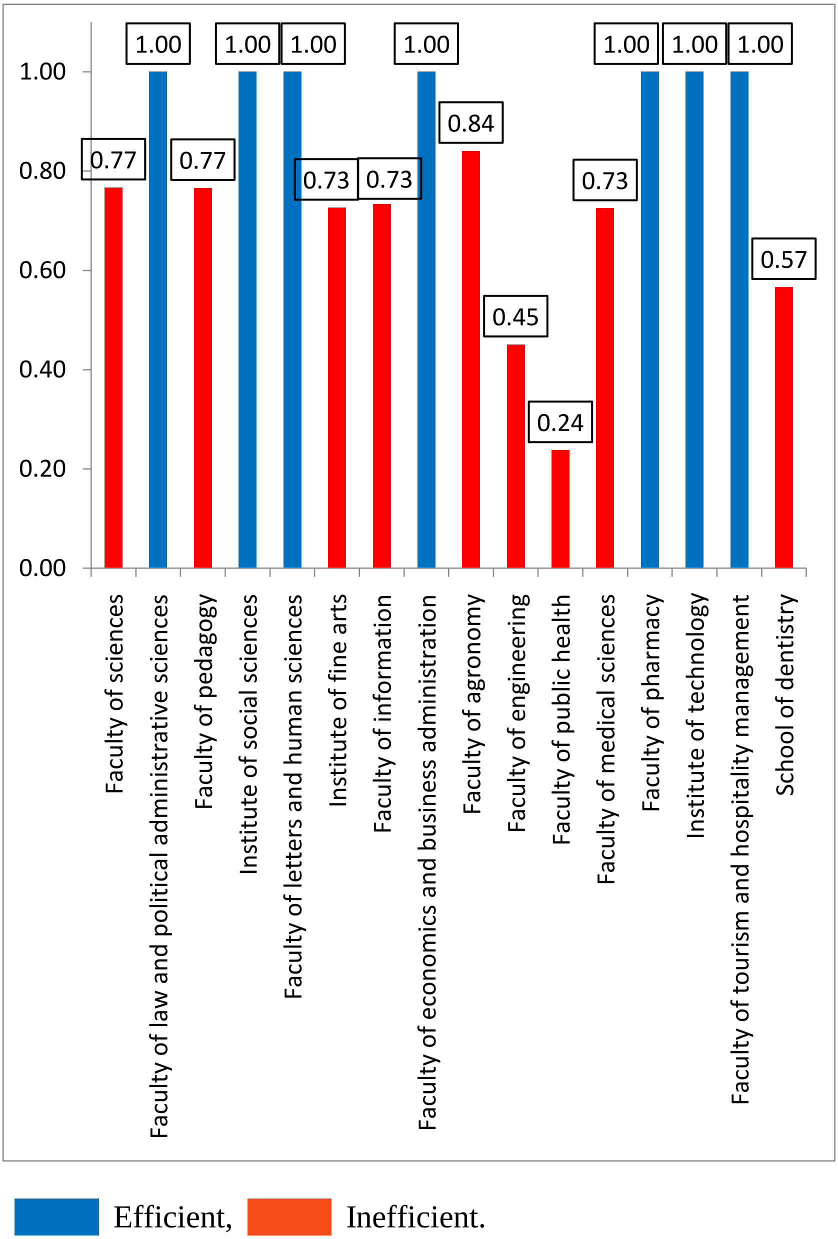


Figure 5: Efficiency of the faculties using all the inputs and outputs (first strategy) during 2013

d) Decomposition of overall technical efficiency: Pure technical and scale efficiencies

The overall technical efficiency (OTE) helps to measure two kinds of efficiencies: pure technical efficiency (PTE) and scale efficiency (SE) which is due to inappropriate faculty size. On the contrary to OTE measure, the PTE is an efficiency measure derived from BCC under variable returns to scale assumption. This measure is devoid from the scale effects. Hence, the inefficiencies deriving from this model result from managerial underperformance (i.e. managerial inefficiency) in organizing the faculty's inputs. In DEA literature, faculties that attain OTE and PTE scores equal to 1 are known as 'globally efficient' and 'locally efficient' faculties respectively.

