Evaluation and Comparison of Static and Dynamic Efficiency of IT-Service Industry

By

Hyunwoo Goh*
Seokyeong University, Seoul, Korea
E-mail : skuie@naver.com

Abstract

The IT-Service industry is facing an opportunity for market expansion due to the growth of the 4th industrial revolution and the impact of the COVID-19 pandemic. In order to take advantage of this opportunity, management efficiency must be maximized. This study evaluates and compares the efficiency of related companies. Efficiency is evaluated statically and dynamically, and comparison is made for two techniques of dynamic efficiency. It is empirically shown that analyzing the efficiency analysis techniques in connection with the research can increase the reliability of the analysis. Through this study, we present a new perspective on the importance of management efficiency and how to evaluate it.
Key Words: DEA, Malmquist Production Index, IT-Service, Efficiency

1. Introduction

The IT-Service industry is an industry in which various companies collaborate with each other and provide IT-Service to customers. The structure of this IT-Service industry is very complex. Horizontal competition between comprehensive IT-service companies and vertical cooperative relationships between comprehensive IT-service companies, comprehensive IT-service companies, software companies, and specialized sub-contractors are developing in various ways. In such an environment, it is not easy to see the IT-Service industry at a glance.

The IT-service industry is defined by several organizations as follows. KITSIA (Korea Information Technology Service Industry Association) promotes the IT-Service industry by 'using optimal information technology to enhance organizational competitiveness, enhance the added value of work and business in the relevant field, and to converge with existing industries based on information technology. It is defined as 'an industry that creates new services' (classified into consulting, system integration, outsourcing, IT convergence service, and education and training). On the other hand, Gartner defines the IT-Service industry as 'a service that pursues efficiency and reform in existing businesses by IT or leads to the creation of new businesses by a company, an industry that provides services such as education for new introductions'. And IDC (International Data Corporation) defines the IT-Service industry as ‘a knowledge service industry across information technology, which operates the best technical requirements for evaluation, measurement, and process in system construction and development’. Mentioning the definition of the IT services industry is due to the need to clarify the shape of the IT services market and business.

The IT-service industry in Korea has the characteristics of being sensitive to economic conditions. Unlike the past high-growth era, the recent decade has been a period of continuous low growth, slowing the industry's growth. And the industry as a whole is suffering from the COVID-19 pandemic that in 2020. However, with the digital transformation in the post

COVID-19 era and the emergence of the new word ‘untact’, new business methods such as non-face-to-face and contactless consumption, distance education, and telecommuting are emerging as examples of business evolution based on untact technology. In addition, as a new market emerges in line with the growth of the 4th industrial revolution, the service levels and methods of companies providing IT-Service are different from those of existing services, and it is expected to provide new opportunities for companies to utilize them well.

In such a rapidly changing environment, companies must be able to efficiently maintain their management structure. In other words, the quantity of output factors relative to the quantity of input factors, that is, productivity, should be relatively superior to other companies in the industry. This is an essential and very important factor for a company to survive regardless of the external environment. There are many studies related to this, and in particular, research targeting the IT-Service industry has been continuously conducted since 2015 (H. Goh, 2015, 2021; H. W. Goh, 2018, 2019).

First, this study evaluates and analyzes the static and dynamic efficiency of 9 years. Second, it was performed to compare with the study results of H. Goh (2021) using another dynamic efficiency analysis methodology. As a result of this study, we present a reliable evaluation methodology that can be continuously monitored while being based on efficiency to enhance the competitiveness of the IT-Service industry.

2. Malmquist Productivity Index(MPI)

DEA analysis can measure the efficiency of each year at a certain point in time. Though, there are some limitations in understanding the change in productivity of each decision-making unit according to time fluctuations during the analysis period.

In this study, a dynamic efficiency analysis using the malmquist productivity index (MPI) is performed to measure the change in productivity.

