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## Evaluating the Performance Efficiency of the Iraqi Cement Company through Stochastic Frontier Analysis (SFA): A Quantitative Assessment

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### Abstract

#### Background

The General Company for the Cement Industry in Iraq seeks to encourage cement consumption. It is essential to utilize the resources of existing manufacturing industries and the technologies more efficiently to obtain demand. Therefore, researchers sought to assess the efficiency of the cement industry at the company level in Iraq.

#### Method and materials

The Cobb-Douglas stochastic frontier analysis (SFA) methods are used. Data were obtained and taken by the Iraqi general cement company thirteen factories

#### Result

The efficiency rate was achieved that at 63 % which means that the rate is average and can that work must be done to improve low efficiency factories. Factory No. 4 in Basra was the most efficient, with an ideal technical efficiency of  $0.99936599 \approx 1$ , while Factory No. 10 in Muthanna was highly efficient, with an efficiency of 0.94064895. Similarly, Factory No. 5, Kufa, recorded an efficiency of 0.92725490, as did Factory No. 8, Badush AL-tousieea, recorded an efficiency of 0.87543953.

#### Conclusions

Preferably use of SFA to identify competencies that in that the industrial and to get in efficiency in cement the production, should focus on improving technical efficiency while focusing on the selection of appropriate technologies and optimal utilization of resources in proportion to the scale of work.

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## 1. Introduction

The Cement is the most productive [1-3]. Iraq produces and consumes large quantities of cement annually [4]. During the year . the Iraq cement company can be produce that more than ten million tons . [5] [6]

The Efficiency is the measure of performance then an the indicator of factory success. Efficiency studies show that productivity can be increased by improving the Efficiency of low - volume factories without the need to introduce the technologies that in crease the resource .

Industrial sector the efficiency is a key factor in achieving balance in the productive sector (energy, fuel, with raw materials)the In efficiency estimates use in deciding whether that increase productivity, improvements or the introduction of new technologies. In Iraq, cement has become a cash product, and its importance is rapidly growing in local and the international factories [7]. Lack of capital and workers ignorance of market prices some are of the majoring reasons contributed to ineffective cement marketing .[8]. Industrial worker Efficiency is an tool important for improving decisions and enhancing factories' ability to cope with rising the costs , changing company conditions , rapid technological advancements, and economic difficulties to be achieve optimal production . The efficiency of workers in production plants depends on their level of education, years of experience, the modern technology , and in put other [9-16]. The research includes estimating the efficiency of cement industry and improvements in productivity.. Workers must be needed improve their industrial Efficiency to achieve financial the profit, There are differences in the resources used Effectively in different factories and the SFA [17–20].. Resources must be utilized optimally to achieve maximum production and income. Workers' decisions regarding improving factory efficiency depend on identifying the factors of inefficiency. It is the important to assess that efficiency of the cement industry understand a potential and opportunities then expanding and sustaining in Iraq cement production. [21]

## 2. Methods and materials

### *Data and variables*

The data from 13 individual factories of the General Company for Cement in Iraq. the collected the following independent variables from the company's monitoring and planning department (capital, raw materials, energy and fuel) ,within a year2022 .

### *Methods of estimation*

The pioneering article by “Farrell (1957)” on efficiency measurement has helped to develop various methods of efficiency analysis. SFA is used as a basic model in efficiency research and is considered an important model. [22] In the general and the SFA is used to evaluate the performance of the sector industrial however, the number of studies conducted using the SFA methods for production is low . This is study has the SFA used method and model to estimate the determinants of efficiency in the Iraqi Cement Public Company. The method will be discussed as follows :

### *Stochastic Frontier Analysis (SFA)*

The stochastic boundary function was first proposed and worked on independently by aigner et al [23, 24]. The production Cobb-Douglas function has been widely used by researchers worldwide and is suitable for applied research in various fields, including industry, production industrial, etc.[25].

$$\ln Y_i = \sum_{j=1}^n a_j \ln(X_{ij}) + \varepsilon_i \quad i= 1, 2, 3, \dots, n \quad (1)$$

It means  $y_i$  denotes the profit value of the factories ,the  $x_{ij}$  represents in put variables ,  $a_j$  is a constant term ,  $j$  is the in put coefficient and  $\varepsilon_i$  denotes the error term . This study assumes a constant return to scale. That is the sum of the coefficients is equal to no.1 . the Cobb-Douglas function can be written as follows :

$$\ln \text{profit} = \beta_0 + \beta_1 \ln \text{Capital} + \beta_2 \ln \text{Raw materials} + \beta_3 \ln \text{Energy and Fuel} \quad (2)$$

Where the Ln profit is the natural log of production cement, ( $\beta_0$ ) is the term constant. B1 is input variables including capital, raw material value, energy and fuel and the error term is  $\epsilon_i$ . Furthermore, the TE (technical efficiency) of the inputs is analysed using the stochastic frontier production model. The frontier model in this study is on the stochastic efficiency model of Balletti and et al. [26, 27].