Table 5 reports the OTE, PTE, and SE scores. We notice that 7 faculties have the status of 'locally efficient' since they achieved an OTE score equal to 1. In addition, four faculties out of the 7 efficient faculties under VRS are 'globally efficient'. For the three faculties that became efficient under VRS assumption but were found to be inefficient under CRS case, we can infer that the latter inefficiencies are not caused by poor input utilization (i.e., managerial inefficiency) rather caused by the operations of the faculties with inappropriate scale size. The remaining 9 faculties that have PTE < 1 are assumed to have managerial inefficiency. These faculties have both PTE and SE scores less than 1 and their inefficiency stems from both pure technical and scale inefficiencies. Out of 9 faculties, 5 faculties have PTE score less than SE score. This implies that the inefficiency in resource utilization in the 5 faculties is primarily attributed to the managerial inefficiency rather than to the scale inefficiency.

The analysis of the PTE and SE measures for these faculties as a whole shows that the technical inefficiency in these faculties is due to both poor input utilization (i.e. pure technical inefficiency) and failure to operate at most productive scale size (i.e. scale inefficiency). The average PTE for 16 faculties is around 80% (see table 6). This indicates that 20% of the about 37% overall technical inefficiency is attributed to faculty managers who are not following appropriate management practices and selecting incorrect input combinations. The remaining overall technical inefficiency is attributed to inappropriate scale of faculties.

Table 5: BCC, CCR, and Scale Efficiency of the Faculties of the Lebanese University in 2013.

DMU	DMU Name	Scale Efficiency (SE)	BCC Efficiency (PTE)	CCR Efficiency (OTE)
1	Faculty of sciences	0.94	0.77	0.72
2	Faculty of law and political administrative sciences	1.00	1.00	1.00
3	Faculty of pedagogy	0.74	0.77	0.57
4	Institute of social sciences	1.00	1.00	1.00
5	Faculty of letters and human sciences	1.00	1.00	1.00
6	Institute of fine arts	0.81	0.73	0.59
7	Faculty of information	0.71	0.73	0.52
8	Faculty of economics and business administration	1.00	1.00	1.00
9	Faculty of agronomy	0.74	0.84	0.63
10	Faculty of engineering	0.86	0.45	0.39
11	Faculty of public health	0.76	0.24	0.18
12	Faculty of medical sciences	0.75	0.73	0.54
13	Faculty of pharmacy	0.69	1.00	0.69
14	Institute of technology	0.76	1.00	0.76
15	Faculty of tourism and hospitality management	0.33	1.00	0.33
16	School of dentistry	0.35	0.57	0.20

Efficient

Table 6: Descriptive statistics of OTE, PTE, and SE scores

DMU	**Scale Efficiency (SE)**	**BCC Efficiency (PTE)**	**CCR Efficiency (OTE)**
N	16	16	16
Average efficiency	0.78	0.80	0.63
Standard Deviation	0.20	0.23	0.27
Minimum	0.33	0.23	0.18
Maximum	1	1	1
Average inefficiency (%)	22%	20%	37%

e) Target values

Data envelopment analysis is a linear programming that provides optimal solution with non-zero input and output slacks corresponding to input and output constraints. The slacks exist only for the inefficient faculties and provide important information related to the areas which an inefficient faculty needs to improve in order to achieve the status of efficient one. Slacks represent only the leftover portions of inefficiencies; the input-slack represents the input excess and output slack indicates the output which is under-produced (Avkiran, 1999a; Ozcan, 2008).

The inefficient faculties can benefit from this study by using the CCR model to compute the amounts by which they should reduce their inputs to become efficient.

Table 7 reports the input and output slacks derived from CCR model for 12 inefficient faculties at the Lebanese University.

The analysis of the slacks for all inefficient faculties shows that among the input variables, five faculties have non-zero slacks for academic staff and three faculties have non-zero slacks for non-academic staff. As to non-zero slacks for output variables, there are four faculties with non-zero slacks for graduate students, six for postgraduate students, and two for research.

The source of inefficiency for each faculty with respect to the input and output variables can be investigated using slacks and inefficiency scores (1 - efficiency scores). The target values of these variables at faculty level are calculated using OTE scores, optimum values of slacks and actual values.

