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A Study on the Productivity Improvement of PropTech Forum Construction Company in Korea

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Abstract. Currently, in the domestic construction market, several companies are actively investing in the proptech sector to develop real estate development and high-tech technology, and the domestic proptech sector is continuously growing. However, the construction market is still dominated by sales projects that rely on short-term finance, and there is a lack of discussion between the government and companies on ways to improve productivity. In addition, productivity improvement, operation, and management are vulnerable due to reckless investment focused only on profitability of small companies, and there are significant differences in productivity, operational efficiency, and size among domestic companies. This study aims to study the operational status and productivity improvement measures of domestic proptech construction companies. Therefore, among domestic construction companies, construction companies belonging to the Korea PropTech Forum were selected as analysis targets and an analysis of corporate productivity was conducted. As an analysis method, the Malmquist productivity index analysis, which can analyze changes in productivity and efficiency over a specific period through various outputs, was used. As variables used in the analysis, capital and number of employees was derived from input factors, assets, operating income, and net income were derived from output factors. Through the Mamquist productivity index analysis, trend analysis was conducted according to time point changes, and the degree of change in productivity between different time points was compared and analyzed. Results show that productivity improved due to the overall increase in MPI by year, but the index of flows such as MPI during the entire period was different by period. This means that the factors affecting productivity improvement have changed by period, sensitively reacting to external factors such as the construction industry or the COVID-19 situation. This study is significant because it identifies changes in the productivity index of proptech construction companies and suggests efficient operation of companies and ways to improve productivity.

Keywords: PropTech, operational status, productivity improvement, mamquist productivity index, trend analysis

1. Introduction

1.1. Background and purpose of the study

Currently, the domestic proptech market is expanding from the real estate brokerage platform and sharing service sector, which was a key area in the early proptech sector, to smart construction technology incorporating high-end technology. As a result, new companies that incorporate proptech are emerging in line with the atmosphere of the real estate construction market. In addition, existing real estate construction companies are actively investing and collaborating in the proptech sector along with the trend of the times such as productivity improvement and smart construction technology transformation amid rapid growth and globalization in the proptech sector. According to the "Business Collaboration in Proptech Eco-system" released by the Korea Proptech Forum, 316 cases (26.2%) of collaboration between proptech companies were the most active as of the end of July 2021, followed by 224 cases (18.6%). Moreover, the Korea PropTech Forum announced that as of May 2021, the cumulative investment by proptech sector was about 1.69 trillion won, attracting over 200 billion won annually since 2017 (Korea Proptech Forum 2021).

Table 1: Cumulative investment amount by Proptech sector according to business collaboration in Proptech eco-system

Field	Amount (KRW 100 million)	Field	Amount (KRW 100 million)
real estate marketing platform	6,782	Shared Services	4,278
interior design	1,729	Property data	1,131
Funding/P2P	1,120	Smart Construction Technology	1,111
IoT/Smart Home	308	Property Management Solutions	212
Blockchain	204	Renewable energy technology	40

The government's policy support in the proptech field is being provided along with active investment by companies. In 2021, the Ministry of Land, Infrastructure and Transport announced the "First Basic Plan for the Promotion of the Real Estate Service Industry", which includes a plan to intensively foster promising new industries such as PropTech (Ministry of Land, Infrastructure and Transport 2020). This development in the field of proptech will be able to efficiently deliver

information to consumers in the real estate construction market and alleviate the problem of asymmetric information delivery. However, the real estate construction market, which has entered the proptech sector, is still vulnerable is still vulnerable to poor productivity, operational efficiency, and management due to short-term financial-oriented sales projects and investment and development that focus only on the profitability of small companies. In addition, there are significant differences in size and form among domestic companies, and discussions with the government on productivity are insufficient (JaeYoung et al., 2020). Therefore, the productivity index for four years is identified through productivity analysis of domestic proptech construction companies, and trend analysis is conducted by dividing them into Technical Efficiency Change Index (TECI), Pure Efficiency Change Index (PECI), and Scale Efficiency Change Index (SECI). The purpose of this is to identify changes in productivity at different points in time through the analysis results, and to find ways to efficiently operate and improve productivity of domestic proptech construction companies. The structure of this study is as follows. In the introduction to Chapter 1, the background and purpose of the study were explained in detail. In Chapter 2, the theoretical review explained the concept of proptech, then examined each previous study and explained the difference from this study. Chapter 3 explains the analysis methods necessary for the study and presents the scope of the study. Chapter 4 Analysis Results presented the basic statistics used in the analysis, and the results of MPI analysis were presented for each period. Finally, in the conclusion of Chapter 5, based on the analysis results, the implications of this study, the limitations of the study, and the matters to be considered in future studies were presented.

