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### DETERMINATION OF EFFICIENCIES OF INFORMATION TECHNOLOGY SECTOR COMPANIES TRADED ON BORSA İSTANBUL IN TERMS OF FINANCIAL PERFORMANCES UNDER THE EFFECT OF COVID-19 PANDEMIC BY USING DEA WINDOW ANALYSIS (\*)

#### BORSA İSTANBUL'DA İŞLEM GÖREN BİLİŞİM SEKTÖRÜ ŞİRKETLERİNİN COVID-19 PANDEMİSİ ETKİSİ ALTINDA FİNANSAL PERFORMANS AÇISINDAN ETKİNLİKLERİNİN VZA PENCERE ANALİZİ KULLANILARAK BELİRLENMESİ

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**Abstract:** Window analysis is a time-dependent variant of Data Envelopment Analysis (DEA) and it is based on the moving average method. It is used for showing the trend of Decision Making Units' (DMUs') performance over various times. The efficiency changes of 13 companies operating in Borsa Istanbul (BIST) Information Technology (IT) sector for quarterly periods between 2019:03 and 2021:06 are evaluated by DEA Window Analysis. The input-oriented CCR model and the input-oriented BCC Windows analysis models are applied on data set. When the CCR model and BCC model window analysis results are evaluated together, one of the first two periods with the highest average efficiency for both of them is 2021:06, and the period with the lowest average efficiency for both of them is 2019:09. DESPC company has the highest average efficiency for both models.

**Keywords:** BIST, COVID-19, Efficiency, Financial Performance, DEA Window Analysis

**JEL:** C61, C81, D53, D57, L25

**Öz:** Pencere analizi, Veri Zarflama Analizi'nin (VZA) zamana bağlı bir çeşididir ve hareketli ortalama yöntemini temel alır. Karar Verme Birimleri'nin (KVB'ler) performansının çeşitli zamanlardaki eğilimini göstermek için kullanışlıdır. Borsa İstanbul (BIST) Bilgi Teknolojileri (BT) sektöründe faaliyet gösteren 13 şirketin 2019:03 ve 2021:06 arasındaki üçer aylık dönemler itibarıyla etkinlik değişimleri VZA Pencere Analizi ile değerlendirilir. Veri kümesi üzerinde girdi odaklı CCR modeli ve girdi odaklı BCC Pencere analiz modelleri uygulanır. CCR modeli ve BCC modeli pencere analizi sonuçları birlikte değerlendirildiğinde her iki model için ortalama etkinliğin en yüksek olduğu ilk iki dönemden biri 2021:06, her iki model için ortalama etkinliğin en düşük olduğu dönem ise 2019:09'dur. DESPC firması her iki model için de en yüksek ortalama etkinliğe sahiptir.

**Anahtar Kelimeler:** BIST, COVID-19, Etkinlik, Finansal Performans, VZA Pencere Analizi

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## 1. Introduction

The emergence of the novel coronavirus in late December 2019, in Wuhan, the seventh-largest city of China, sparked a global outbreak, with the virus rapidly spreading to various countries worldwide. With a surge in the number of cases and fatalities, on March 11, 2020, the outbreak was formally designated as a pandemic by the World Health Organization (WHO) (Kılıç, 2020: 67). Moreover, on that day, Türkiye reported its first case of COVID-19.

The pandemic has necessitated various regulations and restrictions in people's social and economic lives, including prohibitions on large gatherings. Many countries have implemented distance education systems, while many companies have shifted to a work-from-home model. Domestic and international travel has been severely curtailed, and shopping centers and restaurants have been forced to close. Moreover, mask mandates and curfews have been intermittently imposed during this period (Kılıç, 2020: 67).

The effect of the COVID-19 pandemic on different sectors and businesses operating within those sectors varies due to the differences in their structures and dynamics. Therefore, it is crucial to analyze the effects of the epidemic on a sectoral level, considering the diversity of the businesses operating in each sector. Such an examination would provide insights into the unique challenges faced by each sector and enable the development of tailored solutions to address the impacts of the pandemic.

Stock exchanges serve as a platform where investors can trade various financial instruments in a fair, reliable, and competitive environment. In Türkiye, Borsa Istanbul (BIST) is the sole stock exchange institution that provides this service. Borsa Istanbul, before known as the Istanbul Stock Exchange, was founded in 1986 and underwent a name change on April 5, 2013. Borsa Istanbul plays a crucial role in facilitating the trading activities of investors who engage in buying and selling stocks in Türkiye. It operates under the supervision of the Capital Markets Board (CMB) of Türkiye, in accordance with the Capital Markets Law (Matriks, 2022; Eryiğit, 2022: 1). Therefore, Borsa Istanbul plays a vital role in the country's financial sector, enabling investors to carry out their trading activities in a regulated and transparent environment.