Table 7: Slacks for inefficient faculties at the Lebanese University

Inefficient faculty	**Input Slacks**		**Output Slacks**		
	Total number of academic staff	**Total number of nonacademic staff**	**Total number of undergraduate students**	**Total number of postgraduate students**	**Total number of research**
Faculty of Sciences	0.00000	0.00000	0.00000	0.00000	0.00000
Faculty of Pedagogy	**12.33840**	0.00000	**985.74704**	0.00000	0.00000
Institute of Fine Arts	**90.61975**	0.00000	**2059.41121**	0.00000	**5.79813**
Faculty of Information	0.00000	0.00000	0.00000	0.00000	0.00000
Faculty of Agronomy	0.00000	**1.81187**	**889.70380**	0.00000	0.00000
Faculty of Engineering	0.00000	**9.35128**	0.00000	**93.23076**	0.00000
Faculty of Public Health	0.00000	**20.11437**	0.00000	0.00000	0.00000
Faculty of Medical Sciences	**142.27917**	0.00000	0.00000	**259.71916**	**0.78001**
Faculty of Pharmacy	0.00000	**14.94934**	**105.70732**	**50.48780**	0.00000
Institute of Technology	**77.16570**	0.00000	0.00000	**164.54299**	0.00000
Faculty of Tourism and Hospitality Management	0.00000	0.00000	0.00000	**27.74676**	0.00000
School of Dentistry	0.50915	0.00000	0.00000	**89.02473**	0.00000

We use the following formulae to define a target point $(\hat{x}, \hat{y})$:

$$\hat{x}_{io} = \theta_0^* x_{io} - s_i^{-*} \qquad i = 1, 2, \ldots\ldots, m$$

$$targeted\ input\ value = radial\ adjustment - slack\ adjustment$$

$$\hat{y}_{io} = y_{io} + s_i^{+*} \qquad i = 1, 2, \ldots\ldots, s$$

$$targeted\ output\ value = observed\ value + slack\ adjustment$$

Where:

$\hat{x}_{i0}$ is the target input i for o-th faculty,

$\hat{y}_{i0}$ is the target output r for o-th faculty,

x_{io} is the actual input i for o-th faculty,

y_{io} is the actual input i for o-th faculty,

θ_0^* is the OTE score of the o-th faculty,

s_i^{-*} are the optimal input slacks,

s_i^{+*} are the optimal output slacks.

Table 8 reports the actual and targeted values of inputs and outputs for each faculty. Inefficient faculties with input slacks need besides the proportional reduction of all inputs by the levels of observed technical inefficiency to add the required slacks. As to the observed outputs they need to be added to the required slacks.

From table 8 we notice the potential improvement in input-output activities needed to put an inefficient faculty onto the efficient frontier. In order to show the potential input reduction and output addition we consider the case of Faculty of Public Health. To move onto the efficient frontier, this faculty needs to reduce its academic staff by 83.6% and its non-academic staff by 45.4%. It has also to increase their research from 1 per year to 2 per year. We notice that this faculty doesn't have postgraduate students and according to the obtained results, it needs to take 260 postgraduate students. Consequently, this faculty is able, with lower inputs, to produce more outputs than the actual situation.

Similar conclusions can be drawn for other inefficient faculties.

Considering the Lebanese University as a whole, we need to reduce, on average, academic staff and non-academic staff by 37.8% and 38.5% respectively and augment the graduates, postgraduates, and research by 6.8%, 7.1%, and 1% respectively. The execution of these instructions will project all the inefficient faculties onto the efficient frontier.

Table 8: The actual and target values of the input variables in the CCR model (1st scenario)

	Input Variables				Output Variables					
DMU	Academic staff Value	Academic staff Target	Nonacademic staff Value	Nonacademic staff Target	Graduate students Value	Graduate students Target	Postgraduate students Value	Postgraduate students Target	Researc h Value	Research Target
1	829	599	443	320	11716	11716	2071	2071	27	27
2	262	262	245	245	8976	8976	28	28	3	3
3	295	155	83	47	1191	2177	406	406	11	11
4	151	151	155	155	3699	3699	1021	1021	2	2
5	749	749	295	295	14955	14955	3210	3210	22	22
6	489	197	132	78	1882	3941	846	846	0	6
7	116	60	106	55	1463	1463	358	358	1	1
8	493	493	137	137	6105	6105	1059	1059	41	41
9	103	64	89	54	490	1380	360	360	2	2
10	244	94	183	61	2334	2334	0	93	4	4
11	453	82	549	79	2513	2513	199	199	1	1
12	374	61	44	24	1210	1210	0	260	1	2

