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Efficiency Evaluation of Cyber Security Based on EBM-DEA Model

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Abstract: Cyber security aims to protect against the unlawful use of systems, networks, and technologies by lowering the likelihood of cyberattacks and thwarting their execution. The comparatively low degree of security, which plays an essential part in the activities of any nation, has been a primary contributor to the low overall operational efficiency. In addition, implementing machine learning and artificial intelligence would make the network vulnerable to several severe vulnerabilities in terms of cybersecurity, which could lead to disastrous results. Therefore, research into the efficacy of cyber security is essential to ensure the future safety of the whole world. An EBM evaluation approach was utilized in this research project so that the production efficiency of firms on a micro level could be assessed. After that, it analyzed the effectiveness of cybersecurity organizations' input and output variables by using financial data for 2020 from sources in the US market. It was found that DMU 1, DMU 7, DMU 9, and DMU 10 had the highest performance levels. After doing an efficiency analysis of the ten most prominent organizations now functioning in the cybersecurity sector, we realized that three of those companies required significant modifications. However, four of the other businesses were typically more efficient.

Keywords: EBM (Epsilon-based measure) Model, Cybersecurity, 5G security, AI security, Cyber security industry.

Introduction

All aspects of society are changing because of technology. We discover that technology is being used and relied upon more and more in our personal lives and incorporated into more and more activities at work."Industry 4.0 " or "the fourth industrial revolution" are both for this transition. Fourth Industrial Revolution, also known as Industry 4.0, is a theory that predicts rapid change to occur in the 21st century in the areas of technology, industries, and societal patterns and processes(Gan et al., 2021). This change is theorized to result from growing interconnectedness and intelligent automation.

Because of this, more cyber-attacks exist on computer systems, networks, programs, devices, and data as automation and 5G technologies become more widespread (Shrestha et al., 2021). Because of this, the efficiency of a nation's cyber security measures is crucial to developing all aspects of a country's infrastructure, including its financial, economic, agricultural, medical, and even national security systems. To enhance competitiveness, assure a sustainable future, and increase overall corporate efficiencies, it is essential to examine the efficiencies in cyber security, from which the opportunities for improvement can be discovered at each company. These efficiencies can be found by looking at each company's improvement spaces in their cyber security practices.

Within the existing body of research on efficiency, which has been chiefly conducted from a more generalist vantage point, only a select few articles have taken a specific look at the efficiency of cybersecurity organizations. In addition, rather than focusing on how input and output indicators affect efficiency, most studies have broken down efficiency before analyzing the causes. To help fill in some of these research gaps, the authors of this work use the DEA methodology and an EBM (epsilon-based measure) model to conduct a statistical analysis of the operational efficiency of 10 different cyber security businesses.

Literature Review

Traditional, static DEA analyses separate the efficacy of an enterprise into three subcategories: scale performance, entire technical performance, and natural technical performance (Bian & Yang, 2010). The EBM technique analyzes manufacturing performance from an organization's dynamic factor of view (Bin Arfaj et al., 2022). In conclusion, the slack variables have no longer been considered in maximum cybersecurity performance analyses, which is inconsistent with accurate manufacturing. This is because natural technical performance is the first aspect affecting ordinary cybersecurity performance and whether a typical DEA method or the Malmquist index methodology is correct (Chen et al., 2022). To treat this deficiency, EBM models have been applied to discover the performance of the cybersecurity enterprise (Chen & He, 2017). Despite each favored and undesirable output, the performance remains vulnerable to being overvalued within the radial path distance characteristic version. This is because the goal characteristic is to maximize entry and output inefficiencies.

Although the EBM version has been applied to engage in studies on effectiveness, the version has been used to discover and expand usage handiest a small percent of the time (Chen et al., 2018). In conclusion, researchers have investigated the performance of the usage of monetary sources by using plenty of DEA models. Because there haven't been any studies on cybersecurity performance research the use of EBM models, this paper uses an EBM version to look at the performance of the cybersecurity business (Chen et al., 2019). This is due to the fact there haven't been any studies on cybersecurity performance research that have used each "radial and non-radial EBM model" (Tone & Tsutsui, 2010) (Tavana et al., 2013).