The IT sector is rapidly growing due to technological advancements and changes in the current era. This study aims to investigate how the initial shock generated by the COVID-19 pandemic affected the efficiency of IT firms listed on the Borsa Istanbul. The research is a component of Eryiğit's (2022) master's thesis and employs the DEA Window analysis method to analyze the pandemic's influence on the financial ratios and efficiencies of 13 Borsa Istanbul listed firms. The research intends to provide insights into the effect of the pandemic on the IT sector's performance and efficiency. The research utilizes data from the periods between March 2019 and June 2021. The overall trend of the companies is analyzed by interpreting the averages obtained in each window using Window Analysis. Window Analysis allows the interpretation of not only the window efficiencies of the firms but also the average of the company in all periods, the period averages of all companies, and finally the general average for the whole companies for all periods. This study is noteworthy for its utilization of current data, encompassing the period of the COVID-19 pandemic, to scrutinize, on a

company-by-company basis, the efficacy fluctuations of firms operating in the ever-evolving field of information technology, which are listed on Borsa Istanbul.

## 2. Literature Review

A wide range of studies conducted in Türkiye and globally examine the efficiency assessments of companies within the information technology (IT) sector through the usage of Data Envelopment Analysis (DEA). Some of the articles and thesis in Türkiye in the literature are as follows.

Tektüfekçi (2010: 72-76) evaluated the financial performance of publicly listed technology enterprises on the Istanbul Stock Exchange (ISE), using a dataset from 2007 to 2009. The study utilized input variables such as total debt/equity ratio, receivables turnover, and current ratio, while earnings per share and profit/sales were used as output variables. The findings revealed that only one company was identified as efficient. Atilla and Kabataş (2015: 166-175) analyzed 11 IT sector firms listed in BIST by using data collected between 2010 and 2014. The study aims to assess these companies' financial performance and efficiency. The analysis results provided insights into the financial status and efficiency of the companies under examination. In his study, Özdağoğlu (2015: 334-339) analyzed the financial data of 12 firms listed in the informatics index of Borsa Istanbul for the year 2014. The input variables for the study were liquid assets, stocks, tangible fixed assets, and equity capital, while the output variables were gross sales and profit/loss before tax. The study found that companies with high gross sales were inefficient, whereas those with less gross sales compared to the sector average were found to be efficient. In the study conducted by Yeniay (2017: iv, 70-72), the financial performance and efficiency of 15 technology sector firms listed on BIST were analyzed using data from 2013 to 2015. Window Analysis, DEA analysis, and Malmquist TFP Index methods were employed. Input variables such as average collection period, stock turnover and current ratio, while return on assets and return on equity were used as output variables. The study sought to ascertain the financial ratios and efficiency metrics of the companies throughout the years. In his study, Özcan (2020: 55) evaluated the financial performances of 15 technology firms traded on BIST using DEA with quarterly data from 2017:03 to 2019:03. The input variables were receivables turnover, total debt/equity and current ratio, while return on equity and net profit margin were used as output variables. This study shows that just four firms demonstrated efficiency in the year 2019. Gedik (2020: 67) conducted an efficiency analysis on 7 IT sector companies between 2014-2016, using the DEA continuous Malmquist TFP Index method. The input variables included liquid assets, inventories, equity, and tangible assets, while the output variables were profit/loss before tax and revenue. The study provided improvement in rates for inefficient firms to become efficient. In 2021, Özkan conducted an efficiency analysis of 18 BIST-traded IT sector companies using the DEA method and 2019 data. The study utilized an input-oriented CCR model and conducted a Super Efficiency analysis to determine the efficiency order between the companies. The results provided target values for the inefficient companies (Özkan, 2021: 264-265). Uygurtürk and Yıldız (2021:3) investigated the relationship between the financial performance and efficiency of firms in the information technology field on the BIST. The study used a data set for the years range of 2014-2018, with operating expenses, sales costs, and total assets as input variables, and pre-tax income from continuing operations and sales revenue as output variables. The efficiency of companies was

determined using the DEA method, while the Gray Relational Analysis technique was utilized to rank financial performance. The results of the study indicated a consistency between the two techniques.

### 3. Research Methodology

#### 3.1. Window analysis

Cross-section analysis is applied in DEA, meaning that each DMU is observed merely once. However, in a lot of studies, observations for DMUs are observed at various periods, and panel data analysis is applied to focus on time-varying efficiency changes for the DMUs concerned. Window analysis found by Charnes, Clark, Cooper, and Golany (1984) allows this panel data analysis to be performed. Window Analysis is a time-dependent variant of DEA and is based on the moving average method. It is beneficial for showing the trend of DMUs' performance over various times. The analysis treats and calculates the data of a DMU for different periods as a diverse DMU. In this manner, the performance of a specific unit is in comparison with its performance in previous periods as well as with the performance of other units. The point to be considered in the analysis is the assumption that there is no technological difference in each of the windows since the decision units for a certain period are evaluated according to each other and their data. In this respect, the use of short time intervals in the analysis reduces this problem and reliable results can be obtained in terms of window analysis (Küpeli, 2015: 19).

