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# Unpacking Efficiency Determinants of Data Envelopment Analysis (DEA) Model: A Survey Approach

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**ABSTRACT:** This paper advances the notion that for domestic firms to compete and be at par with world class firms in this highly competitive globalised business environment, they need to be efficient in their operations and systems. The (DEA) model unlike other performance models, offers more as it can handle complex an multiple decision making units (DMU). Moreover, the (DEA) model is flexible and can be adapted to many situations and therein help managers gain a better and comprehensive understanding of the overall company's performance and efficiency. To prove its worth as an effective performance tool, (DEA) model has in some instances gone on to prove inefficiencies in some of the best and internationally renowned companies.

**KEYWORDS:** Efficiency, Data Envelopment Analysis. Performance, efficient frontier, Decision Making Units, Scatter diagram, MaxDEA8 Basic 1, linear programming, input-output, relative efficiency, and efficiency index.

## I. INTRODUCTION

The desire for efficiency in all forms of organization units has led to the intensification and widening of tools for assessing performance (Athanasopoulos, 2012). Data Envelopment Analysis (DEA) model is one of the most widely used techniques in efficiency assessment (Ateai and Nesarian, 2015). Data Envelopment Analysis (DEA) can estimate the overall, pure technical and scale efficiencies (Tahira, Bakar, and Haron, 2009). Data Envelopment Analysis (DEA) is a non-parametric optimisation linear programming method for the assessment of productivity of Decision Making Units (DMU) expressed as an input-output ratio, where (DMUs) are discrete units of observation located on or near the frontier (Manzoni and Islam (2012). Data Envelopment Analysis (DEA) unlike other liner programming models that offer management alternatives on decisions; instead evaluates relative efficiency of the decisions management had planned, adopted, and implemented (Banker, Charnes and Cooper, 1984). The (DEA) model is shown below as figure 1. Though appearing formula dense, the model in figure 1 represents a sequence of linear programmes that must be solved (Athanasopoulos, 2012). These days the task is even made simpler with (DEA) Microsoft programs some freely downloadable from the internet.

## II. RELATED WORK

### Concept

The application of the (DEA) model as a tool for efficiency evaluation in areas of business like banking industry has become popular in today's global and competitive business environment (Kuan, Wong, and Behrouz, 2010) This has been a direct result of growing international competition that has not only put pressure on the management but also on performance measurement as local businesses try to measure up to quality and efficiency of their rivalries (Grnavova and Ivanova, 2018).

In recent years, (DEA) has been widely used for efficiency evaluation in different areas, especially in the banking industry (Kuan, Wong, and Behrouz, 2010). This has been a direct result of growing international competition that has



not only put pressure on the management but also on performance measurement (Grnavova and Ivanova, 2018). Hence, (DEA) models with their unique capabilities of flexibility and ability of handling multiple and complex decision situations, popular in the banking industry, have been adopted to measure performance levels of identified (DMUs) (Grnavova and Ivanova, 2018).

The main applications of the (DEA) model has been the evaluation of management decisions and program efficiencies of (DMUs) (Banker, Charnes and Cooper, 1984).

The popularity of (DEA) model is that it enables managers to determine efficiency and even benchmark performance after determining areas of inefficiency in some of the company units like departments or functions (Othman, Mohd-Zamil, Rasid, Valibashi, and Mokhba (2016).

The (DEA) model idea of efficiency is that used in engineering and the natural sciences where there is a comparison of the amount of work performed by a machine vis a vis the amount of energy expended in the process (Tahir, et. al., 2009). Consequently, (DEA) models with their unique capabilities of flexibility and ability of handling multiple and complex decision situations, popular in the banking industry, have been adopted to measure performance (Grnavova and Ivanova, 2018).

With (DEA) the notion is that efficiency is the ratio of output to input; such that the more output per unit of input the greater will be the efficiency (Othman, et. al., 2016). There are basically, three forms of efficiency, technical efficiency, scale efficiency and allocative efficiency (Othman, et. al., 2016). The technical efficiency is a condition of employing fewer resources but with greater output, while scale efficiency referring to optimal activity volume level and finally allocative efficiency referring to optimal level of mix inputs to produce product or services (Ibid).