	Input Variables				Output Variables					
DMU	Academic staff Value	Academic staff Target	Nonacademic staff Value	Nonacademic staff Target	Graduate students Value	Graduate students Target	Postgraduate students Value	Postgraduate students Target	Researc h Value	Research Target
13	52	36	36	10	341	447	27	77	3	3
14	190	67	26	20	901	901	0	165	5	5
15	67	22	28	9	420	420	40	68	1	1
16	160	31	50	10	463	463	0	89	2	2

Efficient DMUs

f) Malmquist productivity index

The relative productivity change of faculties over time is measured using Malmquist productivity index (MI). This method is based on DEA models. For each faculty, the combination of inputs and outputs in periods t and t+1 is used to determine whether the variation in its performance is due to technical efficiency change (TEC) or technological change (TC).

Hence, the use of Malmquist indexes allows us to compare the productivity change within faculties and the productivity change within the Lebanese University. Moreover, the total factor productivity gives rise to changes in efficiency and changes in technology. The interpretation of Malmquist total factor productivity implies considering all its components. These indicate improvement when they are greater than one while a value less than one refers to regression or deterioration and a value equals to one refers to stagnation or no improvement. We used DEAFrontier software developed by Zhu (2003) and we applied Constant Returns to Scale input oriented. The reciprocals of the original estimates are reported for ease of interpretation, so that values above unity denote progress and vice versa.

The results are presented in tables 9 and 10. The total average of the period, for each faculty, indicates that 62.50% of the faculties have shown improvement in total productivity over the period 2008-2013 (see table 9). Moreover, these faculties have shown an improvement in efficiency change by 31.25% and technological change by 68.75%. However, the annual average results revealed an improvement in productivity by 80%, in efficiency change by 20%, and in technological change by 80% (see table 10). It is noticed that there was an improvement in total productivity with the exception of the year 2010-2011where a deterioration of the productivity has been observed. The overall means of the period 2008-2013 show that the productivity change recorded an improvement by 2.82%, and technological change improved by 3.78%, and the efficiency change deteriorated by 2.68%. The year 2011-2012 recorded the highest improvement in productivity change by 28%, and efficiency change by 7.73, and technological change by 18.58%.

A graphical representation of the average productivity change, efficiency change, and technological change within faculties over the period 2008-2013 and within Lebanese University over the afore-mentioned period is provided in figures 6 and 7 respectively.

Figure 6 shows that, Faculty of Dentistry is the most productive faculty over the period 2008-2013. It recorded an improvement in productivity by 28%. However, Faculty of engineering recorded the least productivity change. It deteriorated by 24%. As to the productivity change of The Institute of Social Sciences, it remains unchanged during the study period.

Figure 7 reveals that the year 2011-2012 recorded the highest improvement in productivity change by 29%. However, the year 2010-2011 recorded the highest deterioration by 24%.

Table 9: values of the total factor productivity (Malmquist index) and its components: technical efficiency change and technological change.

Mean (2008-2013)	Malmquist Index	Efficiency Change	Frontier Shift
DMUs			
Faculty of sciences	1.008	0.930	1.081
Faculty of law and political administrative sciences	1.024	1.045	0.979
Faculty of pedagogy	1.013	1.020	1.05
Institute of social sciences	0.996	1.000	0.996
Faculty of letters and human sciences	1.019	1.000	1.019
Institute of fine arts	1.214	1.129	1.064
Faculty of information	1.026	0.927	1.069
Faculty of economics and business administration	1.117	1.000	1.117
Faculty of agronomy	1.128	0.928	1.063
Faculty of engineering	0.762	0.785	0.982
Faculty of public health	0.918	0.903	1.003

Mean (2008-2013)	Malmquist Index	Efficiency Change	Frontier Shift
Faculty of medical sciences	1.096	1.157	0.928
Faculty of pharmacy	0.965	0.979	1.060
Institute of technology	0.952	0.907	0.998
Faculty of tourism and hospitality management	0.757	0.781	1.015
School of dentistry	1.262	1.242	1.018
Mean (2008-2013)	1.016	0.983	1.028
	tfpch <1=06	effch <1=08	techch <1=05
	tfpch >1=10	effch >1=05	techch >1=11
	tfpch =1=0	effch =1=03	techch =1=0

where tfpch is the total factor productivity change, effch is the efficiency change, and techch is the technological change.