When  $n$  DMUs ( $m=1, \dots, n$ ) are monitored in  $P$  periods ( $t=1, \dots, P$ ) total  $n \times P$  observations are obtained, where  $r$  represents the number of inputs and  $s$  the number of outputs, one  $m$  observation at  $t$  time  $DMU_t^m$  forms the input vector of  $r$  dimension  $x_t^m = (x_{1t}^m, x_{2t}^m, \dots, x_{rt}^m)^T$  and output vector of  $s$  dimension  $y_t^m = (y_{1t}^m, y_{2t}^m, \dots, y_{st}^m)^T$  (Küpeli, 2015: 19; Asmild et al., 2004). When  $1 \leq k \leq P$  and  $1 \leq w \leq P-k$ , the window starting at  $w$  width at  $k$  time is expressed as  $k_w$  and  $nxw$  observations are formed. The input and output matrices for the window analysis model are expressed as (Asmild et al., 2004):

$$x_{kw} = (x_k^1, x_k^2, \dots, x_k^n, x_{k+1}^1, x_{k+1}^2, \dots, x_{k+1}^n, \dots, x_{k+w}^1, x_{k+w}^2, \dots, x_{k+w}^n)$$

$$y_{kw} = (y_k^1, y_k^2, \dots, y_k^n, y_{k+1}^1, y_{k+1}^2, \dots, y_{k+1}^n, \dots, y_{k+w}^1, y_{k+w}^2, \dots, y_{k+w}^n)$$

In the input-oriented approach for  $DMU_t'$ , the DEA window model is represented by the formula:

$$\begin{aligned} \theta'_{kwt} &= \min_{\theta, \lambda} \theta \\ -X_{kw} \lambda + \theta x'_t &\geq 0 \\ Y_{kw} \lambda - y'_t &\geq 0 \\ \lambda_m &\geq 0, m = 1, \dots, nxw \end{aligned}$$

The concepts of DMU number, duration, and window size are used in the analysis. The period number, in which the DMU is to be analyzed, represents the duration. The choice of window size is left to the researcher. The condition for its selection is that the selected window size is not more than the duration variable (Küpeli, 2015: 20). For example; considering the panel dataset for five DMUs ( $n=5$ ) for a six ( $T=6$ ) year period, if a 3-year ( $w=3$ ) window is used; each DMU is evaluated as a dissimilar DMU for each of the 3 years in the 1st window (Year1, Year2, Year3). In the next step, the window is shifted and the analysis is made for the second set of 3 years (Year 2, Year 3, Year 4) of the five companies. The procedure is carried out by shifting the window forward one period at a time, and a separate analysis is conducted for the last three years (Year 4, Year 5, Year 6) in which DMU is examined ( $T-w-1$ ) in each analysis ( $nxw$ ). This process is repeated until the final window analysis is completed (Kayalı, 2020: 38).

According to Table 1  $\theta_{W,T}^o$  represents the DMU's (o) relative effectiveness in that window (W) and period (T) (Kayalı, 2020: 39).

In the interpretation of the obtained table, the analysis allows to make inferences based on rows and columns. Accordingly, the behavior trend of the decision units can be interpreted on a row basis, and the stability in their performance can be interpreted by inferences on a column basis (Küpeli, 2015: 20).

**Table 1. DEA Window Analysis Format**

DMU	Period Window	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
DMU1	Window 1	$\theta_{1,1}^1$	$\theta_{1,2}^1$	$\theta_{1,3}^1$			
	Window 2		$\theta_{2,2}^1$	$\theta_{2,3}^1$	$\theta_{2,4}^1$		
	Window 3			$\theta_{3,3}^1$	$\theta_{3,4}^1$	$\theta_{3,5}^1$	
	Window 4				$\theta_{4,4}^1$	$\theta_{4,5}^1$	$\theta_{4,6}^1$
DMU2	Window 1	$\theta_{1,1}^2$	$\theta_{1,2}^2$	$\theta_{1,3}^2$			
	Window 2		$\theta_{2,2}^2$	$\theta_{2,3}^2$	$\theta_{2,4}^2$		
	Window 3			$\theta_{3,3}^2$	$\theta_{3,4}^2$	$\theta_{3,5}^2$	
	Window 4				$\theta_{4,4}^2$	$\theta_{4,5}^2$	$\theta_{4,6}^2$
DMU3	Window 1	$\theta_{1,1}^3$	$\theta_{1,2}^3$	$\theta_{1,3}^3$			
	Window 2		$\theta_{2,2}^3$	$\theta_{2,3}^3$	$\theta_{2,4}^3$		
	Window 3			$\theta_{3,3}^3$	$\theta_{3,4}^3$	$\theta_{3,5}^3$	
	Window 4				$\theta_{4,4}^3$	$\theta_{4,5}^3$	$\theta_{4,6}^3$
DMU4	Window 1	$\theta_{1,1}^4$	$\theta_{1,2}^4$	$\theta_{1,3}^4$			
	Window 2		$\theta_{2,2}^4$	$\theta_{2,3}^4$	$\theta_{2,4}^4$		
	Window 3			$\theta_{3,3}^4$	$\theta_{3,4}^4$	$\theta_{3,5}^4$	
	Window 4				$\theta_{4,4}^4$	$\theta_{4,5}^4$	$\theta_{4,6}^4$
DMU5	Window 1	$\theta_{1,1}^5$	$\theta_{1,2}^5$	$\theta_{1,3}^5$			
	Window 2		$\theta_{2,2}^5$	$\theta_{2,3}^5$	$\theta_{2,4}^5$		
	Window 3			$\theta_{3,3}^5$	$\theta_{3,4}^5$	$\theta_{3,5}^5$	
	Window 4				$\theta_{4,4}^5$	$\theta_{4,5}^5$	$\theta_{4,6}^5$