The (DEA) model evaluates past accomplishments of the relative efficiencies of management accomplishments (Banker, Charnes and Cooper, 1984). The efficiency in (DEA) model is determined by the scores that lie on the efficient frontier curve shown in figure 2. However, one should take note that the efficient frontier is not analogous to the production frontier as we know it in classical economics (Banker, Charnes and Cooper, 1984).

Data Envelopment Analysis scores high as a performance and efficiency measurement tool. Literature shows that (DEA) model can lead to improved management practice and performance of organisations as it is capable of identifying inefficient (DMUs). In some instances (DEA) model has even picked areas of inefficiency in some of the best performing companies. A situation that helps management to further fine-tune the operations and business systems.

**Figure 1** contains a set of (DMUs) that use two outputs per unit of input with (DMUs) A, B and C defining an empirical efficient frontier like figure 2. The use of (DEA) model does not provide any information, other than an efficiency **index** of one (i.e.1 for efficient units and zero for an inefficient units, for the three efficient (DMUs) A, B and C (Athanasopoulos, 2012). Simply, (DEA) model helps to identify efficient companies and to construct efficient production frontier (Curtis and Hantas, 2020). These days with digital technology it is even easier as one simply creates a table in Microsoft excel and merely imports the same table information to, say, MaxD8Basic 1 program and extract all the necessary information like, the (DEA) model scores, the efficient frontier, scatter diagram and the summary, all of which are very informative to the decision makers or company management.



Figure 1 Data Envelopment Analysis models

Offensive model	Defensive model
<p><i>Phase A</i></p> <p>Max <math>z'_k = z_k</math></p> <p>st <math>\sum_{j=1}^n \lambda_j^{ik} x_{ij} \leq x_{ik} \quad \forall i</math></p> <p><math>\sum_{j=1}^n \lambda_j^{ik} y_{rj} \geq z'_k y_{rk} \quad \forall r</math></p> <p><math>z'_k</math> free <math>\lambda_j^{ik} \geq 0</math></p>	<p><i>Phase A</i></p> <p>Min <math>h_k = \sum_{i=1}^m v_i^{ik} x_{ik}</math></p> <p><math>\sum_{r=1}^s u_r^{ik} y_{rk} = 1</math></p> <p><math>\sum_{i=1}^m v_i^{ik} x_{ij} - \sum_{r=1}^s u_r^{ik} y_{rj} \geq 0</math></p> <p><math>v_j^{ik}, u_r^{ik} \geq 0</math></p>
<p><i>Phase B</i></p> <p>Max <math>\sum_i s_i^- / x_{ik} + \sum_r s_r^+ / y_{rk}</math></p> <p>st <math>\sum_{j=1}^n \lambda_j^k x_{ij} + s_i^- = x_{ik} \quad \forall i</math></p> <p><math>\sum_{j=1}^n \lambda_j^k y_{rj} - s_r^+ = z_k y_{rk} \quad \forall r</math></p> <p><math>z_k = \text{Max} z'_k</math></p> <p><math>s_i^-, s_r^+, \lambda_j^k \geq 0</math></p>	<p><i>Phase B</i></p> <p>Min <math>\sum_{i=1}^m v_i^k x_{ik} - \sum_{r=1}^s u_r^k \frac{y_{rk}}{h_k}</math></p> <p><math>\sum_{i=1}^m v_i^k x_{ik} - \sum_{r=1}^s u_r^k \frac{y_{rk}}{h_k} \geq 0</math></p> <p><math>\sum_{i=1}^m v_i^k x_{ij} - \sum_{r=1}^s u_r^k y_{rj} \geq 0 \quad \forall j \neq k</math></p> <p><math>v_j^k \geq 1/x_{ik}, u_r^k \geq 1/y_{rk}</math></p>

### III. METHODOLOGY

The study endeavours to survey theoretical and empirical literature on the general Data Envelopment Analysis (DEA) model of performance and efficiency measurement. The survey intention is to define and interrogate the (DEA) model; its implications, interpretation for performance measurement and managerial decision making. The researcher hopes to bring out the notion that in a globalised economy no business can neglect performance and efficiency issues and expect to survive. Global competition and quality requirement impresses upon domestic as it does on international enterprises to efficiently deliver high quality products and services. For relevant literature and other information sources the researcher capitalised on the rich digital resources such as online Researchgate journals, Google scholar articles, online dictionaries, and online open dissertation sources. The research also exploited the power of internet search engines to search for key terms such as efficiency, performance, and Data Envelopment Analysis and text books addressing (DEA) topics. An attempt was also made to gather recent theoretical and empirical literature directly addressing the study like: Banker, Charnes and Cooper (1984), Othman, et. al., (2016), Tahir, et. al., (2009), Ataei, and Naserian, (2015), Curtis, and Hantas, (2020) and Manzoniand Islam (2012).

