Dynamic Management Efficiency Evaluation of Education Service Industry and COVID-19 Pandemic Impact Analysis

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Abstracts: In Korea, the education service industry is always the subject of attention not only for its industrial aspect, but also for parents' enthusiasm for their children's education and the nation's high enthusiasm for learning. In particular, during the COVID-19 pandemic, changes in the education service industry have had an impact on society as a whole. This study deals with changes in the management efficiency of Korea's education service industry for 6 years and seeks to determine whether the COVID-19 pandemic has affected management efficiency changes. Therefore, from 2017 to 2022, the management efficiency of educational service companies is evaluated and analyzed. For this dynamic efficiency analysis, the DEA/Window technique was used, and the trend and stability of management efficiency were evaluated. Meanwhile, to analyze the difference in management efficiency between the time of the COVID-19 pandemic and before, a paired-samples t-test is conducted to determine statistical significance. It is expected that the management efficiency of educational service companies will be improved by utilizing the results of this study.

Keywords: DEA, DEA/Window, Paired-Samples T-Test, Education-Service, Efficiency.

1. INTRODUCTION

Due to the recent COVID-19 pandemic, the 10 trillion won educational service industry is facing new opportunities amidst difficulties. The strengths of Korea's educational services are high educational zeal and excellent educational contents. Entrepreneurship in the Internet-based education service industry (e-learning) is also active, along with high enthusiasm for education, excellence in educational content, and Internet environment. Recently, edu-tech is attracting attention, and advanced technologies such as AI, big data, and the Internet of Things (IoT) are being applied to education.

The weakness of Korea's education service industry is its weak sales structure and intensifying competition with platform companies. Although the e-learning market was active from the beginning of the industry, preparation for digital education was weak compared to other industries. As the COVID-19 pandemic took a direct hit to the private education market, which has a large proportion of academies and on-site learning, the sales structure centered on face-to-face sales and sales of textbooks mainly consumed at academies revealed its limitations.

However, In terms of opportunities in the educational service industry, Korea's high enthusiasm for education for children and adults is the core of the growth engine of the private education market, despite the crisis of a decline in the school-age population. This is also a factor leading the expansion of the children's education market and the lifelong education market for adults.

On the other hand, as a threat to Korea's education service industry, the future of the education industry is threatened by the low birth rate. Korea is a country with a low birth rate, and the number of students is rapidly declining. To respond to this, government policy changes, such as improving the college admission system, are inevitable. University crises, such as insufficient quotas and closures due to a decrease in the school-age population, are already a reality. The total university recruitment quota for the 2021 school year was about 550,000 people, but about 420,000 people took the CSAT (the college scholastic ability test).

As such, the management environment of Korea's educational service industry is at a turning point where opportunities and risks exist both internally and externally. Therefore, it is necessary to enhance the competitiveness of the entire education service industry and use it as a bridgehead to advance into the global education market. There is a study by Goh [5] on management efficiency that can enhance the competitiveness of the education service industry, and in particular, there is no study including the COVID-19 pandemic period, so continuous and active research is needed.

This study aims to evaluate the dynamic relative efficiency of companies in the education service industry, focusing on the improvement of management efficiency in the competitiveness of the education service industry. The dynamic relative efficiency evaluation uses the DEA/Winow methodology and evaluates the trend and stability of efficiency. Meanwhile, a paired-sample t-test is conducted to conduct statistical analysis to determine whether the COVID-19 pandemic has had an impact on corporate management efficiency. It is hoped that this will set companies on the right track to improve efficiency.

2. Methodology

2.1 Data Envelopment Analysis (DEA)

DEA is a non-parametric efficiency measure. This is different from other efficiency measurement methods that assume specific functional shapes in advance and estimate parameters. This method calculates the empirical efficiency frontier using the data between the empirical input and output factors of the evaluation target based on the linear programming method, and then measures the inefficiency by comparing how far the evaluation targets are from the efficiency frontier.

At this time, the efficiently evaluated decision making unit (DMU) is relatively evaluated and does not represent an absolute meaning. Relative efficiency is the relative value of an organization's efficiency compared to its maximum.

In general, among the DEA models, the most representative models are the CCR model by Charnes, Cooper, and Rhodes [2] and the BCC model by Banker, Charnes, and Cooper [1].. The difference between the two models is that the basic assumptions in the production relationship between input and output factors are different. In other words, the CCR model is a model that assumes returns to scale (CRS), in which input factors increase at a constant rate and output factors increase at a constant rate. On the other hand, the BCC model assumes that returns to scale (VRS) are assumed and that when inputs are increased at a constant rate, output factors do not increase at a constant rate. In addition, these two models are divided into Input Oriented and Output Oriented depending on whether they focus on input factors or output factors.