The Methodologies and Frameworks of Research

To assess the effectiveness of a range of inputs and outputs, Data Envelopment Analysis (DEA) models that are based on "radial measurements," such as the CCR and BCC (Bian & Yang, 2010) models, likewise models based on non-radial metrics, such as the SBM model, may be utilized to evaluate the efficiency of a variety of inputs and outputs (Chen & He, 2017). [CCR] and [BCC] are abbreviations for the CCR and BCC models, respectively (Chen et al.,2022). Radial measurements assume that all components vary proportionately, which is rarely the case. These measurements also ignore slack factors, such as excessive or inadequate output (Chen et al., 2018). The SBM models (non-radial slack variable efficiency), which are based on slack variable efficiency and do not employ radial estimate assumptions, aim to optimize input and output inefficiencies by selecting the points that are the farthest away from the frontier (Tone & Tsutsui, 2010). However, as a result, they lose the information regarding the original ratio used to calculate the efficiency front projection value. The results almost always differ from the estimates since the amount of room for improvement is so significant. As a potential answer to this issue, in 2010, Tone suggested three EBM (epsilon-based measure) models that contained both "radial and non-radial components" (Chen & He, 2017). These models were "input-oriented, output-oriented, and non-oriented," respectively. Both radial and non-radial properties were taken into consideration by the models (Chen et al., 2019).

The conventional "unguided EBM calculation model" can be summarized as follows when the input-oriented EBM (EBM I-C) for DMUo = (xo, yo) is provided:

$$\delta^* = \min_{\theta,\lambda,s^-} \theta - \varepsilon_x \sum_{i=1}^{m} \frac{\omega_i^- s_i^-}{x_{io}} \tag{1}$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j = \theta x_{io} - s_{i,}^{-} i \; = 1, \dots, m$$

$$\sum_{j=1}^{n} y_{ij}\lambda_j \geq y_{ro,r} = 1, \dots, s$$
$$\lambda_j \geq 0, j = 1,2, \dots, n$$
$$s_{i,}^{-} \geq \; 0, i = 1,2, \dots, n$$

Where λ_j shows the dominant direction of DMU's intensity, "o" indicates that DMU is being evaluated, $s_{i,}^{-}$ and ω_i^{-} reflect the amount of weight and slack that is present in the *i*th input, ε_x It is a parameter that relies on the degree of dispersion of inputs and represents the radial qualities. Whereas $s_{i,}^{-}$ and ω_i^{-} describe how much slack and weight are present in the input, respectively, ε_x is a variable demonstrating the radial characteristics and affects the amount of scattering present in the inputs. "o" indicates that DMU is being evaluated. (Wang et al., 2021)

Research and Analysis Based on Empirical Evidence

Data Sources

This report aims to assist decision-makers (Li et al., 2021; Moreira et al., 2021; Wang et al., 2021)in evaluating what kinds of security process changes are essential by analyzing the operational efficiencies of ten cybersecurity organizations in the year 2020. There is a wide range of sizes and technologies among cyber security companies. From a structural aspect, these ten organizations have enhanced their data and market-oriented operations. Therefore, the writers compiled a list of ten cyber security businesses on the US Stock Exchange in 2020. Table 1 contains the names of all DMUs.

Table 1. List of DMUs

Units	Companies Name	Stock ID
DMU 1	Synopsys	SNPS
DMU 2	Palo Alto Networks	PANW
DMU 3	Oracle	ORCL
DMU 4	Microsoft	MSFT
DMU 5	IBM	IBM
DMU 6	BlackBerry Ltd	BB
DMU 7	Cisco Systems, Inc.	CSCO
DMU 8	CyberArk	CYBR
DMU 9	Fortinet	FTNT
DMU 10	Juniper Networks	JNPR

Evaluation of DMUs' Performance

We use the EBM-I-C, input-oriented under the assumption of constant returns-to-scale in DEA (Alghassab, 2022; Alharbi et al., 2021; Bian & Yang, 2010; Bin Arfaj et al., 2022; Chen et al., 2022; Chen & He, 2017; Chen et al., 2018; Chen et al., 2019), to evaluate the effectiveness of each cybersecurity company. This part's financial data from 2020 is shown in Table 2. The 2020 efficiency will be shown in Tables 3 and 4 below. Before evaluating the DMUs' efficiency using EBM, one of the most crucial considerations was assessing whether a positive value for the data existed. Aside from that, there's an isotonic relationship between the input and output data. The coefficient of correlation (Wu et al., 2020), which ranges from 0 to +1, defines the link between two variables. The two variables were highly correlated if the index was close to +1. If the correlation coefficient is close to 0, the connection between the input and the output is not very strong.