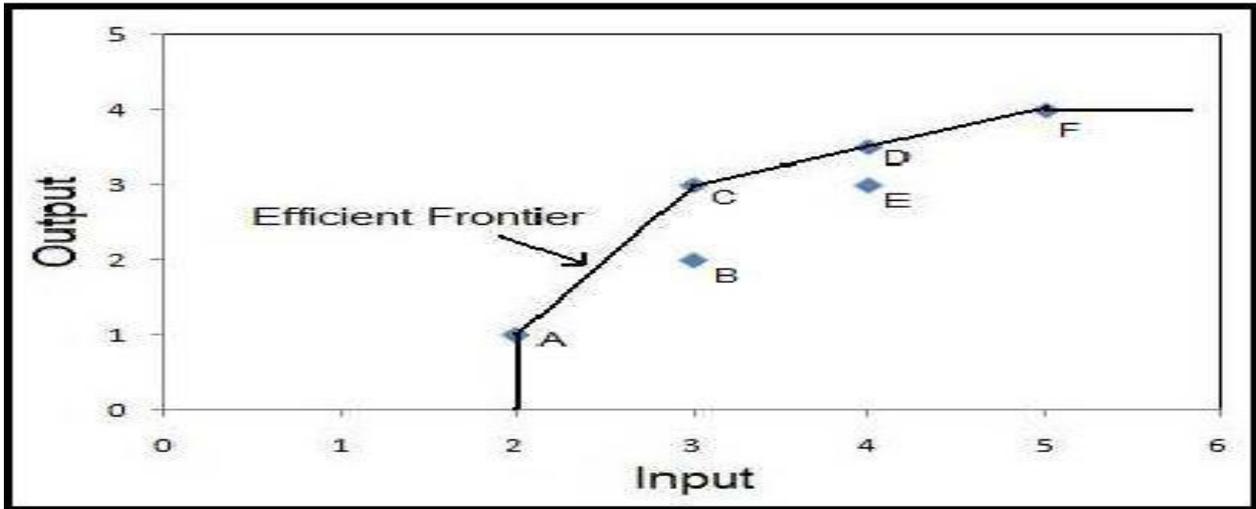
### IV. DISCUSSION

Data Envelopment Analysis, (DEA) has established itself as one of the most popular methods employed in studies intended to measure efficiency of companies or any organisation (Charnes et al.1984). In these and related studies the main concerns are usually around productivity and efficiency of the (DMUs). When using the (DEA) the researcher must carefully select his or her inputs and outputs from the data under consideration. In a study like bank productivity level indicators, the starting point may be first defining a bank's objectives and then specifying its respective inputs and outputs (Gregorian and Manole, 2002). This procedure of stating inputs-outputs will always be the case in instances where a Decision Making Unit (DMU) is any entity that employs inputs to produce any form of output. Relative



Technical Efficiency is the “ability of the (DMUs) to obtain output, from a given set of inputs. Consequently, (DEA) is widely used in almost any sector of economic activity like hospitals, banks, Hotels, ports, education, agriculture, fisheries, etc. (Curtis and Hantas, 2020). Efficiency is determined by the efficient frontier shown in figure 2 below. Here efficient units will be A, C, D, and F since they lie directly on the frontier.

Figure 2 Efficient frontier



Source: Kuah and Behrouzi (2010).

While on the other hand, units B and E will be inefficient. With (DEA) the researchers or management are afforded the opportunity to further interrogate even the efficient units. Hence, (DEA) is appreciated in many performance studies as a powerful tool that enables comparisons of (DMUs) even if there are multiple inputs and outputs. The (DEA) model is basically linear programming based technique for measuring the relative performance of organizational units (Curtis and Hantas, 2020; Banker, Charnes and Cooper, 1984).