Table 10: Average of annual malmquist index, efficiency change, and technological efficiency

Period	Malmquist Index	Efficiency Change	Frontier Shift
2008-2009	1.00241	0.98498	1.01144
2009-2010	1.06136	0.97953	1.06253
2010-2011	0.75703	0.88918	0.85119
2011-2012	1.28587	1.07732	1.18580
2012-2013	1.02827	0.93475	1.07839
Mean	**1.02699**	**0.97315**	**1.03787**
	tfpch <1=01	effch <1=04	techch <1=01
	tfpch >1=04	effch >1=01	techch >1=04
	tfpch =1=0	effch =1=0	techch =1=0

tfpch = total factor productivity change, effch = efficiency change, techch = technological change.

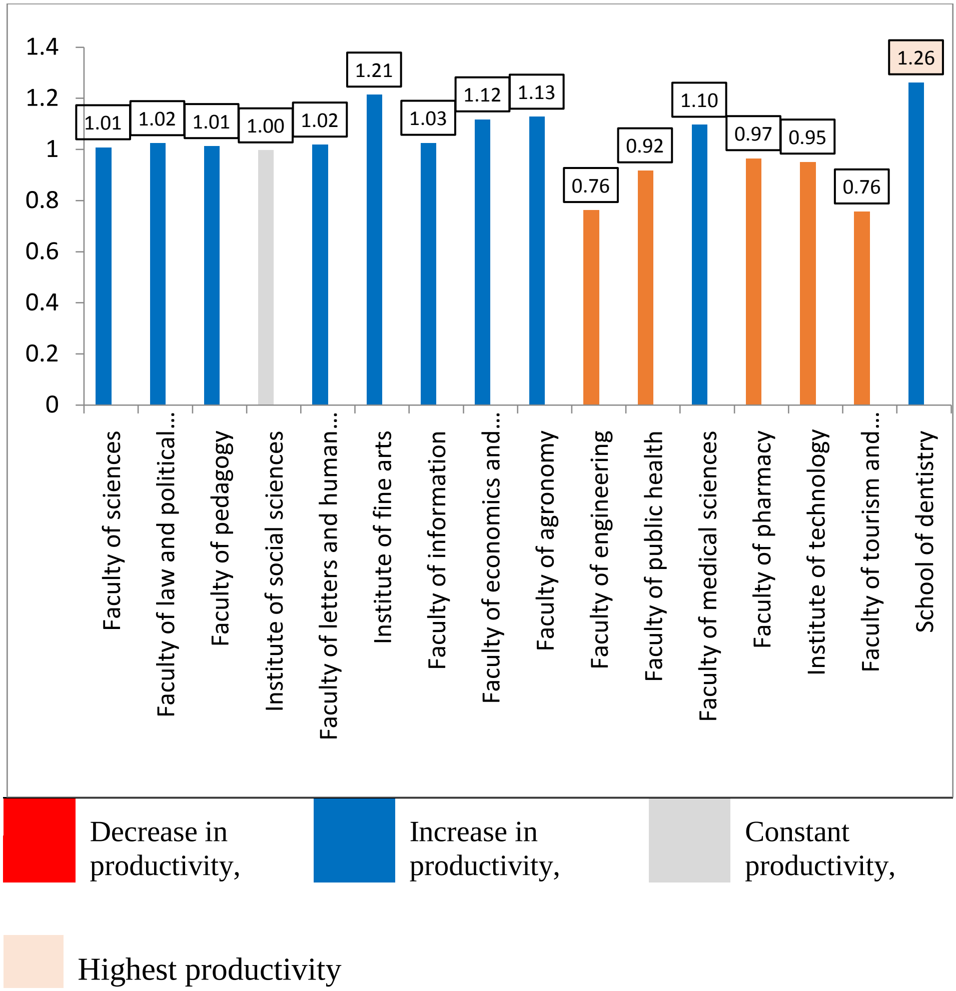


Figure 6: Total factor productivity (plot of the Malmquist index values).