In this study, an input-oriented model is used, which aims to maximize the output factor level at a given input factor level. First, in the case of the input-based CCR model, under the premise that the k*th* observation belongs to the production possibility set, the degree of efficiency (θ^k) of this observation is the ratio at which the input can be reduced to the maximum while the output is fixed. It can be presented as Equation (1).

$$\theta^{k^*} = \min_{\theta,\lambda} \theta^k$$

subject to

$$\theta^k x_m^k \geq \sum_{j=1}^{J} x_m^j \lambda^j \qquad (m = 1,2,\ldots,M);$$

$$y_n^k \leq \sum_{j=1}^{J} y_n^j \lambda^j \qquad (n = 1,2,\ldots,N); \qquad (1)$$

$$\lambda^j \geq 0 \quad (j = 1,2,\ldots,J)$$

Meanwhile, in the case of the input-based BCC model, it can be presented as in Equation (2), but the condition ($\sum_{j=1}^{J} \lambda^j = 1$) is added to Equation (1).

$$\theta^{k^*} = \min_{\theta,\lambda} \theta^k$$

subject to

$$\theta^k x_m^k \geq \sum_{j=1}^{J} x_m^j \lambda^j \qquad (m = 1,2, \dots, M);$$

$$y_n^k \leq \sum_{j=1}^{J} y_n^j \lambda^j \qquad (n = 1,2, \dots, N); \tag{2}$$

$$\sum_{j=1}^{J} \lambda^j = 1 \,;$$

$$\lambda^j \geq 0 \quad (j = 1, 2, \dots, J)$$

2.2 DEA/Window

DEA/Window analysis evaluates dynamic efficiency and has the following characteristics. First, it is easy to grasp the trend of dynamic changes in the rise or fall of relative efficiency, and it is possible to evaluate the stability of efficiency fluctuations. Second, analysis over multiple periods can prevent excessive input of resources to obtain inefficient outputs. Third, even the same DMU is considered as a separate DMU depending on the period, so the DEA problem that can occur due to the difference in relative productivity of the DMU can be solved.

In the DEA/Window analysis, when k is the width of the analysis period to observe the dynamic change, the window width (*p*) can be obtained using Equation (3). In addition, the trend and stability can be obtained by performing DEA analysis using a moving average.

$$p = \begin{cases} \frac{k+1}{2} & k \text{ is odd} \\ \frac{k+1}{2} \pm \frac{1}{2} & k \text{ is even} \end{cases} \tag{3}$$

The number of windows (*w*) becomes *w=k-p+1* as shown in Table 1. When the width (*p*) of the window is determined, the window efficiency evaluation is sequentially analyzed through a moving average. That is, when the number of DMUs is *n*, *pn* DMUs are evaluated from period *1* to *p* in the first window, and *pn* DMUs are evaluated from period *2* to *p+1* in the second window. It moves backward by one period and evaluates until the last window. And you can get window characteristics like Table 1.

Table 1. Characteristics of DEA/Winow

Number of windows	$w = k - p + 1$
Number of DMUs for each window	*np*
Total number of DMUs	*npw*
Width of window	$p = \begin{cases} \frac{k+1}{2} & k \text{ is odd} \\ \frac{k+1}{2} \pm \frac{1}{2} & k \text{ is even} \end{cases}$

3. Empirical Efficiency Analysis

3.1 Analysis target and factor selection

This study targets 18 educational service companies listed on the Korea Exchange (KRX). Assets, liabilities, and capital were selected as input factors, and sales, operating profit, and net income were selected as output factors. This is to ensure reliable analysis by securing transparent and objective data through the public disclosure system, which obliges stakeholders, such as investors, to inform the management of the company and the data necessary for exercising rights or making investment decisions. Data are collected from 18 companies for 6 years and used for analysis Table 2. In DEA, the company to be analyzed is called the DMU, and it is indicated by the corresponding symbol.