Source: Kayalı, 2020; Eryiğit, 2022

## 4. Results

In this study, 13 IT sector companies, which were listed in the IT sector in BIST and the data for the determined input and output variables could be accessed in the selected time interval between 2019:03 and 2021:06, are studied. The companies' transaction codes in BIST will be used in the results of the analysis. The input and output variables frequently used in the literature to evaluate companies' financial performance were chosen. Current Ratio, Accounts Receivable Turnover Rate, and Cash Ratio were chosen as input variables, while Return on Assets and Return on Equity were selected as output variables. To ensure that the data set for the companies adheres to the DEA's positive assumption, negative values for relevant variables were converted into positive values using a formula  $(X_{rj} - X_{jmin}) / (X_{jmax} - X_{jmin})$  where:  $X_{rj}$   $r$ th output value of  $j$ th decision unit,  $X_{jmin}$ : Minimum  $r$  value and  $X_{jmax}$ : Maximum  $r$  value (Yıldız, 2007: 96-97).

### 4.1. Window Analysis Results

In this section, the efficiency alterations of 13 companies operating in the Borsa Istanbul Information Technology (BIST IT) sector in 3 periods (window width  $w=3$ ) for quarterly periods between 2019:03 and 2021:06 are measured by DEA Window Analysis. From Table 2, it is evident that the addition of a new time dimension to each window results in a reduction in the first added time dimension. The first window (Window 1) covers 2019:03, 2019:06, and 2019:09. In the second window (Window 2), 2019:03 will be omitted and 2019:09 will be added. It continues like that there will be 8 windows.

**Table 2. Windows breakdown**

WINDOWS										
Windows 1	2019:03	2019:06	2019:09							
Windows 2		2019:06	2019:09	2020:03						
Windows 3			2019:09	2020:03	2020:06					
Windows 4				2020:03	2020:06	2020:09				
Windows 5					2020:06	2020:09	2020:12			
Windows 6						2020:09	2020:12	2021:03		
Windows 7							2020:12	2021:03	2021:06	
Windows 8								2021:03	2021:06	2021:09

Source: Eryigit, 2022

According to the Window Analysis results of the CCR Model, the general average efficiency value is 0.450 for all 10 periods and all companies. The column-by-period basis average efficiencies are presented in Table 3.

**Table 3. Column-by-Period Average Efficiency, Standard Deviation and Range Values for Window Analysis results of the CCR Model**

	2019:03	2019:06	2019:09	2019:12	2020:03	2020:06	2020:09	2020:12	2021:03	2021:06
Mean	0.749	0.639	0.117	0.675	0.223	0.369	0.485	0.372	0.661	0.722
Std. Dev.	0.299	0.291	0.111	0.315	0.212	0.284	0.376	0.339	0.332	0.321
Range	1.000	1.000	0.464	1.000	0.739	0.972	0.992	0.966	0.954	1.000

Source: Eryigit, 2022

From Table 3, it is obvious that the highest average efficiencies are 0.749 for 2019:03 and 0.722 for 2021:06. The period with the lowest average efficiency performance is 2019:09.

The rankings of the companies based on their mean efficiency scores obtained during the whole periods from the Window Analysis results of the CCR Model are presented in Table 4.

**Table 4. Efficiencies of companies for CCR Window Analysis results**

Companies	Average	Standard Deviation	Range	Rank
DESPC	0.697	0.341	0.823	1
FONET	0.679	0.351	0.816	2
INDES	0.606	0.372	0.913	3
DGATE	0.561	0.295	0.798	4
KAREL	0.561	0.356	0.964	5
KRONT	0.553	0.378	0.965	6
LOGO	0.526	0.338	0.923	7
LINK	0.468	0.329	0.971	8
ARENA	0.276	0.246	0.975	9
PKART	0.272	0.255	0.977	10
KFEIN	0.252	0.262	1.000	11
ARMDA	0.220	0.236	0.792	12
ALCTL	0.175	0.250	0.860	13

**Source:** Eryigit, 2022

From Table 4 it is obvious that DESPC has the highest average efficiency value of 0.697. FONET and INDES with values of 0.679 and 0.606, follow it respectively. ALCTL company has the lowest average efficiency value of 0.175, low standard deviation and range. Since ARMDA is the company with the smallest standard deviation and range of efficiency values, it can be said that it has a homogeneous performance history. The largest standard deviation value belongs to KRONT.