Deciding on inputs output for (DEA) model is important. Curtis and Hantas (2020) in their study of energy took the size of total assets as the most crucial input in the sector, since electricity generation is a capital intensive DMUs. Then revenues were used as the No. 1 output. The whole idea in this study was to determine how effectively assets were transformed to energy production. The same study used earnings before income tax (EBIT) to measures the efficiency of operations compared to revenues achieved and it represented the output No. 2. What is important whenever applying the (DEA) is to define the relevant inputs and outputs to be measured? Hence with (DEA) performance model, it is imperative to understand this important relationship in one’s data.

Efficiency with (DEA) model is an index of total outputs produced, divided by the total inputs used for that purpose (Curtis and Hantas, 2020). Generally, (DEA) model formula will be as shown below.

$$\text{Efficiency} = (\text{output} / \text{input})$$

The above formula depicts the processes that entail to arrive at efficiency measures by the formulae in Figure 1. “The efficiency score of each unit is expressed compared to the optimal performance of (DMUs) that excel in the group of reference that is under scrutiny (Curtis and Hantas, 2020, p. 333.)”

With (DEA) the resulting efficiency scores lie between zero and one, mathematically expressed, it would be (0; 1]. In reality, (DEA) scores divide (DMUs) into two categories, the efficient and inefficient ones. Score one (1) gets the decision case (s) located on the frontier and that is considered efficient and constitutes the base for comparison (Curtis and Hantas, 2020).The inefficient (DMUs) are rated greater than zero, but lower than one (1). Practical application of



(DEA) model is that it shows that (DMUs) can improve efficiency through (DEA) model benchmarking, the adoption of best practices and the adoption of an appropriate strategy to obtain a more suitable production scale (Curtis and Hantas, 2020).

When using (DEA) model, we consider the size of total assets as the most crucial input in the sector, which is characterized by fixed capital intensive (DMUs). Revenues are used as the No. 1 output. It reflects how effectively assets are transformed to energy production, prices are predetermined by long term contracts (Curtis and Hantas, 2020). While the EBIT measures the efficiency of operation compared to revenues achieved and represents the output No. 2. An illustration will help clarify how the (DEA) model works, and how one interprets the results to determine whether the (DMUs) are efficient or inefficient. We shall refer to table 1 below which shows hypothetical results of revenues, costs and profits of a company called Clicks Ltd over a 10-year period.

**Table 1** Clicks revenues, cost and profit over 10-year period

YEAR(S)	REVENUE	COST	PROFIT
1	2000	1300	700
2	2300	1600	700
3	2200	1400	800
4	2400	1550	850
5	1999	1300	699
6	2100	1800	300
7	2500	1600	900
8	2600	1700	900
9	2700	1400	300
10	3000	1800	1200

**Source:** Assumed hypothetical case.

In this case revenues are an important output for one to make profits. The costs are an input while the profits are an output. Applying MaxDEA8 Basic 1 to table 1 above one gets the posted results:

**Table 2** Clicks 10-Year Data Envelopment Analysis model scores.

NO	DMU	Score	Benchmark(Lambda)	S/M(REVENUE)	S/M(COST)	Projection(COST)	Projection(PROFIT)
1	01	0.841346154	10(0.666667)	0	-100	1200	800
2	02	0.708559783	10(0.766667)	0	-220	1380	920
3	03	0.883116883	10(0.733333)	0	-80	1320	880
4	04	0.853998656	10(0.800000)	0	-110	1440	960
5	05	0.840362778	10(0.666333)	0	-100.6	1199.4	799.6
6	06	0.303571429	10(0.700000)	0	-540	1260	840
7	07	0.871875	10(0.833333)	0	-100	1500	1000