Table 2. Descriptive Statistics of Input/Output Factors

(unit : hundred million won)

Factor	Statistics	2017	2018	2019	2020	2021	2022
Asset	Max	8,221.0	8,303.3	24,535.5	8,451.6	8,135.7	9,047.1
	Min	112.0	128.0	123.0	145.3	141.7	187.2
	Ave	1,605.7	1,914.9	3,119.6	2,169.1	2,446.1	2,495.6
	SD	2,104.6	2,290.2	5,779.2	2,431.8	2,645.5	2,741.0
Liabilities	Max	2,290.0	3,342.9	19,817.7	2,913.6	3,981.0	4,710.1
	Min	26.0	14.6	25.7	14.4	10.3	21.2
	Ave	467.1	666.5	1,735.2	818.0	998.0	1,064.3
	SD	585.8	854.6	4,573.2	977.9	1,241.9	1,419.9
Capital	Max	6,751.0	6,168.3	6,132.3	5,588.9	5,164.0	4,337.0
	Min	-12.0	3.3	-50.9	13.7	22.3	43.8
	Ave	1,138.7	1,248.3	1,384.4	1,351.2	1,448.2	1,431.3
	SD	1,621.6	1,562.7	1,713.9	1,522.7	1,503.2	1,450.2
Sales	Max	7,568.0	7,631.4	7,619.4	8,451.6	8,138.8	9,332.8
	Min	86.0	86.8	76.4	13.7	76.2	94.9
	Ave	1,494.4	1,698.0	1,847.1	1,910.1	2,111.8	2,347.3
	SD	2,074.8	2,138.2	2,192.1	2,344.4	2,491.3	2,870.8
Operational Profit	Max	471.0	482.1	596.4	328.2	990.1	1,353.9
	Min	-37.0	-44.1	-71.4	-280.3	-283.1	-499.6
	Ave	97.6	112.9	126.8	42.9	133.7	145.6
	SD	135.6	137.5	160.1	130.9	257.1	355.3
Net Profit	Max	407.0	428.0	484.3	224.0	815.4	995.6
	Min	-81.0	-55.8	-1,506.1	-181.8	-424.5	-1,361.7
	Ave	69.6	91.3	-7.0	28.2	113.7	37.3
	SD	124.4	121.4	399.7	100.9	248.5	422.6

3.2 DEA/Window Analysis

For dynamic efficiency analysis, the DEA/Window technique is used for CCR-I and BCC-I models. For the analysis, data from 18 companies were collected for 6 years from 2017 to 2022. Here, the total number of DMUs (n) is 18, the total period of comparison (k) is 6 years, and the width of the window (p) is 3 according to Equation (3). Therefore, the number of windows ($w=k-p+1$) is 4, the number of DMUs for each window (np) is 54, and the total number of DMUs (npw) is 216.

If the width of the window is long, the number of DMUs used for analysis for each window is maximized, so the degree of freedom increases. In particular, it is advantageous even when the number of DMUs is small. Meanwhile, if the length of the window is shortened, the number of windows increases, and there is little difference from the static analysis result. In addition, the result value of the length of the window is different depending on whether the window is included at a specific point in time.

3.2.1 Window-I-C Model

This model is a window model applied to the input-oriented CCR model with constant return on scale (CRS).

1) Ranking Analysis of Efficiency

The DEA/Window analysis results are summarized in <Table 4>. In the table Win-Ave. represents the average of each window, and DMU-Ave. is Win-Ave. represents the average of 6-year efficiencies. The efficiency ranking was analyzed in the order of DMU D18-D17-D01-D14-D15-D04-D02-D13-D11-D06-D16-D03-D09-D12-D05-D08-D07-D10.

Table 4. Summary of Window-I-C Analysis Results

Yr. DMU	‘17	‘18	‘19	‘20	‘21	‘22	Win-Ave.	DMU-Ave.	Rank
D01	1	0.984	0.828				0.938	0.913	3
		1	0.858	0.809			0.889		
			1	0.983	0.854		0.946		
				0.913	0.810	0.914	0.879		
D02	0.596	0.631	0.785				0.671	0.733	7
		0.635	0.785	0.599			0.673		
			1	0.834	0.800		0.878		
				0.731	0.682	0.722	0.712		
D03	0.730	0.558	0.478				0.589	0.555	12
		0.646	0.496	0.445			0.529		
			0.624	0.500	0.512		0.545		
				0.493	0.513	0.658	0.555		
D04	0.802	0.704	0.601				0.703	0.755	6
		0.705	0.601	0.533			0.613		
			0.777	0.733	1		0.837		
				0.639	0.964	1	0.868		
D05	0.670	0.571	0.156				0.466	0.516	15
		0.600	0.171	0.587			0.453		
			0.137	0.636	0.691		0.488		
				0.607	0.663	0.697	0.656		
D06	0.370	0.381	0.496				0.416	0.624	10
		0.427	0.496	0.471			0.465		
			0.794	0.772	1		0.855		
				0.584	0.700	1	0.761		
D07	0.402	0.433	0.430				0.422	0.469	17
		0.453	0.450	0.442			0.448		
			0.470	0.520	0.543		0.511		
				0.493	0.495	0.494	0.494		
D08	0.446	0.469	0.459				0.458	0.479	16
		0.491	0.480	0.418			0.463		
			0.534	0.422	0.468		0.475		
				0.422	0.446	0.690	0.519		
D09	0.369	0.523	0.529				0.474	0.554	13
		0.546	0.552	0.546			0.548		
			0.650	0.669	0.580		0.633		
				0.597	0.516	0.575	0.563		
D10	0.476	0.425	0.270				0.390	0.446	18
		0.425	0.292	0.356			0.358		
			0.414	0.573	0.754		0.580		
				0.418	0.539	0.414	0.457		