The Pearson's correlation of the DMUs is shown in Table 4 for each year. The minimal correlation coefficient, as seen in the findings, was 0.4918, higher than 0. This demonstrates that all data variables were correlated in a meaningful sense, making it possible to carry out EBM.

Table 2. Data in 2020 (currency unit: million USD)

DMUs	(I)Assets	(I)Liabilities	(I)Operating Expenses	(O)Revenue	(O)Gross Profit
DMU 1	8,752	3,118	2,234	3,685	2,891
DMU 2	9,065	7,964	2,588	3,408	2,409
DMU 3	115,438	102,721	16,928	39,068	31,130
DMU 4	301,311	105,184	5,294	12,958	11,812
DMU 5	155,971	135,245	28,680	73,621	35,575
DMU 6	3,888	1,359	946	893	643
DMU 7	94,853	56,933	17,582	49,301	31,683
DMU 8	1,562	855	376	464	382
DMU 9	4,045	3,189	1,533	2,594	2,024
DMU 10	9,378	4,835	1,533	4,445	2,574

Table 3. Statistics on input/output data year 2020

	Assets	Liabilities	Operating Expenses	Revenue	Gross Profit
Max	301311	135245	28680	73621	35575
Min	1562.4	855.06	375.85	464.43	381.86
Average	70426	42140	7769.4	19044	12112
SD	93872	50497	9273.9	24435	13915

Table 4. Pearson's correlation coefficient year 2020

	Assets	Liabilities	Operating Expenses	Revenue	Gross Profit
Assets	1	0.8551	0.4924	0.4918	0.5557
Liabilities	0.8551	1	0.842	0.8254	0.8538
Operating Expenses	0.4924	0.842	1	0.9962	0.9657
Revenue	0.4918	0.8254	0.9962	1	0.9646
Gross Profit	0.5557	0.8538	0.9657	0.9646	1

An affinity index was used to establish two parameters incorporating the radial and nonradical models, as indicated in the EBM model. The Pearson's correlation coefficient was replaced with the affinity index between two vectors. The values they appropriated had to meet the criterion. $0 \leq P(a, b) \leq 1$. The deviation of variables was used to calculate the diversity index (Bian & Yang, 2010) of the vectors, and $0 \leq D(a,b) = D(b,a) \leq 1/2$. The only time it was equal to 0 was when the two vectors were proportionate. To guarantee that the input and output variables were in sufficient condition to assess the effectiveness of the DMUs using EBM, the affinity and diversity indicators were utilized (Li et al., 2021; Liang et al., 2020; Moreira et al., 2021; Tian et al., 2019; Tone & Tsutsui, 2010; Wang et al., 2021). Tables 5 and 6 show the diversity index and affinity indicator matrices used to ensure that the input and output variables corresponded to the criteria for measuring the effectiveness of the DMUs in the EBM model. According to the findings, the diversity matrix values vary from 0 to 0.2994, and the affinity matrix values range from 0.4013 to 1, as shown in Tables 5 and 6. Because the data variables matched the EBM model's criteria, the model may be used to rank the efficiency/inefficiency of DMUs.

Table 5. Diversity matrix in EBM model 2020

	Assets	Liabilities	Operating Expenses
Assets	0	0.2994	0.1619
Liabilities	0.2994	0	0.2059
Operating Expenses	0.1619	0.2059	0

Table 6. Affinity matrix in EBM model 2020

	Assets	Liabilities	Operating Expenses
Assets	1	0.4013	0.6762
Liabilities	0.4013	1	0.5883
Operating Expenses	0.6762	0.5883	1

The weight to input/output and epsilon indicator is crucial in eliminating the EBM score (Jin et al., 2021; Li et al., 2019; Liang et al., 2020; Tian et al., 2019; Wang et al., 2018; Wang et al., 2021; Yu et al., 2019) for each DMU. A weighted index (Li et al., 2021)specifies the degree to which input influences output. According to

Table 7, all weight indexes are positive, indicating that information changes will influence production, and if input values increase, output values will also increase.