Table 5 shows the average efficiency values of the firms for each window. The window averages obtained with the help of the 3-period CCR model window analysis, the trends and changes of the companies will be observed. Performance trends of companies follow one of the following 4 situations (Apan et al., 2019: 120): continuously or non-continuously increasing trend, continuously or non-continuously decreasing trend, stationary trend, and a very wavy trend. However, the preferred case among these situations is the stationary trend with an efficiency value of 1. In this way, the company's average efficiency will be 1, and its standard deviation and range will be 0. When the companies' average efficiencies in Table 4 are examined, no company providing this situation is observed.

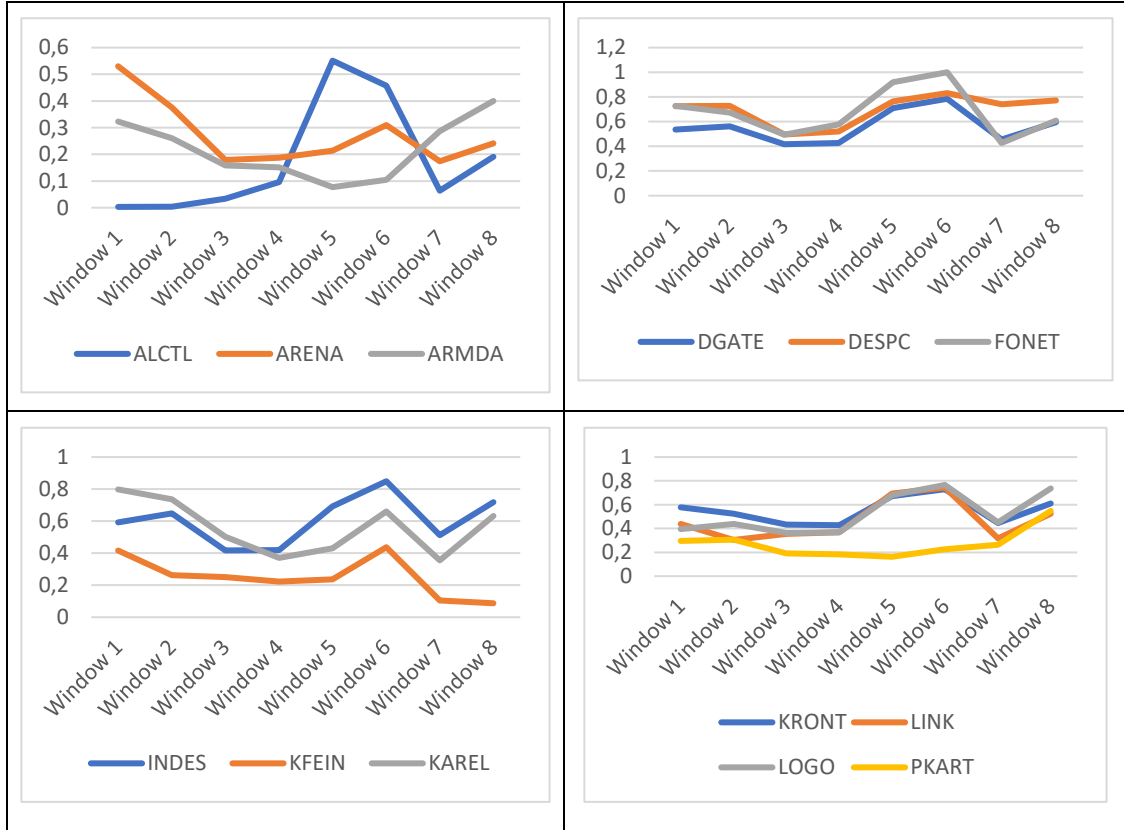
The line graph obtained by using the average efficiency in each window obtained for the companies in Table 5 is given in Figure 1. When Figure 1 is examined, it can be said that all companies show a wavy trend. It has been observed that the efficiency values of companies show fluctuations in the form of increases and decreases. It is seen that companies other than KFEIN have started to increase their average efficiency in the last window period.