D11	0.457	0.572	0.622				0.550	0.660	9
		0.582	0.621	0.536			0.580		
			0.718	0.610	0.802		0.710		
				0.566	0.924	0.909	0.799		
D12	0.499	0.123	1				0.541	0.527	14
		0.130	1	0.418			0.516		
			1	0.647	0.254		0.634		
				0.609	0.234	0.407	0.417		
D13	0.476	0.671	0.700				0.616	0.711	8
		0.674	0.702	0.521			0.633		
			0.908	0.569	0.829		0.768		
				0.545	0.936	1	0.827		
D14	0.962	1	0.955				0.972	0.825	4
		1	0.922	0.614			0.845		
			1	0.656	0.766		0.807		
				0.630	0.714	0.680	0.675		
D15	0.602	1	0.575				0.726	0.755	5
		1	0.607	0.294			0.634		
			1	0.519	1		0.840		
				0.519	1	0.940	0.820		
D16	0.832	0.491	0.494				0.606	0.568	11
		0.553	0.510	0.462			0.508		
			0.786	0.462	0.654		0.634		
				0.462	0.580	0.536	0.526		
D17	1	1	0.758				0.919	0.930	2
		1	0.867	0.796			0.888		
			1	0.911	1		0.970		
				0.825	1	1	0.942		
D18	1	0.860	0.897				0.919	0.980	1
		1	1	1			1		
			1	1	1		1		
				1	1	1	1		

2) Trend Analysis of Efficiency

In order to understand the change in efficiency for all 18 DMUs over the last 6 years, the average efficiency for each window was calculated and shown in Table 5. and Figure 1.

In Table 5., the average value of each window average was the highest in DMU D18 and the lowest in D10.

In the case of DMU, which has a large rise and fall in efficiency each year, it is not easy to grasp the trend of efficiency. However, it is easy to determine the efficiency trend based on the window, even if the rise and fall of the DMU's efficiency is large.

The average efficiency per window started at 0.632 in the first window (17-18-19), dropped to 0.613 in the second window (18-19-20), but rose significantly to 0.728 in the third window (19-20-21). However, it fell to 0.693 in the last window (20-21-22).

As can be seen in the graph, the efficiency window trend for each DMU is a fast upward trend for DMUs D05, D13, and D11 and a gentle upward trend for D08. On the other hand, the efficiency of DMU D14 is rapidly declining, and the efficiency of DMUs D18, D17, and D01, which are over 90%, is trending sideways. It can be seen that the remaining DMUs have a mixture of rising and falling repeatedly.

Table 5. Average through Window of Window-I-C Model

DMU	17-18-19	18-19-20	19-20-21	20-21-22	DMU- AVE.	Rank
D01	0.938	0.889	0.946	0.879	0.913	3
D02	0.671	0.673	0.878	0.712	0.733	7
D03	0.589	0.529	0.545	0.555	0.555	12
D04	0.703	0.613	0.837	0.868	0.755	6
D05	0.466	0.453	0.488	0.656	0.516	15
D06	0.416	0.465	0.855	0.761	0.624	10
D07	0.422	0.448	0.511	0.494	0.469	17
D08	0.458	0.463	0.475	0.519	0.479	16
D09	0.474	0.548	0.633	0.563	0.554	13
D10	0.390	0.358	0.580	0.457	0.446	18
D11	0.550	0.580	0.710	0.799	0.660	9
D12	0.541	0.516	0.634	0.417	0.527	14
D13	0.616	0.633	0.768	0.827	0.711	8
D14	0.972	0.845	0.807	0.675	0.825	4
D15	0.726	0.634	0.840	0.820	0.755	5
D16	0.606	0.508	0.634	0.526	0.568	11
D17	0.919	0.888	0.970	0.942	0.930	2
D18	0.919	1	1	1	0.980	1
Ave.	0.632	0.613	0.728	0.693	0.667	