2. Theoretical considerations

2.1. Concept of Proptech

PropTech is a combination of real estate assets (Property) and technology. This involves all technologies and services that help increase productivity by incorporating advanced “information technology (IT)” and “high-tech technologies” such as “blockchain”, “big data analysis”, “AI (artificial intelligence)”, “mobile channels”, and “VR (virtual reality)” into real estate services (HyunJun et al., 2021). PropTech is a concept created by the advancement of RE-Tech (Real Estate Technology) and refers to technologies and services to increase productivity in the real estate construction market by developing ICT (Information Communication Technology) of high-tech (Jungyun et al., 2021; Hakyun 2021). The 4th Industrial Revolution is the next-generation industrial revolution in which the real estate market is converged with ICT and encompasses all terms such as retech, fintech, platform business, sharing economy, and contech. Currently, the field of proptech in Korea is concentrated in real estate service industries such as Zigbang, Dabang, Zillow, and Letty abroad, but can be divided into asset management, housing

management, development, and finance (Sangyoung 2020; SunJu and SeeSoon 2021). According to JLL (2018), a global real estate consulting company, proptech is divided into value chains, and claims that corporate investment is large in the order of real estate brokerage and rental, real estate management, project development, investment and financing. In this way, the proptech business area can be classified into four categories. First, it provides various real estate information such as listing for sale, technology-based brokerage, sharing office, and data analysis as real estate brokerage and rental areas. Second, as the management area of real estate, it is a management service for buildings and tenants such as smart home repair and management, tenant management, repair and service. Third, as project development areas, it is a proptech area necessary for real estate development such as design support services, online marketplace for construction materials, virtual reality and 3D, and construction support tools. Fourth, the area of investment and financing consists of personal loans and crowdfunding, and fintech corresponds to this area (JaeYoung and SeungBong 2021; Yunkyung and Seonghwan 2019; JLL 2018).

2.2. Prior research review

Currently, domestic and foreign studies on the productivity index of real estate construction companies are insufficient. This study is a study on the productivity index of proptech companies among real estate construction companies, and it was considered that previous studies that combined proptech's theoretical concept and outlook should be reviewed together with Mamquist productivity index analysis.

2.2.1. Prior research on proptech

Lee Jeong-yoon, Oh Gyeong-ju, Ahn Jae-joon (2021) published a paper entitled, “Study on the Development Direction of Domestic Proptech Company: Focusing on the Real Estate Platform Information Provision Function” which suggests the direction the industry should go and a plan to help the development of the real estate industry.

Lee Sang-young (2020) explains the academic definition of proptech in “Proptech Classifications and Development Prospects”, predicts the development potential of the proptech industry through classification of proptech types, and systematically reviews necessary systems and reform plans in the future .

In their study entitled, “A Study of the Capacity Enhancement and Countermeasure of the Real Estate Industry in the Prop-tech Era,” Kim Seon-joo and Jang Hee-soon (2021) conducted a survey of real estate experts to compare and analyze the differences in their opinions on studying the real estate industry's capacity building and countermeasures in the proptech era .

Kim Jae-young and Park Seung-bong (2021) classifies areas in the business field of Proptech and what values are generated for each area in their paper entitled,

"Towards a Value-Creation Framework for Proptech Business." A framework for new value creation was presented by suggesting a method.

Yunkyung Heo and Seonghwan Kim (2019) conducted their study entitled, "Proptech Company, The New Future of The Real Estate Industry" and suggested how to understand the current proptech market and how to approach it in the future especially that since 2017, the global proptech market has grown rapidly.

2.2.2. Prior research using the Malmquist Productivity Index (MPI)

Lee Joon-woo, Park Sung-hoon, Oh Jae-kyun, and L Yeo Ki-tae (2018) measured the efficiency of cargo forwarding companies using Super-SBM analysis and Malmquist analysis among DEA analysis techniques through "An Analysis of Forwarding Companies' Efficiency handling Overseas Construction Project Logistics using DEA".

In their study entitled, "An Analysis of the Productivity of Domestic Construction Companies with Malmquist Productivity Index," Joo Soo-min and Hong Jong-eui (2019) measured productivity changes of 30 domestic construction companies using data envelope analysis and Malmquist productivity index analysis, and the efficiency accordingly. They identified and suggested implications for policy establishment necessary to increase operational efficiency of companies (Jin and Lee 2018; Sun and Li 019).

Jeon Jong-seop and Heo Sik (2020) confirmed the operational efficiency and productivity index of the arts center over time using data envelope analysis and Mamquist productivity index analysis through "Analysis of Efficiency and Productivity Changes in Korean Arts and Cultural Centers: Focusing on the Malmquist Productivity Index".

Ahn Kyung-ae (2017) conducted an empirical analysis using DEA and Mamquist productivity indices through " A Comparative Study on Productivity of the Certified Logistics Company by using the Bootstrapped Malmquist Productivity Indices ", and found that acquisition and cancellation of comprehensive logistics certification did not significantly affect corporate efficiency (Harrison and Kortuem, 2018).