Where  $\text{Ln}Y_i$  denotes the profit value of the  $i$ -th plant,  $X_i$  is a set of production input variables and other independent variables, and  $\epsilon_i$  is the error term. The term error consists of two components.

$$\ln y_i = \beta_0 + \beta_1 \text{Ln}X_{i1} + \beta_2 \text{Ln}X_{i2} + \beta_3 \text{Ln}X_{i3} + \dots + \beta_m \text{Ln}X_{im} + \epsilon_i \text{ .given that } \epsilon_i = v_i - u_i \quad (3)$$

**Variable Description**

**Table 1: Summary Description of Variables Included in the Model**

Variable	Name	Description	unit
Dependent Variables			
Profits	LnProfits	Cement profit amount	Price
Independent Variables			
Capital	Ln Capital	Amounts of capital involved in the production process	Ton &price
Raw materials	Ln Raw materials	The value of raw materials used in cement production	Ton &price
Energy & fuel	Ln Energy and fuel	The amount of energy and fuel used to produce cement	Ton &price

**Source :prepared by the researcher**

The Table 1 description a brief of the included variables in the model. The used dependent variable in this study is the cement profit (Ln profit) of the factories measuring in billions. On the right side, the independent variable including capital (Ln capital), value of raw materials (Ln Raw materials), energy and fuel (Ln Energy and fuel).

**Description of the standard model used in measuring efficiency.**

The stage of describing and formulating the mathematical model is the first step that is taken when trying to study any relationship between several exploited variables [28, 29]. After that it is necessary and is considered the most important step, and according to it, the relationship between the variables is formulated mathematically to obtain the model through which technical efficiency will be measured. This process of describing and formulating the mathematical model requires identifying the dependent independent variables and dependent variables, and determining the mathematical form of the model in terms of the number of equations and their properties, and then making the theoretical expectations that will be based on it as theoretical criteria when evaluating the model [30, 31].

**Mathematical model ( SFA )**

The mathematical model Stochastic Frontier Analysis (SFA) is discussed as follows : [32, 33, 34.35]. The sfa was used and implemented. can it is a model to measure the level of technical efficiency of factories and estimate the technical efficiency of factories.

The stochastic frontier analysis is conducted using the (SFA Frontier) program, and this program is described as an easy tool for estimating the stochastic frontiers (parametric estimation methods) and in order to know which factory of these factories gives the best performance under the conditions it lives through producing outputs represented by profits to the costs it bears in a relative number of inputs such as (capital, value of raw materials, energy and fuel) in order to evaluate the performance of thirteen factories out of 18 factories, and by measuring the technical efficiency of

the factories under study The overall analysis of this research was conducted during the year (2022) in order to catch any changes that may occur in the efficiency assessment of cement factories in this year and is done within the random frontier analysis SFA and technical efficiency TE of Iraqi cement according estimate the manufacturing establishments. The sfa method working in :

- Results on the reasons for not achieving full technical efficiency 100% in managing resources or inputs.
- It also helps in providing proposals to raise efficiency and reduce waste in inputs and thus increase production. The process of estimating technical efficiency is using the stochastic frontier analysis SFA method according to the following steps [36].
  - ✓ The first step: The method (OLS) is used to obtain linear parameters unbiased.
  - ✓ The second step: The method COLS is used to obtain unbiased linear parameters including B0 and the method Cobb-Douglas estimated by the previous methods takes the following form : [ 37 ].

$$Y_i = X_i \beta - u_i \tag{4}$$

Where:

$Y_i$ : Outputs of the  $i$ -th institution. (Dependent variable)

$X_i$ : is a vector of  $k \times 1$  inputs of the institution. (Independent variables)

$\beta$ : Vector of the estimated model parameters .