**Table 5. Average Efficiency scores for each company in each window according to CCR window analysis results**

	Window 1	Window 2	Window 3	Window 4	Window 5	Window 6	Window 7	Window 8
Companies	2019:03 2019:06 2019:09	2019:06 2019:09 2019:12	2019:09 2019:12 2020:03	2019:12 2020:03 2020:06	2020:03 2020:06 2020:09	2020:06 2020:09 2020:12	2020:09 2020:12 2021:03	2020:12 2021:03 2021:06
ALCTL	0.003	0.004	0.034	0.096	0.551	0.457	0.064	0.191
ARENA	0.530	0.376	0.179	0.187	0.214	0.310	0.174	0.241
ARMDA	0.323	0.261	0.158	0.151	0.077	0.105	0.287	0.400
DGATE	0.536	0.561	0.417	0.428	0.710	0.785	0.456	0.595
DESPC	0.726	0.727	0.496	0.520	0.764	0.831	0.741	0.773
FONET	0.728	0.674	0.495	0.578	0.920	1.000	0.427	0.608
INDES	0.593	0.649	0.417	0.419	0.692	0.849	0.513	0.719
KFEIN	0.416	0.263	0.251	0.223	0.237	0.437	0.105	0.087
KAREL	0.798	0.736	0.503	0.371	0.430	0.661	0.355	0.632
KRONT	0.579	0.524	0.432	0.428	0.673	0.730	0.446	0.610
LINK	0.439	0.304	0.355	0.369	0.693	0.744	0.317	0.524
LOGO	0.396	0.439	0.363	0.369	0.681	0.766	0.453	0.738
PKART	0.296	0.306	0.190	0.182	0.163	0.227	0.264	0.548

Source: Eryigit, 2022





**Figure 1. Line Graph for Average Efficiency Scores for each company in each Window according to CCR Window Analysis results**

Source: Eryigit, 2022

According to the Window Analysis results of the BCC Model, the general average efficiency value is 0.811 for whole periods and for all companies. The column-by-period basis average efficiencies are given in Table 6. Table 6 shows that if it is examined on a column basis, that is, by periods, there has been an increase in the average efficiency after the 2020:09 period, which is accepted as the post-COVID-19 period, and seen that the periods with the highest average efficiency performances are 2021:06 with a value of 0.950 and 2021:03 with a value of 0.915.

**Table 6. Column-by-Period Average Efficiency, Standard Deviation and Range Values for Window Analysis results of the BCC Model**

	2019:03	2019:06	2019:09	2019:12	2020:03	2020:06	2020:09	2020:12	2021:03	2021:06
<b>Mean</b>	0.858	0.787	0.694	0.800	0.849	0.809	0.797	0.806	0.915	0.950
<b>Std. Dev.</b>	0.190	0.197	0.217	0.195	0.206	0.211	0.248	0.240	0.123	0.117
<b>Range</b>	0.597	0.593	0.764	0.713	0.598	0.745	0.824	0.866	0.404	0.404

Source: Eryigit, 2022

Table 7 presents the rankings of companies based on their average efficiency scores obtained from the Window Analysis results of the BCC model throughout the analyzed period.

**Table 7. Efficiencies of companies for BCC Window Analysis results**

Companies	Average	Standard Deviation	Range	Rank
<b>DESPC</b>	0.983	0.036	0.135	1
<b>INDES</b>	0.970	0.058	0.162	2
<b>KAREL</b>	0.936	0.071	0.188	3
<b>KRONT</b>	0.931	0.125	0.406	4
<b>FONET</b>	0.923	0.169	0.546	5
<b>DGATE</b>	0.882	0.107	0.318	6
<b>ARMDA</b>	0.855	0.129	0.368	7
<b>LOGO</b>	0.830	0.166	0.498	8
<b>ARENA</b>	0.782	0.085	0.375	9
<b>ALCTL</b>	0.729	0.125	0.468	10
<b>LINK</b>	0.613	0.306	0.866	11
<b>KFEIN</b>	0.560	0.285	0.731	12
<b>PKART</b>	0.554	0.135	0.597	13

**Source:** Eryiğit, 2022

It is clear from Table 7 that the company with the highest average efficiency value of 0.983 is DESPC. It can also be interpreted that the company has a homogeneous history in terms of efficiency performance since DESPC is also the company with the smallest standard deviation and range. DESPC is followed by INDES with a 0.970 average efficiency value and KAREL with a 0.936 average efficiency value. These 3 companies with the highest average efficiency have also the smallest standard deviation and range values in the same rank. The lowest average efficiency belongs to PKART company with an average efficiency value of 0.554. The fact that the standard deviation and range values in the window analysis CCR model are higher than the window analysis BCC model indicates that the efficiency changes of the companies are higher.