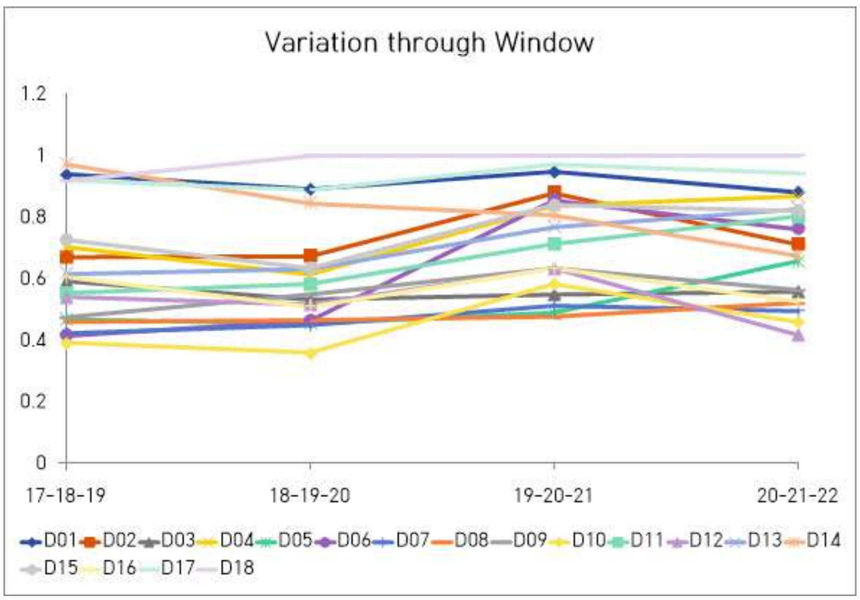

Figure 1. Variation through Window of Window-I-C Model

3) Stability Analysis of Efficiency

In evaluating efficiency, stability is also important along with the trend of efficiency. High stability means small fluctuations in efficiency. In this study, stability is evaluated by three volatility scales: SD, LDY, and LDP. By analyzing these values, it is possible to identify the efficiency trend of companies over the past six years and their stability against changes.

SD is the standard deviation of the average of the four windows, and the lower it is, the more stable the efficiency of the window is judged to be around the average. The largest difference between scores in the same year (LDY) means the maximum value among the difference in efficiency scores of each DMU within the same year, and the lower the difference, the more stable the efficiency by year. The largest difference between scores across the entire period (LDP) mention the difference between the maximum and minimum efficiency scores during the entire analysis period, and the lower the difference, the smaller the range of change in efficiency during the entire analysis period. The results of these scales are shown in Table 6. In the table, rank refers to the order of averages of DMU efficiencies.

The DMU order with the smallest SD is D07(0.041)-D18(0.048)-D08(0.074)-D09(0.076)-D01(0.079)-D03(0.089)-D17(0.094)- ... -D13(0.173)- D05(0.211)-D02(0.226)-D15(0.259)-D12(0.330).

And LDY this small DMU order is D05(0.049)-D08(0.075)-D14(0.078)-D07(0.079)-D11(0.121)-...-D02(0.234)-D17(0.242)-D16(0.292) -D06(0.301)-D15(0.425).

On the other hand, this small DMU order for LPD is D18(0.140)-D07(0.141)-D01(0.191)-D17(0.242)-D08(0.272)-D03(0.286)-...-D13(0.524)-D05(0.561)-D06(0.630)-D15(0.706)-D12(0.877).

Table 6. Stability Analysis of Efficiency

DMU	DMU-AVE.*	Rank	SD	LDY	LPD
D01	0.913	3	0.079	0.174	0.191
D02	0.733	7	0.117	0.234	0.404
D03	0.555	12	0.089	0.147	0.286
D04	0.755	6	0.160	0.200	0.467
D05	0.516	15	0.221	0.049	0.561
D06	0.624	10	0.226	0.301	0.630
D07	0.469	17	0.041	0.079	0.141
D08	0.479	16	0.074	0.075	0.272
D09	0.554	13	0.076	0.123	0.300
D10	0.446	18	0.130	0.216	0.484
D11	0.660	9	0.148	0.121	0.466
D12	0.527	14	0.330	0.229	0.877
D13	0.711	8	0.173	0.208	0.524
D14	0.825	4	0.161	0.078	0.386
D15	0.755	5	0.259	0.425	0.706
D16	0.568	11	0.126	0.292	0.370
D17	0.930	2	0.094	0.242	0.242
D18	0.980	1	0.048	0.140	0.140

* the average efficiency over 6 years

3.2.2 Window-I-B Model

This model is a window model applied to the input-oriented BCC model with variable return on scale (VRS).

1) Ranking Analysis of Efficiency

The DEA/Window analysis results are shown in Table 7. The efficiency ranking was analyzed in the order of DMU D18-D06-D01-D15-D03-D17-D05-D13-D14-D12-D11-D02-D04-D16-D10-D09-D08-D07.