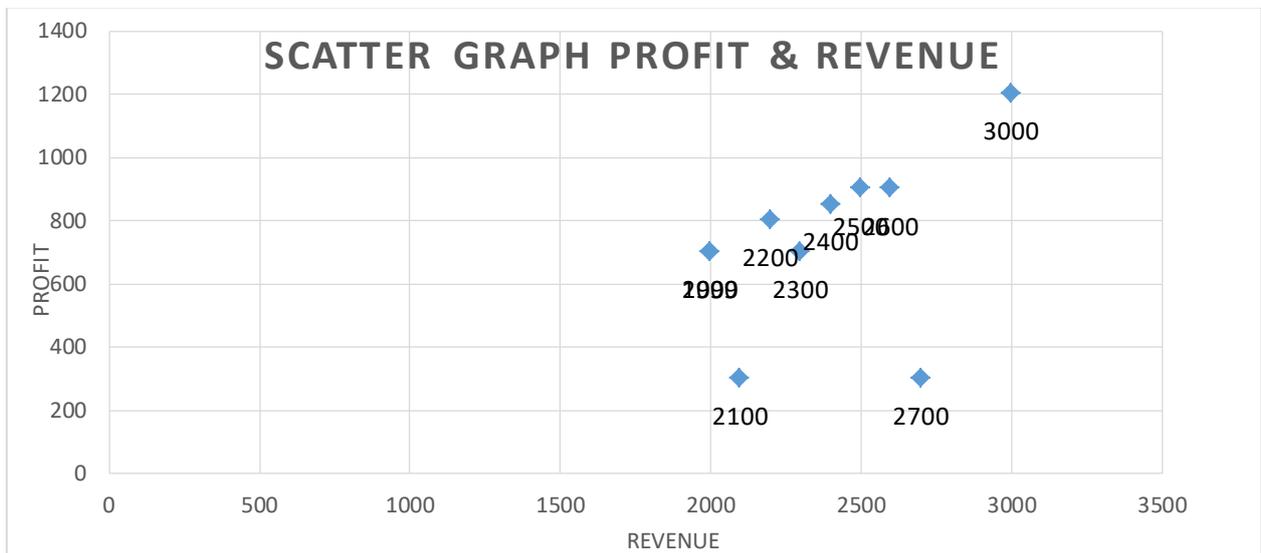


8	08	0.829751 131	10(0.866667)	0	-140	1560	1040
9	09	0.299603 175	10(0.777778)	-366.666667	0	1400	933.333333
10	10	1	10(1.000000)	0	0	1800	1200

Source: Self-generated from MaxDEA8 Basic 1

Looking at table 2 above the shaded column indicates the performance scores of revenues output vs. input the costs. Significantly, all the years 1 to 9 are less than 1, indicating inefficiency. While year 10, has a score of 1 indicating efficiency.

Figure 3 The scatter graph of Clicks profits and revenues.



Source: Self-constructed from MaxD38 Basic 1

The results posted in table 2 below have scores less than one for the years 1 to 9 serve for year 10. This is understandable since even in table 1 above year 10 has a significant profit of R1800. Again by inspection year 6 and 9 are the worst and similarly, (DEA) model posted a very low efficiency score here of 0.303 and 0.299 respectively. With this understanding and the ability to correctly identify the (DMUs) inputs and outputs one can easily process complex data to determine efficiency and inefficiency. This makes (DEA) model a tool for benchmarking and best practices in the management process (Curtis and Hantas, 2020). Hence, (DEA) enhances efficiency and improves wealth for all parties involved. Efficiency in operations is essential as it contributes to the improvement of allocation of the factors of production, and thus to the overall wealth and prosperity in the economy (Curtis and Hantas, 2020). Again (DEA) analysis is very flexible it can be extended to incorporate other output variables such as job creation numbers, and environmental pollution data. Furthermore, the (DEA) model can even accommodate stakeholders’ wellbeing concerns for the (DMU)’s entire ecosystem (Curtis and Hantas, 2020).

Moreover, (DEA) model offers the flexibility of extracting other relevant information tools like the scatter graph in figure 3 indicative of Clicks Ltd profits and revenues. When the line of best fit is drawn on figure 3 scatter graph, a growth trend can be established. Moreover, one can even use the line of best fit to extrapolate intermediate efficiency values. This kind of information is invaluable as it allows a decision maker to tell if there is an emerging adverse trend that warrants an emergent corrective action.



## V. CONCLUSION

In conclusion; from the discussion above it is evident that there is a relentless quest for efficiency in all forms of business enterprises, whether the for-profit or the for-no-profit enterprises. In the public sector, all forms of state-owned enterprises must prove to the stakeholders why they should continue securing funding they get. On the other hand, local businesses are hard pressed to withstand the pressures from the world class international firms with the best performance and efficient systems that have entered local markets and continue to do so. It is a do or die situation out there.

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