Table 7. Weight to input/output and epsilon for EBM model year 2020.

Weight to Input/Output		
Assets	Liabilities	Operating Expenses
0.33	0.309	0.361753438

The efficiency of ten cybersecurity companies will be obtained based on EBM's factor weight and epsilon. The result of Epsilon for EBM of 2020 is approximately 0.441, which satisfies the condition: 0 < Epsilon index < 1.

Table 8. Efficiency Score of EBM model 2020

No.	DMU	Score	Rank
1	DMU 1	1	1
7	DMU 7	1	1
9	DMU 9	1	1
10	DMU 10	1	1
4	DMU 4	0.934	5
3	DMU 3	0.925	6
5	DMU 5	0.874	7
8	DMU 8	0.68	8
2	DMU 2	0.627	9
6	DMU 6	0.56	10

The efficiency score of DMUs is compared in Figure 1. It can be observed from the figure that in 2020, the performance scores of organizations vary. When they achieved the first rank in 2020, Synopsys, Cisco Systems, Inc., Fortinet, and Juniper Networks will be regarded as the most effective manufacturers of units and ideals suppliers. In contrast, DMU 2 and DMU 6- Palo Alto Networks and BlackBerry Ltd are the last four efficient units and ideal suppliers.

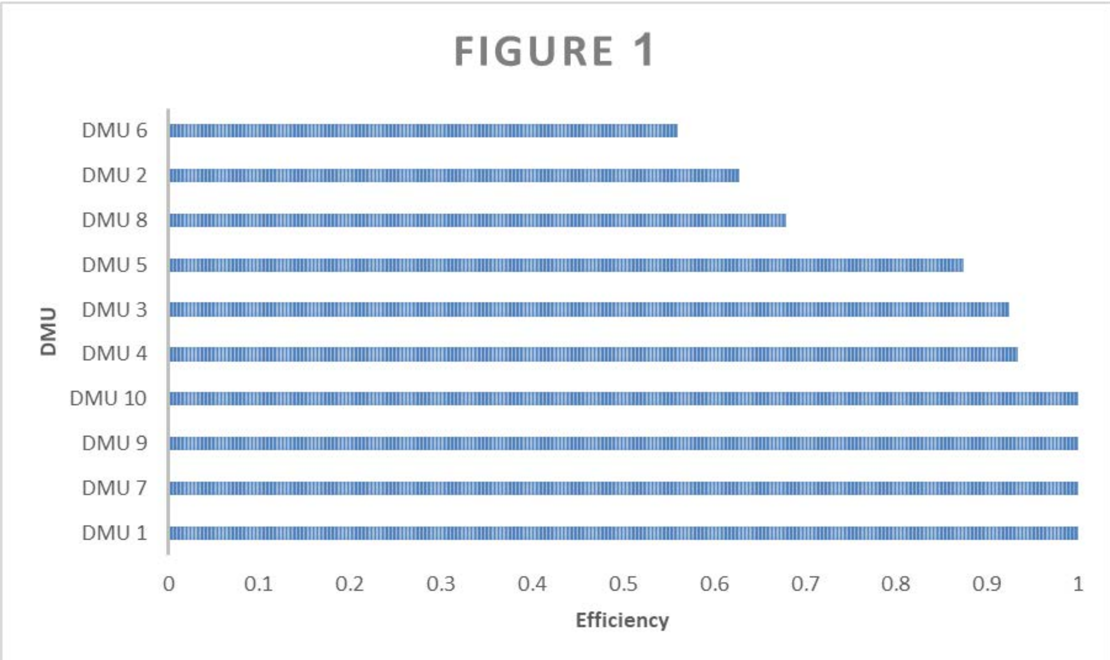

Figure 1. The efficiency score of DMUs

Conclusions and Recommendations

The following courses of action will be suggested following the original study direction if it is recommended that this line of investigation be continued in the future.

(i). Many other topics and locations may be investigated, which brings us to the first strategy, which is to do the research with the only intention of using what was learned. The second strategy involves combining DEA models with other forecasting models, such as fuzzy or grey.

(ii). The author suggests that future research on the same subject alter the input and output components and then compare the findings of these two different approaches. A more objective result can be attained by doing things in this manner. Other elements, such as the total units of production, undesired factors, such as recalled defective units, and non-financial variables, are all feasible to be considered.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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