Table 7. Summary of Window-I-B Analysis Results

Yr. / DMU	‘17	‘18	‘19	‘20	‘21	‘22	Win- Ave.	DMU-Ave.
D01	1	1	1				1	0.979
		1	1	0.874			0.958	
			1	1	0.891		0.964	
				1	0.981	1	0.994	
D02	0.607	0.637	1				0.748	0.796
		0.637	1	0.600			0.746	
			1	0.836	0.867		0.901	
				0.779	0.741	0.843	0.788	

D03	1	1	1				1	0.937
		1	1	0.764			0.921	
			1	0.854	0.870		0.908	
				0.893	0.865	1	0.919	
D04	0.864	0.711	0.741				0.772	0.792
		0.715	0.741	0.558			0.671	
			0.781	0.749	1		0.843	
				0.661	0.980	1	0.880	
D05	1	1	0.725				0.908	0.914
		1	0.725	0.995			0.907	
			0.622	0.972	1		0.865	
				0.926	0.998	1	0.974	
D06	1	0.996	0.928				0.975	0.985
		1	0.951	1			0.984	
			0.948	1	1		0.983	
				1	1	1	1	
D07	0.430	0.440	0.454				0.441	0.487
		0.462	0.462	0.446			0.457	
			0.487	0.536	0.551		0.525	
				0.525	0.525	0.522	0.524	
D08	0.448	0.472	0.459				0.460	0.489
		0.507	0.507	0.443			0.486	
			0.541	0.426	0.473		0.480	
				0.424	0.461	0.712	0.532	
D09	0.391	0.531	0.533				0.485	0.574
		0.563	0.584	0.601			0.582	
			0.658	0.676	0.594		0.643	
				0.628	0.528	0.603	0.586	
D10	0.496	0.919	0.311				0.575	0.693
		0.919	0.325	0.716			0.654	
			0.474	0.689	1		0.721	
				0.675	1	0.797	0.824	
D11	0.473	0.681	0.985				0.713	
		0.681	0.985	0.671			0.779	
			0.868	0.663	1		0.844	
				0.694	0.930	1	0.875	0.803
D12	1	0.323	1				0.774	0.829
		0.342	1	0.977			0.773	
			1	0.976	0.666		0.881	
				0.970	0.688	1.000	0.886	
D13	0.496	1	1				0.832	0.899
		1	1	0.819			0.940	
			1	0.754	1		0.918	
				0.724	1	1	0.908	
D14	0.988	1	1				0.996	0.857
		1	1	0.619			0.873	
			1	0.660	0.771		0.810	
				0.665	0.771	0.815	0.750	
D15	0.977	1	0.867				0.948	0.978
		1	0.889	1			0.963	
			1	1	1		1	
				1	1	1	1	
D16	1	0.536	0.570				0.702	0.682
		0.645	0.651	0.486			0.594	

			0.906	0.591	0.796		0.765	
				0.591	0.786	0.629	0.669	
D17	1	1	0.767				0.922	0.936
		1	0.918	0.801			0.906	
			1	0.911	1		0.970	
				0.830	1	1	0.943	
D18	1	0.970	1				0.990	0.998
		1	1	1			1	
			1	1	1		1	
				1	1	1	1	

2) Trend Analysis of Efficiency

In order to understand the efficiency change for all 18 DMUs over the last 6 years, the average of the efficiency by window was calculated and shown in Table 8. and Figure 2.

In Table 8., the average value of each window average was the highest in DMU D18 and the lowest in D09.

The average efficiency per window started at 0.791 in the first window (17-18-19), dropped slightly to 0.788 in the second window (18-19-20), but significantly decreased to 0.834 in the third window (19-20-21). It rose and rose slightly to 0.836 in the last window (20-21-22).

As can be seen in the graph, the efficiency window trend for each DMU is continuously increasing for DMUs D10, D07, and D12 and continuously decreasing for DMU D14. DMUs D18, D06, D01, and D15 with efficiencies above 95% are trending sideways. It can be seen that the remaining DMUs have a mixture of rising and falling repeatedly.