The formula for calculating MPI can be expressed as Equation (1) and (2) below (Färe & Grosskopf, 1992).

$$M(x^{t+1}, y^{t+1}, x^t, y^t)$$

$$= \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \quad (1)$$

$$= \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \quad (2)$$

$$= Technical\ Efficiency\ Change\ Idex(TECI) \times Technical\ Change\ Idex(TCI)$$

In general, a value of $M(x^{t+1}, y^{t+1}, x^t, y^t) > 1$ means that productivity increased over two periods, and a value of $M(x^{t+1}, y^{t+1}, x^t, y^t) < 1$ means that productivity decreased at time t+1 compared to time t.

The MPI of Equation (1) can be decomposed as in Equation (2). The left side of Equation (2) shows that any DMU between time t and time t+1 is the production frontier compared to the previous point. It measures the technical efficiency change index (TECI), which indicates how close it is from the production frontier. The square bracket on the right measures the technical change index (TCI) that evaluates how the change in production technology between two periods contributes to the change in productivity, and it can be expressed as MPI = TECI × TCI.

In general, TECI is a measure to evaluate the change in efficiency at the technological level of constant return on scale (CRS) in two periods. If TECI > 1, it means that it is closer to the production frontier at time t+1 than at time t. This means that there is a catching-up effect, where the efficiency is improved similar to that of the producer with the highest efficiency of the technology. Conversely, if TECI < 1, it is farther away from the production frontier at time t+1 than at time t, which means that the efficiency is lowered and the distance from the best producer is widened. As such, TECI is an index that measures how far away from the production boundary the learning and knowledge diffusion effect, market competitiveness, cost structure, and facility utilization improvement are pursued through internal operation efficiency. On the other hand, TCI is a change in technology and external environment between two periods up to time t+1 compared to time t. Thus it is an index that measures how the shift along the efficient frontier caused changes in productivity. The TCI is more likely to produce more output with the same input when the production frontier rises (expands) further, which is a result of technological progress (TCI > 1) means. However, in the opposite case, it means that technological regression (TCI < 1) has occurred. This reflects the innovation potential and is affected by factors that shift the production possibility frontier, such as new product and production process innovation, new management techniques, and external shocks (Park, 2017).

3. Empirical Efficiency Analysis

3.1 Analysis target and factor selection

Since this study is an extension of Goh's (2021) study, the analysis target and element selection and data are shared. The subject of this study was selected IT-Service companies with management performance of more than 9 years listed on KRX (KoRea eXchange). This is to secure transparent and objective data for reliable analysis. Assets, liabilities, and capital were selected as input factors, and sales, operational profit, and net profit were selected as output factors. The data is used for analysis by collecting input and output factors from 6 companies for 9 years. The company to be analyzed is called a decision making unit (DMU).

3.2 Static Efficiency Analysis

In this study, the efficiency of DMU was analyzed by dividing it into technical efficiency (TE) of CCR-I model, pure technical efficiency (PTE) from BCC-I model, and scale efficiency (SE). SE is TE divided by PTE. <Table 1> shows the static efficiency analysis results of 6 companies for 9 years from 2012 to 2020.

First, It is evaluated as efficient with an efficiency score of '1' of the DMU. Conversely, if it is less than '1', it is evaluated as an inefficient DMU. TE, PTE, SE by year and their respective averages are shown.

Through CCR-I analysis, the number of DMUs with efficient technology efficiency is 3-3-2-5-4-4-2-5-4 in the order of year from 2012 to 2020, The average efficiency of each star was 0.845-0.804-0.736-0.964-0.900-0.858-0.868-0.941-0.867. The number of efficient DMUs was the lowest at 2 in 2014, and the highest in 2015 and 2019 with 5 each. The minimum value of technological efficiency by year is 0.621(D05)-0.547(D04)-0.288(D05)-0.782(D03)-0.630(D05)-0.416(D05)-0.495(D05) from 2012 to 2020. -0.647(D03)-0.475(D03), and in particular, the DMUs D03 and D05 fell short of the average technical efficiency of the DMUs for 9 years, so it was analyzed that it is urgent to improve the technical efficiency.