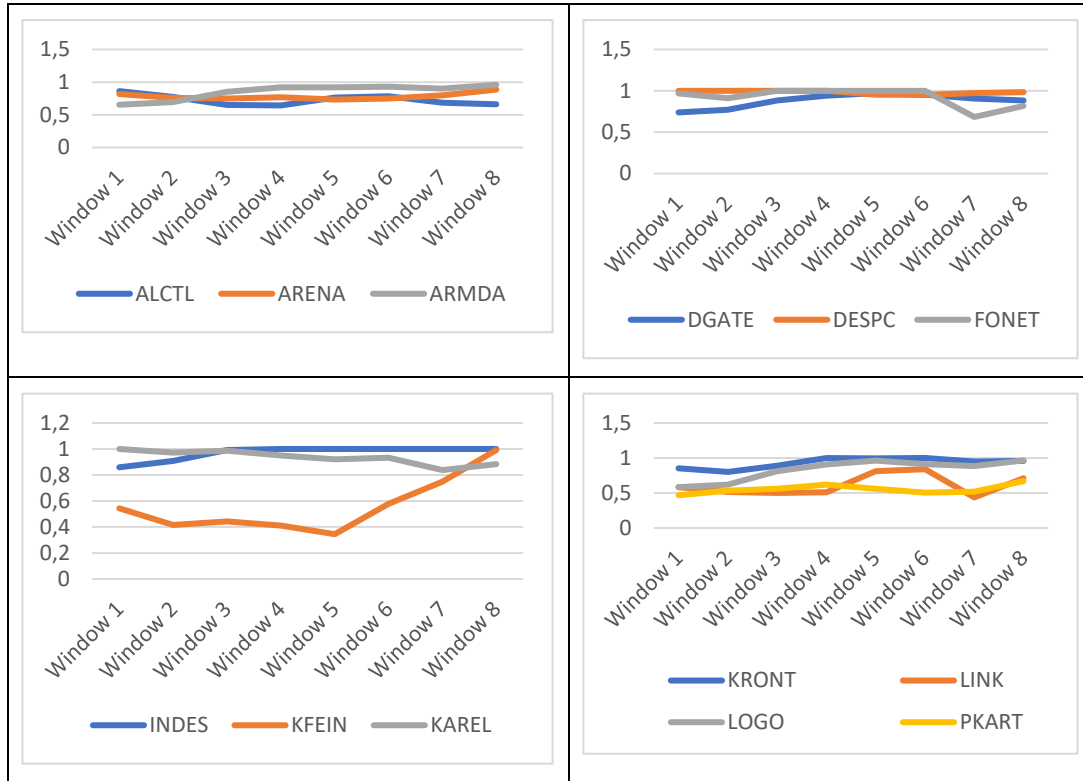
**Table 8. Average efficiency scores for each company in each Window according to BCC Window Analysis results**

	Window 1	Window 2	Window 3	Window 4	Window 5	Window 6	Window 7	Window 8
Companies	2019:03 2019:06 2019:09	2019:06 2019:09 2019:12	2019:09 2019:12 2020:03	2019:12 2020:03 2020:06	2020:03 2020:06 2020:09	2020:06 2020:09 2020:12	2020:09 2020:12 2021:03	2020:12 2021:03 2021:06
ALCTL	0.863	0.775	0.653	0.644	0.763	0.783	0.688	0.663
ARENA	0.816	0.758	0.750	0.767	0.734	0.749	0.800	0.886
ARMDA	0.655	0.698	0.851	0.919	0.923	0.931	0.900	0.960
DGATE	0.739	0.771	0.885	0.943	0.972	0.955	0.907	0.882
DESPC	1.000	1.000	1.000	1.000	0.955	0.951	0.973	0.984
FONET	0.967	0.912	1.000	1.000	1.000	1.000	0.684	0.818
INDES	0.859	0.907	0.991	1.000	1.000	1.000	1.000	1.000
KFEIN	0.545	0.416	0.442	0.410	0.345	0.579	0.748	0.992
KAREL	1.000	0.972	0.986	0.949	0.921	0.933	0.838	0.883
KRONT	0.855	0.801	0.889	0.998	0.993	1.000	0.951	0.958
LINK	0.585	0.513	0.502	0.508	0.811	0.840	0.437	0.711
LOGO	0.583	0.622	0.811	0.906	0.961	0.914	0.885	0.965
PKART	0.469	0.531	0.560	0.620	0.560	0.505	0.520	0.670

**Source:** Eryiğit, 2022

Table 8 presents the average efficiency values of the firms for each window. By window averages obtained with the help of 3-period BCC model window analysis, it will be possible to see the trends and changes of the companies.

The line graph obtained by using the average efficiencies in each window obtained for the companies in Table 8 is given in Figure 2. From Figure 2 it is clear that although ARENA, DGATE, DESPC, and PKART companies do not show a stationary trend, it can be said that the fluctuations regarding these companies are at very small intervals. Significant fluctuations in ALCTL company, sudden decrease and increase in FONET company, and obvious fluctuations in LINK company show that these 3 companies have a wavy trend. The KFEIN company gives the impression of an increasing trend. INDES company also showed an increasing trend and then became stationary. ARMDA, LOGO and KRONT companies also showed a non-continuously increasing trend. KAREL company shows a non-continuously decreasing trend.



**Figure 2. Line Graph for Average Efficiency Scores for each company in each Window according to BCC Window Analysis results**

Source: Eryigit, 2022

When the CCR and BCC Window Analysis results in Table 4 and Table 7 are assessed together, the detailed comments for each firm are as in below.