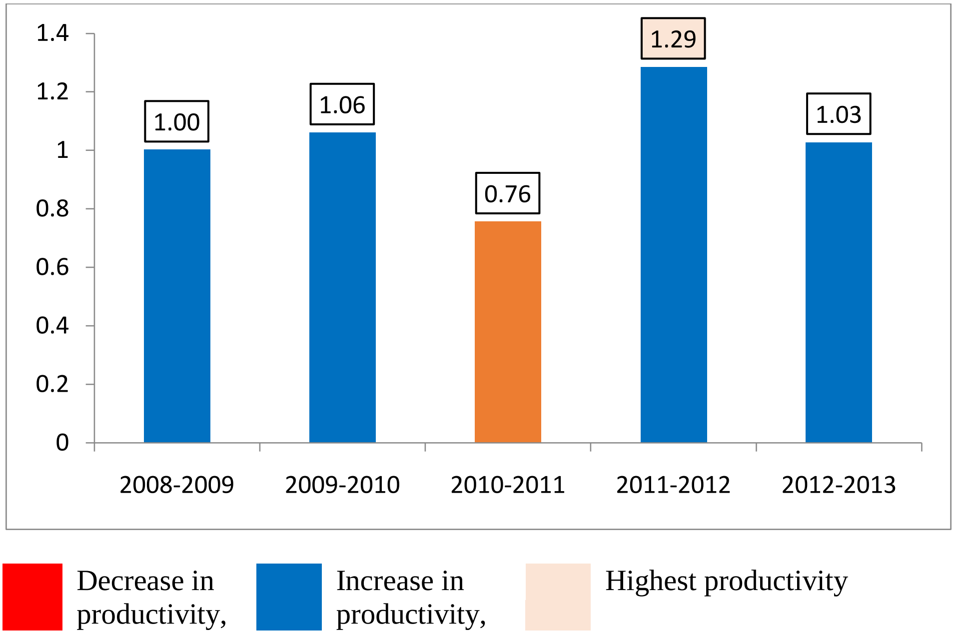


Figure 7: Average of annual productivity change

In summary, the annual Malmquist means shows an improvement in total productivity over the period 2008-2013 that is mainly due to improvement in technological change rather than change in efficiency. Thus, most faculties experienced technological progress. With reference to individual mean productivity change of individual faculties, the afore-mentioned interpretation is valid too.

Section 6: Conclusion

The aim of this research is the evaluation of the performance measures of 16 faculties of the Lebanese University using the Data Envelopment Analysis based on 2012-2013 academic year data. The Constant Return to Scale (CRS) and the Variable Return to Scale (VRS) models based on input oriented approach have been applied in order to determine the relative and scale efficiency of each faculty. The results show that, under Constant Return to Scale, 4 out of 16 faculties are efficient. These faculties are: Faculty of Political and Administrative

Sciences, Institute of Social Sciences, Faculty of Letters and Human Sciences and Faculty of Economics and Business Administration. Under Variable Return to Scale, 7 faculties are proved to be efficient. These are the aforementioned faculties in addition to the Faculty of Pharmacy, Institute of Technology and Faculty of Tourism and Hospitality Management. The analysis of pure technical efficiency and scale efficiency measures for the 16 faculties as a whole shows that the technical inefficiency in these faculties is due to both poor input utilization and failure to operate at most productive scale. The average pure technical inefficiency of the 16 faculties is 80%. This indicates that 20% out of 37% overall technical inefficiency is attributed to faculty management. The rest is attributed to inappropriate scale of faculties. The Mamlquist total productivity index is used to study the productivity change of faculties from 2008 to 2013. The annual Malmquist means show an improvement in total productivity of this period which is mainly due to improvement in technological change rather than in efficiency. Hence, most faculties experience technological progress. In addition, the Faculty of Dentistry is the most productive faculty over this period. It records an improvement of 23%. However, the Faculty of Engineering records the least productive change. It deteriorates by 24%.

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