Table 1. Summary of Static Efficiency Analysis Results

Classfication		D01	D02	D03	D04	D05	D06	Ave.
	TE	1	1	0.77240	0.67555	0.62115	1	0.845
12	PTE	1	1	0.88263	0.67671	1	1	0.927
	SE	1	1	0.87510	0.99829	0.62115	1	0.916
	TE	1	1	0.72197	0.54795	0.55330	1	0.804
13	PTE	1	1	0.81782	0.54841	0.99998	1	0.894
	SE	1	1	0.88279	0.99916	0.55330	1	0.906
	TE	1	0.81161	0.63214	0.68282	0.28825	1	0.736
14	PTE	1	0.99998	0.79639	0.71650	0.99998	1	0.919
	SE	1	0.81161	0.79375	0.95298	0.28825	1	0.808
	TE	1	1	0.78283	1	1	1	0.964
15	PTE	1	1	0.96063	1	1	1	0.993
	SE	1	1	0.81493	1	1	1	0.969
	TE	1	1	0.76808	1	0.63069	1	0.900
16	PTE	1	1	0.96110	1	0.99999	1	0.994
	SE	1	1	0.79913	1	0.63069	1	0.905
	TE	1	1	0.73240	1	0.41623	1	0.858
17	PTE	1	1	0.81386	1	0.99991	1	0.969
	SE	1	1	0.90008	1	0.41631	1	0.886
	TE	1	1	0.88719	0.93059	0.49571	0.89438	0.868
18	PTE	1	1	0.93720	0.94474	0.99995	0.99995	0.980
	SE	1	1	0.94655	0.98501	0.49571	0.89438	0.887
	TE	1	1	0.64728	1	1	1	0.941
19	PTE	1	1	0.90516	1	1	1	0.984
	SE	1	1	0.71501	1	1	1	0.953
	TE	0.72808	1	0.47506	1	1	1	0.867
20	PTE	1	1	0.55959	1	1	1	0.927
	SE	0.72808	1	0.84894	1	1	1	0.930
	TE	0.977	0.984	0.779	0.903	0.750	0.991	0.898
Ave.	PTE	0.984	0.989	0.813	0.910	0.837	0.994	0.921
	SE	0.976	0.984	0.810	0.946	0.750	0.991	0.909

3.3 Dynamic Efficiency Analysis

In this study, the method of obtaining the Malmquist productivity index(MPI) under the CRS assumption using the input-oriented model is described.

3.3.1 TECI analysis

<Table 2> and <Fig. 1> show the change in technological efficiency by year from 2012 to 2020 compared to the previous year, respectively. As a result of TECI analysis, the average technical efficiency of 6 DMUs for 9 years was 1.75, which increased by 75%. It can be seen that, except for the years 2014-2015 (2.11), 2015-2016 (1.08), and 2018-2019 (6.19), the decline can be seen. In the case of individual DMUs, it was found that on average, the DMU with decreased technical efficiency showed D03, the level DMU with D06, and the remaining 4 DMUs (D01, D02, D04, D06) showed increased technical efficiency. Among DMUs with increased technological efficiency, D05 (4.81) in particular increased the most, and in particular, the increase was very large from 2018 to 2019 (30.50). This resulted in an operating loss in 2018 and a large loss in net profit, but in 2019, operational profit turned to a surplus and net profit turned to a large surplus, reflecting a significant improvement in the financial structure. Meanwhile, the DMU with the lowest technical efficiency was D03 (0.98).

Table 2. The Result of TECI Analysis

Catch-up	12=>13	13=>14	14=>15	15=>16	16=>17	17=>18	18=>19	19=>20	Ave
D01	0.86	1.33	1.48	2.02	0.42	1.35	0.77	0.38	1.08
D02	0.97	0.69	1.29	1.09	0.98	1.20	0.91	1.72	1.11
D03	0.95	0.93	1.30	1.18	1.00	0.89	0.77	0.83	0.98
D04	0.81	1.22	3.61	0.96	1.01	0.34	2.95	1.13	1.50
D05	0.93	0.51	4.03	0.27	0.65	1.14	30.50	0.45	4.81
D06	1.16	1.03	0.92	0.99	0.88	0.77	1.23	0.99	1.00
Ave.	0.95	0.95	2.11	1.08	0.82	0.95	6.19	0.92	1.75
Max	1.16	1.33	4.03	2.02	1.01	1.35	30.50	1.72	4.81
Min	0.81	0.51	0.92	0.27	0.42	0.34	0.77	0.38	0.98
SD	0.12	0.31	1.35	0.56	0.24	0.37	11.94	0.49	1.51