For CCR window analysis, ALCTL firm is the company with the lowest performance with an average efficiency of 0.175. According to the BCC window analysis, the average efficiency is 0.729. In terms of efficiency performances for both window analysis models, the company remains below the general average. ARENA company remained below the general average in terms of efficiency performances for both CCR and BCC window analysis models. ARMDA company ranks last in terms of efficiency performance for the CCR window analysis model and it also has the lowest standard deviation and range. The average efficiency for DGATE company is 0.561 for the CCR window analysis model and the 0.882 for BCC window analysis model, which are above the general average efficiency according to the window analysis results of both models. DESPC company with the highest average efficiency in CCR and BCC window analysis. FONET company with an average efficiency value of 0.679 is the second one for the CCR window analysis model. Considering the average efficiency results of the CCR and BCC window analysis, INDES company has a performance above the general average efficiencies with values of 0.606 and 0.970, respectively. According to the CCR and BCC window analysis results, it is seen that the KFEIN company is below the general average efficiencies with average efficiency values of 0.252 and 0.560, respectively. According to CCR and BCC window analysis

results, KAREL company has a performance above the general average with average efficiency values of 0.561 and 0.936, respectively. According to the CCR and BCC window analysis results, KRONT company has a performance above the general average with average efficiency values of 0.553 and 0.931, respectively. According to the CCR window analysis, the LINK company remains above the general average efficiency with a value of 0.468 and according to the BCC window analysis, it is below the general average with an efficiency value of 0.613. According to the CCR and BCC window analysis results, LOGO company has an efficiency performance above the general average with average efficiency values of 0.526 and 0.830, respectively. Considering the results of CCR and BCC window analysis for the PKART company, average efficiencies of 0.272 and 0.554, respectively, are below the general average efficiency values for the models.

## 5. Conclusion

The outbreak of COVID-19 has had varying impacts on different sectors, given the differences in the dynamics and factors that influence each sector. While a few sectors experienced adverse impacts because of the pandemic-related measures and restrictions, others experienced positive effects. This research investigates the impact of the epidemic on the financial performance of IT sector firms listed in BIST, Türkiye, using the DEA Window Analysis technique. The analysis includes periodic data between March 2019 and June 2021, as the first case in Türkiye was reported on March 11, 2020.

The periods 2020:06, 2020:09, 2020:12, 2021:03 and 2021:06 are evaluated as post-COVID-19. The Window analysis method allows adding the time factor to the DEA analysis, for this study the number of periods is chosen as 10 and the window width as 3. The 3-width window averages of the companies and the general trend are examined. At the same time, the average efficiency values, standard deviation, and range values of the companies are interpreted, the periods with the highest and lowest average efficiency are determined, and the periodical effect of the COVID-19 epidemic is examined. The average values of the firms are in comparison with the general average.

For CCR model window analysis, the general average efficiency of all companies and all periods is determined as 0.450, and when monitored by periods, it is observed that the highest average efficiency is 0.749 for the period of 2019:03, and the second period is 2021:06 with an average efficiency of 0.722. It is determined that the lowest efficiency average is 0.117 for the period of 2019:09. According to the model, the company with the highest average efficiency is DESPC with a value of 0.697.

According to the results of the BCC model window analysis, the general average efficiency of all companies and all periods is determined as 0.811 and when monitored by periods, it is observed that with the value of 0.950, the period of 2021:06 has the highest average efficiency and the second period is 2021:03 with an average efficiency of 0.915. The period of 2019:09 has the lowest average efficiency with a value of 0.694. According to the model, the company with the highest average efficiency is DESPC with a value of 0.983.

When the CCR model and BCC model window analysis results are evaluated together, one of the first two periods with the highest average efficiency for these models is 2021:06, and the period with the lowest average efficiency for these models is 2019:09. DESPC company has the highest average efficiency for these models.

In literature, DEA analysis is the popular one for investigating financial efficiencies of IT Sector Companies traded on BIST. The significance of this study is that to our knowledge it is the second time that the IT Sector Companies traded on BIST are examined using the DEA-Window analysis method. Yeniay's (2017) master thesis was the first study in which technology sector firms listed on BIST were analyzed using data from 2013 to 2015 with Window Analysis. In this thesis, the average value of the DESPEC company's window analysis result showed the best performance among companies. Since in our study, DESPC company has the highest average efficiency it is concluded that this firm preserved its efficiency over the years. The difference in our study from Yeniay (2017) is that we used quarterly periods between 2019:03 and 2021:06 to examine the effects of the COVID-19 process on IT Sector companies' financial performances. The contribution of our study is examining the effects of the pandemic period on the IT sector generally and especially evaluating financial efficiency performances on a company-by-company basis during the period including the COVID-19 period.

During the COVID-19 epidemic process there were precautions like lockdowns and mask obligations etc. The COVID-19 epidemic caused a need for businesses and their employees to start or increase the time working from home. Distance education therefore online learning methods and working from home were spread and applied in Türkiye similar to all around the world during these periods. As a result, digitalism has been spread. During the epidemic process, all of these precautions and economic or social changes caused different effects on all sectors. In conclusion during the COVID-19 epidemic process the financial performance efficiencies of the firms are affected in different ways.

In the following years, the study can be further developed by updating data and including different variables in the model, and the monitoring of the impact of the COVID-19 pandemic and post-epidemic effect can be followed in more detail in the long term.

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