$U_i$  : it is considered a random variable related to the technical in efficiency of the institution then  $T_e$  can be expressed mathematically as follows :

$$TE = \frac{y_i}{f(x_i, \hat{B})} = \frac{Y_i}{Y_i^*} = \frac{\exp(x_i B - u_i)}{\exp(x_i B)} = \exp(-u_i) \tag{5}$$

Battese and Coeli proposed another formula for estimating technical efficiency, which is as follows:

$$TE = E [ \exp (-u_i / e_i) ]: \text{With } 0 \leq TE \leq 1$$

The stochastic frontier function differs from the Cobb-Douglas function frontier by adding a random error representing the measurement error  $v_i$  to the random error  $u_i$  representing the inefficiency. then the sfa production function make form [ 38 ].

$$Y_i = X_i \beta + (v_i - u_i)$$

Where:  $i = 1, 2, 3$

$X_i$ : represents the vector of input quantities used by the factory.

$Y_i$ : represents the output (dependent variable)

$v$ : represents the measurement error.

$u$ : represents the value of inefficiency.

By taking the log , of the function in the previous equation , the model becomes as follows :

$$\ln Y_i = \beta_i \ln X_i + (v_i - u_i)$$

It is possible to write the equation in another form :

$$\ln Y_i = \beta_i \ln X_i + \epsilon_i$$

Where:  $\epsilon_i$  is the random variable or what is called the error term consisting of two parts  $v_i$  and  $u_i$ .

- ✓ The third step : The maximum likelihood estimates of the coefficients of the stochastic frontier function can be the likelihood obtained using by ratio method according to the exponential function of the that Cobb-Douglas function. [ 39 ].

### 3. Result and Discussion

#### Summary statistics

The Table 2 will provide a description of all variables included in this model. Summary statistics of the output and input variables of technical efficiency were also presented for the year 2022. The results revealed that the average profitable return from cement production was 1.33 trillion dollars + 100 billion square meters.  $6.78e+07$  billion Iraqi Dinars and a higher limit of  $2.79e+10$  billion Iraqi Dinars. It was noted that among the expenses, the average use of raw material value was  $7.39e+09$  billion Iraqi dinars and the value of raw materials for casting was the most expensive in some of the cement factories in the study sample and the minimum and maximum value of raw materials was  $1.14e+09$  and 109 million dinars. Iraqi respectively. Furthermore, the factories used lower amounts of energy and fuel resulting in a minimum cost for this purpose of 2,452,350 billion Iraqi dinars.

The above table that indicates that the average results of the three independent variables included in the production process ranged between a minimum of 2452350 and the maximum of that  $6.43e+10$  during the study sample period of 2022. This indicates that the maximum and maximum rights of average, Power and fuel minimums. Then the (dependent variable ) lost was  $1.33e+10$

**Table 2: Summary statistics of variables**

Variable	Obs	Mean	Standard Deviation Std.Dev	Minimum	Maximum
Out put					
Profits	13	$1.33e+10$	$1.04e+10$	$6.78e+07$	$2.79e+10$
In put					
Capital	13	$4.17e+10$	$9.79e+09$	$3.05e+10$	$6.43e+10$
Raw materials	13	$7.39e+09$	$4.68e+09$	$1.14e+09$	$1.14e+09$
Energy and fuel	13	$5.01e+09$	$6.34e+09$	2452350	$2.25e+10$

**Source: Prepared by the researcher based on the program spss24**

#### *Results of Estimation and Analysis of the Model ( Estimates of the stochastic frontier production function model for the year 2022 )*

Furthermore, Table 3 shows the results of the Cobb–Douglas stochastic frontier model for the year 2022 The stochastic frontier production function was applied according to the Cobb - Douglas function using the Frontier 4.1 computer program

The results As for of model estimation the TE was estimated using sfa according to the transcendental log production function .

Table (3) presents the estimated parameters of TE, and the table below the results of the (SFA ) model for cement in Iraq.

The result that capital, raw material value, energy and fuel have a statistically positive effect on the technical efficiency of cement production in Iraq. The resulting increase affects the technical efficiency of cement by 0.103 %, 0.10 9% and 0.165% respectively.