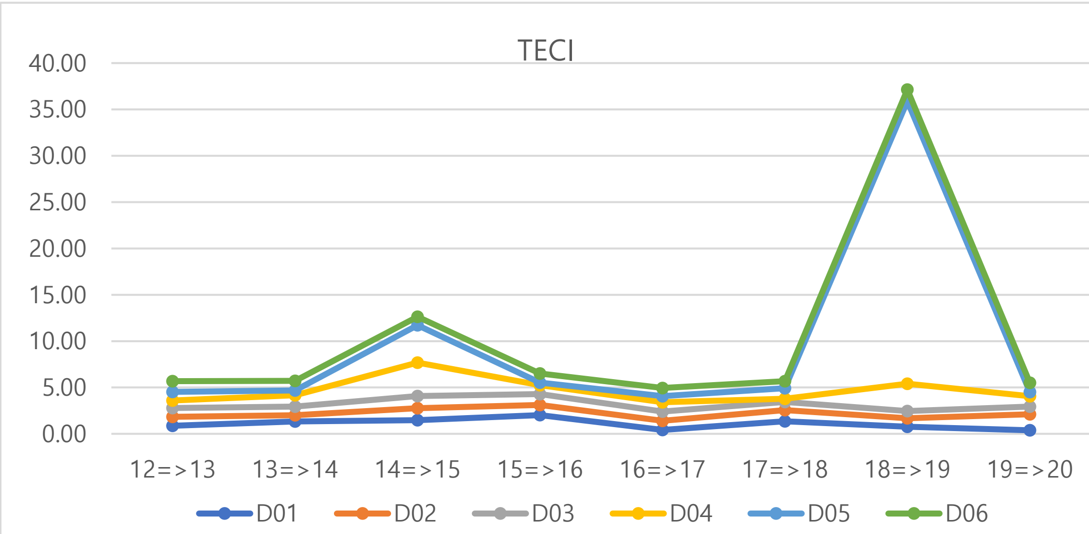

Fig. 1. Technical efficiency change Index

3.3.2 TCI analysis

As a result of TCI analysis from 2012 to 2020, in <Table 3> and <Fig. 2.>, it can be seen that the average technical change of the six DMUs over 9 years was 1.04, and the technical change was insignificant with a standard deviation of 0.04. However, in 2019-2020 (1.40), only 40% of technological progress was achieved compared to the previous period, and technological change in the rest of the period can be said to be stagnant.

In the case of individual DMUs, on average, only D09 (0.97) had a technology regression, and the remaining 5 DMUs made less than 10% technological progress.

Table 3. The Result of TCI analysis

Frontier	12=>13	13=>14	14=>15	15=>16	16=>17	17=>18	18=>19	19=>20	Ave.
D01	0.88	0.98	0.74	0.71	1.61	0.87	1.12	1.78	1.09
D02	0.92	1.20	0.86	1.02	1.07	1.02	1.05	1.08	1.03
D03	0.95	1.07	0.88	1.02	1.06	0.91	1.11	1.27	1.03
D04	0.49	1.15	0.92	0.80	1.06	1.12	1.02	1.54	1.01
D05	0.89	1.07	0.92	1.05	1.06	0.92	0.99	1.79	1.09
D06	0.90	1.00	0.89	1.02	1.02	0.98	1.06	0.91	0.97
Ave.	0.84	1.08	0.87	0.94	1.15	0.97	1.06	1.40	1.04
Max	0.95	1.20	0.92	1.05	1.61	1.12	1.12	1.79	1.09
Min	0.49	0.98	0.74	0.71	1.02	0.87	0.99	0.91	0.97
SD	0.17	0.09	0.07	0.15	0.23	0.09	0.05	0.37	0.04