Table 8. Average through Window of Window-I-B Model

DMU	17-18-19	18-19-20	19-20-21	20-21-22	C-Average
D01	1	0.958	0.964	0.994	0.979
D02	0.748	0.746	0.901	0.788	0.796
D03	1	0.921	0.908	0.919	0.937
D04	0.772	0.671	0.843	0.880	0.792
D05	0.908	0.907	0.865	0.974	0.914
D06	0.975	0.984	0.983	1	0.985
D07	0.441	0.457	0.525	0.524	0.487
D08	0.460	0.486	0.480	0.532	0.489
D09	0.485	0.582	0.643	0.586	0.574
D10	0.575	0.654	0.721	0.824	0.693
D11	0.713	0.779	0.844	0.875	0.803
D12	0.774	0.773	0.881	0.886	0.829
D13	0.832	0.940	0.918	0.908	0.899
D14	0.996	0.873	0.810	0.750	0.857
D15	0.948	0.963	1	1	0.978
D16	0.702	0.594	0.765	0.669	0.682
D17	0.922	0.906	0.970	0.943	0.936
D18	0.990	1	1	1	0.998
Ave.	0.791	0.788	0.834	0.836	

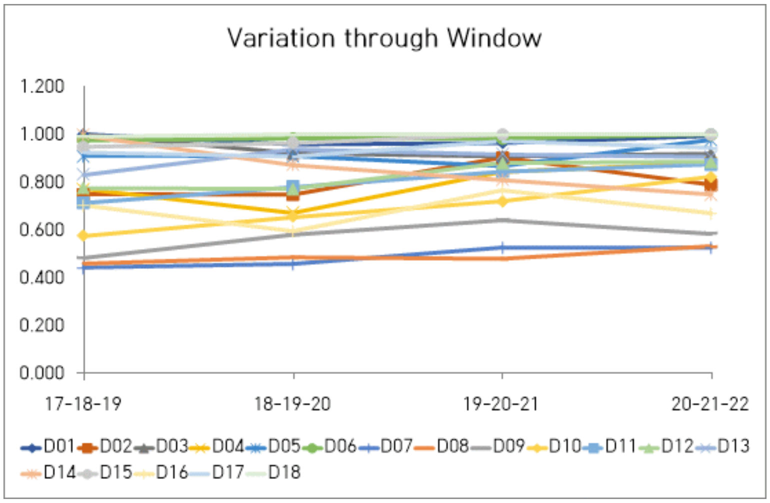

Figure 2. Variation through Window of Window-I-B Model

3) Stability Analysis of Efficiency

Table 9. shows the results of the stability scale in the W-I-B model. In the table, rank refers to the order of averages of DMU efficiencies.

The DMU order with smaller SD is D18(0.009)-D07(0.043)-D01(0.045)-D15(0.047) . . . -D11(0.179)-D10(0.247)-D12(0.330)-D17(0.094).

And the order of DMU with small LDY is D06(0.022)-D12(0.022)-D18(0.030)-...-D17(0.233)-D02(0.236)-D16(0.336).

On the other hand, the DMU with the smallest LPD is in the order of D18(0.030)-D06(0.072)-D07(0.121)-...-D11(0.527)-D12(0.677)-D10(0.689).

Table 9. Stability Analysis of Efficiency

DMU	DMU-Ave.*	Rank	SD	LDY	LPD
D01	0.979	3	0.045	0.126	0.126
D02	0.796	12	0.154	0.236	0.400
D03	0.937	5	0.083	0.129	0.236
D04	0.792	13	0.141	0.191	0.442
D05	0.914	7	0.139	0.103	0.378
D06	0.985	2	0.027	0.022	0.072
D07	0.487	18	0.043	0.090	0.121
D08	0.489	17	0.078	0.082	0.287
D09	0.574	16	0.075	0.125	0.285
D10	0.693	14	0.247	0.164	0.689
D11	0.803	11	0.179	0.116	0.527
D12	0.829	10	0.261	0.022	0.677
D13	0.899	8	0.166	0.095	0.504
D14	0.857	9	0.156	0.046	0.381
D15	0.978	4	0.047	0.133	0.133
D16	0.682	15	0.157	0.336	0.514
D17	0.936	6	0.089	0.233	0.233
D18	0.998	1	0.009	0.030	0.030

* the average efficiency over 6 years

3.2.3 Results of analysis of two models of DEA/Window

First, the trend of DMU D18-D17-D01 of the Window-I-C model and DMU D18-D06-D01-D15-D03-D17 of the Window-I-B model, which have high efficiency rankings, is sideways, and the stability is consistently solid.

Second, DMUs with many changes in stability are the result of efficiency improvement efforts or insufficient efficiency improvement efforts. In the case of the former, DMUs whose efficiency is on the rise include Window-I-C model DMUs (D11, D13, D05) and Window-I-B model DMUs (D10, D11, D12). On the other hand, in the case of the latter, the DMUs with the decreasing efficiency were found to be DMU D14 of the Window-I-C model and DMU D14 of the Window-I-B model.