**Table 3: Estimates of the stochastic sfa production function during the year 2022**

Variable	Parameters	coefficients	StdErr	t-statistics
<b>Dependent variable (cement )</b>				
Constant	beta 0	-0.12629188E+05	0.99930379E+00	-0.12637987E+05
Ln Capital	beta 1	0.10370697E+04	0.88903064E+00	0.11665174E+04
lnRaw materials	beta 2	0.10983916-E+02	0.90914440E+00	-0.12081597E+02
lnEnergy and fuel	beta 3	0.16519767E+01	0.65748785E+00	0.25125585E+01
<b>Variance Parameters</b>				
Sigma squared	$\epsilon^2$	0.57387298E+00	0.29471473E+00	0.19472151E+01
Gamma	$\gamma$	0.99999998E+00	0.56839919E-01	0.17593269E+02
log likelihood function		-0.48138888E+01		
LR test of the one - sided error		0.11365202E+02		

Source: Prepared by the researcher based on the program Frontier 4.2

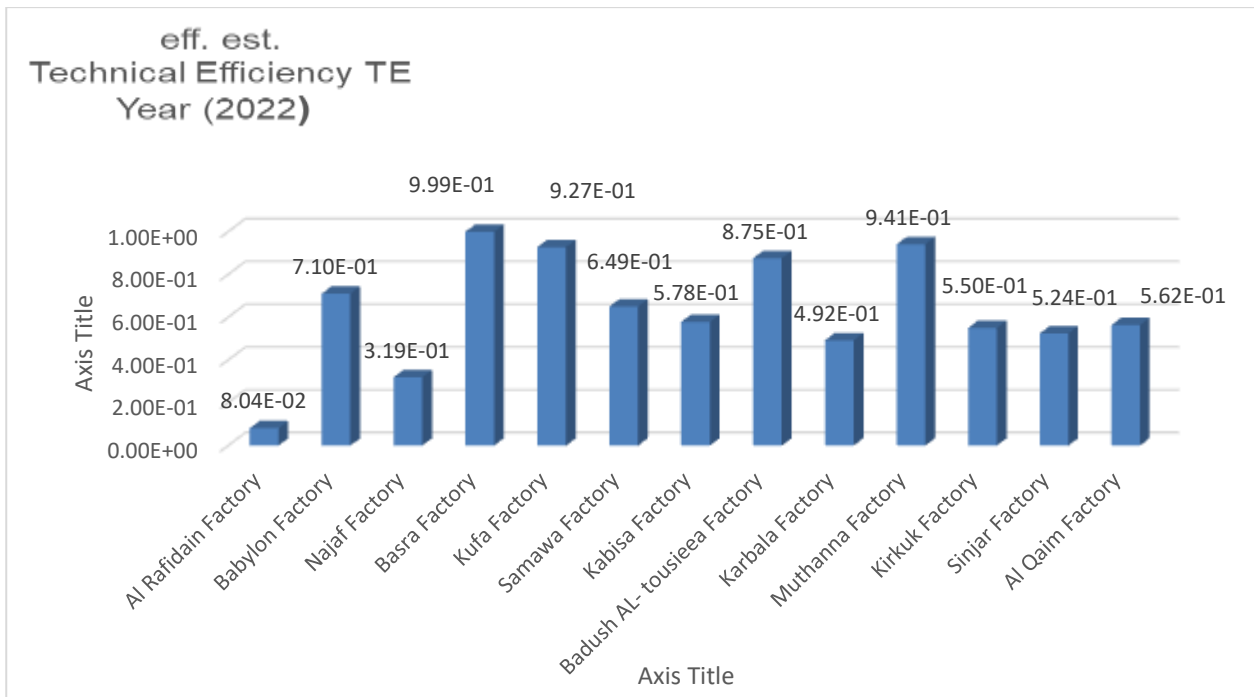
### *Estimation results efficiency scores of Iraqi cement companies for 2022*

The table 4 below shows the efficiency scores of Iraqi cement factories during the year 2022, which were obtained through the transcendental logarithmic production function according to the stochastic frontier analysis model. the highest efficiency rate was achieved by the Basra Factory ( 0.999), Muthanna factory (0.940 )and Kufa factory ( 0.927), As shown in the fig.1. below, number one, and the average technical efficiency( Mean ) was (0.631).