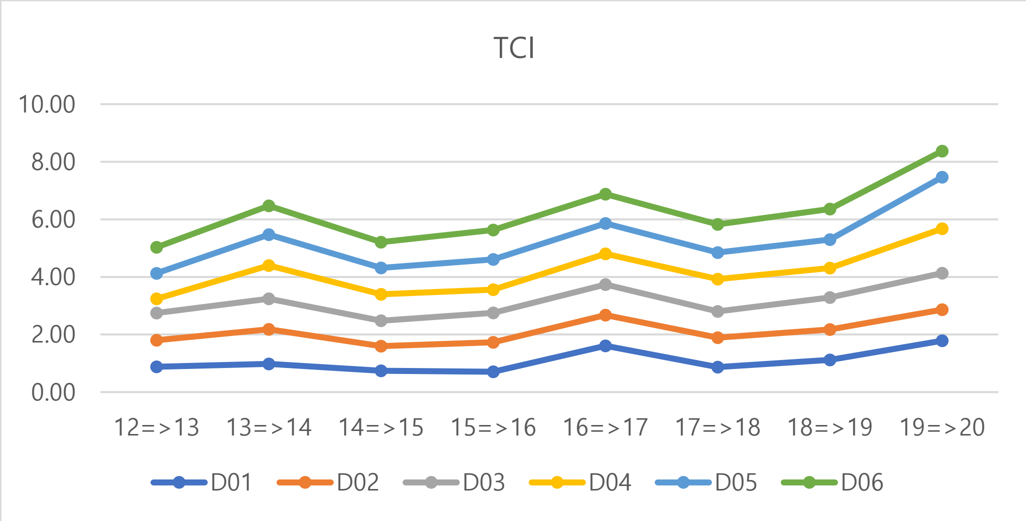

Fig. 2. Technical Change Index

3.3.3 TFPI Analysis

Total factor productivity index (TFPI) means the overall change of each index. The analysis results are in <Table 4> and <Fig. 3>. Looking at the TFPI from 2012 to 2020, the average TFPI of 6 DMUs over 9 years was 1.73, an improvement of 73%. However, the fact that the index of 2018-2019 improved more than 6 times to 6.21 can be seen as the effect that the index of DMU D05 increased more than 30 times to 30.24. It is believed that DMU D05 was influenced by the significant improvement in business performance. Of the individual DMUs, only D06 showed a decrease in TFPI, and the DMUs D01 and D03 have an index of 1.00.

Table 4. The Result of TFPI analysis

Malmquist	12=>13	13=>14	14=>15	15=>16	16=>17	17=>18	18=>19	19=>20	Ave.
D01	0.76	1.30	1.10	1.43	0.68	1.18	0.87	0.68	1.00
D02	0.90	0.82	1.10	1.12	1.05	1.23	0.96	1.86	1.13
D03	0.90	1.00	1.15	1.20	1.06	0.81	0.86	1.05	1.00
D04	0.40	1.41	3.32	0.77	1.07	0.37	3.01	1.75	1.51
D05	0.83	0.55	3.70	0.28	0.69	1.05	30.24	0.81	4.77
D06	1.05	1.03	0.82	1.01	0.90	0.75	1.31	0.90	0.97
Ave.	0.80	1.02	1.87	0.97	0.91	0.90	6.21	1.17	1.73
Max	1.05	1.41	3.70	1.43	1.07	1.23	30.24	1.86	4.77
Min	0.40	0.55	0.82	0.28	0.68	0.37	0.86	0.68	0.97
SD	0.22	0.31	1.28	0.40	0.18	0.32	11.80	0.50	1.50