Third, DMUs whose efficiency trend and stability change move in a boxed range need changes to increase efficiency.

As a result, DMUs with high efficiency need to maintain high stability, and the lower the efficiency, the wider the range of fluctuation, requiring improvement efforts to increase efficiency even when stability is low.

On the other hand, if the efficiency trend is downward, efforts to increase stability by reducing the range of fluctuations are needed. If the efficiency trend is upward, it is important to widen the variance, even if stability is low.

However, DMUs whose efficiency trends and stability move in the box should reflect on their own desire for change.

4. EFFICIENCY DIFFERENCE TEST

We want to find out if there is a difference in management efficiency in the education service industry during the three years of the COVID-19 pandemic and the three years before it. Statistically tested for Window-I-C model and Window-I-B model.

For this purpose, a paired-sample t-test is conducted.

4.1 Test for the Window-I-C Model

The hypothesis is set as follows:

The null hypothesis (Ho) is that there is no difference in average efficiency between the three years of the COVID-19 pandemic and the three years preceding it.

The alternative hypothesis (H1) is that there is a difference in average efficiency between the three years of the COVID-19 pandemic and the three years preceding it.

Paired sample t-test results are shown in Table 10. In the table, the test statistic t=-1.96 and the significance probability (p=0.067) are larger than the significance level (α=0.05), so it is not statistically significant, so the alternative hypothesis is rejected and the null hypothesis is adopted.

Therefore, it can be said that there is no difference in the management efficiency of the CCR-I model before and after COVID-19 in the educational service industry.

Table 10. Result of Paired t-test of Window-I-C Model

		Descriptive statistics			*t(p)*
		N	Mean	SD	
Management Efficiency	Before COVID	18	0.721	0.211	-
	After COVID	18	0.802	0.166	1.961(0.067)

4.2 Test for the Window-I-B Model

The hypothesis is set as follows:

The null hypothesis (Ho) is that there is no difference in average efficiency between the three years of the COVID-19 pandemic and the three years preceding it.

The alternative hypothesis (H1) is that there is a difference in average efficiency between the three years of the COVID-19 pandemic and the three years preceding it.

Paired sample t-test results are shown in Table 11. In the table, the test statistic t=-2.33 and the significance probability (p=0.033) appear smaller than the significance level (α=0.05), so it is statistically significant, so the alternative hypothesis is adopted and the null hypothesis is rejected.

Therefore, it can be said that there is a difference in management efficiency of the BCC-I model before and after COVID-19 in the educational service industry.

Table 11. Result of Paired t-test of Window-I-B Model

		Descriptive statistics			*t(p)*
		N	Mean	SD	
Management Efficiency	Before COVID	18	0.840	0.181	-2.33(0.033)
	After COVID	18	0.906	0.143	

4.3 Analysis of Test Result

As a result of the paired sample t-test for the two models, it was found that the COVID-19 pandemic did not affect management efficiency in the Window-I-C model. However, in the Window-I-B model, it can be judged that the pandemic has affected management efficiency.

This is the difference between the CCR model, which evaluates both size and operational efficiency, and the BCC model, which evaluates only operational efficiency. As a result, it can be judged that the management efficiency of companies that focus on operation is better than companies that have invested in scale during the COVID-19 pandemic.

CONCLUSION

This study discussed two perspectives on the management efficiency of the educational service industry. First, a dynamic efficiency analysis including the COVID-19 pandemic period, and second, an examination of whether the COVID-19 pandemic made a statistically significant difference in management efficiency.

Eighteen educational service companies were selected as study subjects, and the target period was 6 years from 2017 to 2022 for dynamic analysis. Naturally, the COVID-19 pandemic period from 2020 to 2022 is included.

First, the DEA/Window model was used to analyze dynamic efficiency. The W-I-C model combined with the CCR-I model and the W-I-B model combined with the BCC-I model were used to evaluate efficiency, trend analysis, and stability analysis for each. Empirical analysis was conducted. As a result, based on efficiency, trend, and stability, companies that continuously maintain efficiency and companies that need improvement efforts were identified.

And to test whether the difference in efficiency between the COVID-19 pandemic period and the previous period was significant, a paired-sample t-test was conducted for the W-I-C model and the BCC-I model. As a result, the difference in efficiency in the W-I-C model was not significant, but the difference in efficiency in the BCC-I model was judged to be significant. This can be interpreted as the fact that efficient operation, rather than investment in corporate size, contributes to corporate management efficiency during the COVID-19 pandemic.

Using the results of this study, it suggests that continuous dynamic efficiency analysis needs to be conducted periodically in the future and that efforts to improve corporate management efficiency should be continued.

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