**Table 4: Technical efficiency estimates**

eff.-est. Technical Efficiency TE Year (2022)	Cement Factories (Decision Making Units) DMU's	Sequence
0.80425010E-01	Al Rafidain Factory	1
0.70953024E+00	Babylon Factory	2
0.31887986E+00	Najaf Factory	3
0.99936599E+00	Basra Factory	4
0.92725490E+00	Kufa Factory	5
0.64939562E+00	Samawa Factory	6
0.57767681E+00	Kabisa Factory	7
0.87543953E+00	Badush AL- tousieea Factory	8
0.49176652E+00	Karbala Factory	9
0.94064895E+00	Muthanna Factory	10
0.55041533E+00	Kirkuk Factory	11
0.52385315E+00	Sinjar Factory	12
0.56248122E+00	Al Qaim Factory	13
0.63131793E+00	Mean	

Source: Prepared by the researcher using Frontier4.2



**Fig .1. Technical efficiency estimates**

**Source: Prepared by the researcher using Excel**

This figure shows that the Basra factory values =0.999 obtained the highest efficiency index, followed by the Muthanna factory values =0.940 and then the Kufa factory values =0.927 highest efficiency index (0.999>0.940>0.927 )

Mean values of thirteen factory = 0.631

#### 4. Results and Conclusions

The results that the average efficiency score of the SFA model is 0.63131793 (63%), indicating that the overall efficiency of the factories is average, with significant room for improvement. Factory No. 4 in Basra was the most efficient, with an ideal technical efficiency of 0.99936599  $\approx$  1, while Factory No. 10 in Muthanna was highly efficient, with an efficiency of 0.94064895. Similarly, Factory No. 5, Kufa, recorded an efficiency of 0.92725490, as did Factory No. 8, Badush AL- tousieea, recorded an efficiency of 0.87543953. Factory No. 1, Rafidain, recorded an efficiency of 0.080425010, as did Factory No. 3, Najaf, recorded an efficiency of 0.31887986, as did Factory No. 9, Karbala, recorded an efficiency of 0.49176652. the Factories 1 and 3 we have need to reduce their inputs in order to the improve resource utilization . Averagely efficient factories, such as Factory No. 7, Karbala, or Factory No. 11, Kirkuk, there is to increase cement production levels through improved Efficiency . The company’s factories have achieved in the production of cement

This studying required the possibility of raising cement productivities through Efficiency improvement. That sustainable development necessarily requires the introduction of new technologies or the increase of the base resource. Experimental. The result of such method the efficiency score of SFA model, which means that the bounds of the more appropriate SFA .

The study concluded that the more arbitrary frontier analysis applicable to the industry sector since the random error not to be controlled in that sector .

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## تقييم كفاءة أداء شركة الإسمنت العراقية من خلال تحليل الحدود العشوائية (SFA): تقييم كمي

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### معلومات البحث

#### تواريخ البحث:

تاريخ تقديم البحث: 2025/7/7  
تاريخ قبول البحث: 2025/7/28  
تاريخ رفع البحث على الموقع: 2025/12/31

#### الكلمات المفتاحية:

الكفاءة الفنية (TE)، تحليل الحدود العشوائية (SFA)، دالة كوب  
دوغلاس، الانحدار، المربعات الصغرى العادية

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### المستخلص

تسعى الشركة العامة لصناعة الإسمنت في العراق إلى تشجيع استهلاك الإسمنت. ومن الضروري استغلال موارد الصناعات التحويلية الحالية وتقنياتها بكفاءة أكبر لتلبية الطلب. لذلك، سعى الباحثون إلى تقييم كفاءة صناعة الإسمنت على مستوى الشركات في العراق. تم استخدام طريقة تحليل الحدود العشوائية كوب-دوغلاس (SFA) وتم الحصول على البيانات من خلال ثلاثة عشر مصنعاً تابعاً للشركة العامة للإسمنت العراقية. تم تحقيق معدل كفاءة بلغ 63%، مما يعني أن المعدل متوسط، ويجب بذل جهود لتحسين أداء المصانع منخفضة الكفاءة. كان المصنع رقم 4 في البصرة الأكثر كفاءة، بكفاءة فنية مثالية بلغت  $0.99936599 \approx 1$ ، بينما كان المصنع رقم 10 في المثنى عالي الكفاءة، بكفاءة بلغت 0.94064895. وبالمثل، سجل المصنع رقم 5 في الكوفة كفاءة بلغت 0.92725490، كما سجل المصنع رقم 8 في بادوش التوسيع كفاءة بلغت 0.87543953. ويفضل استخدام SFA لتحديد الكفاءات التي ينبغي أن تركز عليها الصناعة ولتحقيق الكفاءة في إنتاج الإسمنت، مع التركيز على تحسين الكفاءة الفنية مع التركيز على اختيار التقنيات المناسبة والاستغلال الأمثل للموارد بما يتناسب مع حجم العمل.