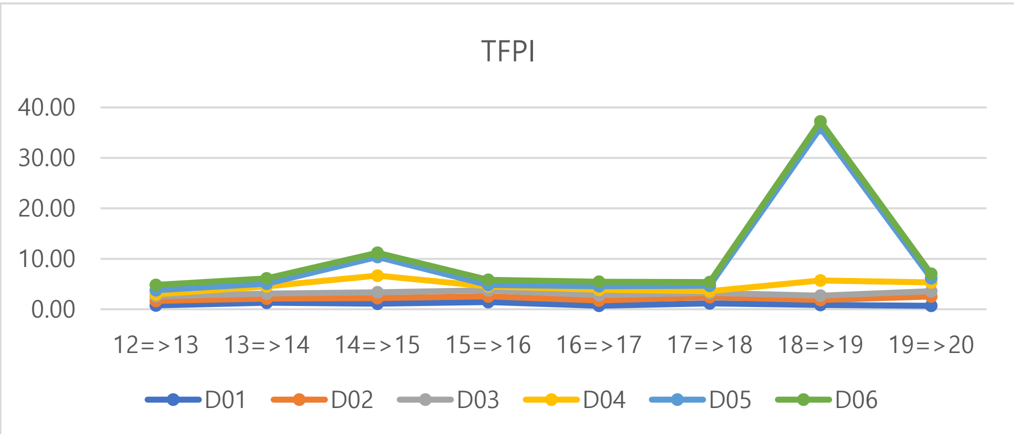

Fig. 3. Total factor productivity index

Recalling that TFPI is TECI × TCI, it can be seen that TECI contributed most to increasing TFPI. In other words, it can be seen that the DMUs have sufficiently demonstrated their operational efficiency internally, and factors such as technological advancement do not play a significant role. In the comparison of <Fig. 1> to <Fig. 3>, the shapes of <Fig. 1> and <Fig. 3> are similar, but the shape of <Fig. 2> is different. It can be intuitively understood that <Fig. 1> mainly influenced <Fig. 3>.

3.3.4 DEA/Window vs Malmquist Production Index Comparison

According to the static efficiency analysis, the DMUs with the lowest average technology efficiency for 9 years are D03 and D05. Here, it is necessary to analyze in connection with two dynamic analysis techniques.

In the dynamic efficiency analysis result of H. Goh (2021) using DEA/Window, the DMUs with low average efficiency are D03 and D05. Looking at the change in efficiency, the efficiency of DMU D03 continues to decrease, while in terms of stability, D03 seems to be the most stable. DMU D05 showed a trend of rebounding after maintaining low efficiency, and the change in efficiency was the largest, which could be interpreted as a positive figure.

In this study using MPI, DMU D03 showed improvement in MFPI 0%, TECI -2%, and TCI 3%, and DMU D05 showed improvement in MFPI 477%, TECI 481%, and TCI 9%.

Overall, DMU D03 and D05, which have low average efficiency for 9 years, urgently need improvement. However, the efficiency of DMU D03 is steadily falling and the MFPI is not fluctuating, so we need to focus on improving TECI and TCI. Although the efficiency of DMU D05 is low, it has a clear trend of rebounding, and it can be said that improvement in TCI is necessary because it can be seen that TECI has made great progress.

In this way, if the DMUs are analyzed by linking the static efficiency analysis and the dynamic efficiency analysis, more detailed analysis is possible and the reliability of the results can be guaranteed.

4. Conclusion

This study analyzed the efficiency and productivity of the IT-Service industry statically and dynamically. Based on the data for 9 years from 2012 to 2020, financial data for 6 companies were used as input and output factors.

Related studies have been conducted since 2015, and in this study, in particular, a comparative analysis with the study in 2021 was also performed.

As a result of the static efficiency analysis, it was found that the DMUs whose technical efficiency did not reach the average were D03 and D05 through CCR-I analysis. Through BCC-I analysis, DMUs with below-average pure technical efficiency were found to be D03, D04 and D05. The SE analysis revealed that the DMUs whose SE was below the mean were D03 and D05. It was analyzed that the efficiency improvement of DMU D03 and D05 is urgent by analyzing three efficiency indicators.

As a result of dynamic efficiency analysis using MPI, TFPI showed improvement of 73% and TECI of 75% for 9 years, but only 4% of TCI. In the end, it suggests that TFPI can advance significantly only when policies that can spread technology and improve utilization are developed along with the introduction of innovative technologies throughout the industry.

Through comparison with the dynamic analysis results of H. Goh (2021) using DEA/Window, it was shown that detailed analysis linking dynamic efficiency analysis methods and static efficiency methods is possible.

It emphasizes the need to introduce and develop innovative technologies to improve the efficiency of the IT-Service industry as a whole.

Through this study, dynamic efficiency analysis methods – MPI and DEA/Window – have different purposes for each analysis and evaluation method. However, it has been shown that the results of analysis and evaluation using both methods together are more reliable when evaluating the dynamic efficiency of a company.

5. Acknowledgments

This research was supported by Seokyeong University in 2022.

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