Won Gu-hwan (2007) analyzed productivity using the Malmquist productivity index in "Productivity Analysis of the Korean Local Public Enterprises Using A Malmquist Approach" to solve problems in the simple regression analysis used in the current system, and improve productivity in terms of scale efficiency as well as technological change. It is meaningful that it is measured.

2.2.3. Difference from previous research

Domestic and foreign real estate construction companies are actively investing in the prop-tech sector, and proptech-related companies are growing rapidly. Accordingly, research and discussions on the prospect or development direction of the proptech field are being actively conducted. However, domestic and foreign research and discussions on how to understand the operation status of construction companies through productivity measurement or improve productivity are insufficient. Therefore, it is judged that it is necessary to discuss ways to improve productivity at a time when proptech construction companies are growing. Unlike previous studies that analyzed only short-term or efficiency among studies related to corporate management performance, the company intends to present results on productivity to find ways to improve corporate production. Therefore, the objectivity of the study was secured using a trend analysis called MPI analysis, and the trend of productivity fluctuations over time was measured. This study is meaningful in that it measures the flow and change of MPI of companies that respond sensitively to the flow of the real estate construction economy and presents implications for future studies.

3. Method and Scope of Research

3.1. Malmquist productivity index analysis

If the DEA analysis model is an analysis method to measure the relative efficiency between DMUs, the Malmquist productivity index analysis is a model to compare and analyze the degree of change in productivity between different time points, and has the meaning of total factor productivity. The Malmquist productivity index was first introduced by Malmquist, a Swedish economist, to measure changes in productivity in a situation where multiple input and output variables are required, and was presented by Caves, Christensen, and Diewer based on a distance function. Through this, the efficiency score at (t + 1) time through estimation analysis and production technology compared to time t is expressed as a ratio, and is expressed as the following formula (GuHwan 2007; Heecheol and JaeHwan 2021).

$$M_I^t = \frac{D_I^t(x^{t+1},\mu^{t+1})}{D_I^t(X^t,\mu^t)} \tag{1}$$

The change in productivity at time t and (t+1) from the above geometric mean is expressed as the following formula (Sumin and Jongyi 2018; Jongsup and Sik 2019).

$$M_I^{t,t+1} = \left[\frac{D_I^t(x^{t+1},y^{t+1})}{D_I^t(x^t,y^t)} \times \frac{D_I^{t+1}(x^{t+1},y^{t+1})}{D_I^{t+1}(x^t,y^t)}\right]^{1/2} \tag{2}$$

D_I^{t+1} If it is greater than 1, productivity increases at (t+1), if less than 1, it decreases, and if it is equal, there is no change. If this formula is divided into

Technology Efficiency Change Index (TECI) and Technology Change Index (TCI), it is expressed as the following formula (GuHwan 2007; Heecheol and JaeHwan 2021).

$$M_I^{t,t+1} = TECI \times TCI,$$

$$M_I^{t,t+1} = \frac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^t(x^t, y^t)} \times \left[\frac{D_I^t(x^{t+1}, y^{t+1})}{D_I^{t+1}(x^{t+1}, y^{t+1})} \frac{D_I^t(x^t, y^t)}{D_I^{t+1}(x^t, y^t)} \right]^{1/2} \quad (3)$$

The technology efficiency change index is divided into pure efficiency change index (PECI) and scale efficiency change index (SECI), and MPI can be estimated by dividing into PECI, SECI, and TECI (GuHwan 2007; Heecheol and JaeHwan 2021).

$$M_I^{t,t+1} = PECI \times TECI \times TCI,$$

$$M_I^{t,t+1} = \frac{V_I^{t+1}(x^{t+1}, \mu^{t+1})}{V_I^t(x^t, \mu^t)} \times \left[\frac{V_I^t(x^t, \mu^t)}{D_I^t(x^t, \mu^t)} \frac{D_I^{t+1}(x^{t+1}, \mu^{t+1})}{V_I^{t+1}(x^{t+1}, \mu^{t+1})} \right] \times \left[\frac{D_I^t(x^{t+1}, \mu^{t+1})}{D_I^{t+1}(x^{t+1}, \mu^{t+1})} \frac{D_I^t(x^t, \mu^t)}{D_I^{t+1}(x^t, \mu^t)} \right]^{\frac{1}{2}} \quad (4)$$

3.2. Scope of research

The Korea Proptech Forum first began recruiting members in 2018, and 380 companies are currently participating, and companies in various academic and research fields such as real estate and finance are subscribed. In this study, an analysis was conducted focusing on real estate-related construction companies among 380 companies of the Korea PropTech Forum. As an analysis method, the four-year productivity index is identified using the Mamquist productivity analysis, and the trend of fluctuations in productivity over time is to be identified. Accordingly, the company's financial statement data disclosed in the Financial Supervisory Service Electronic Public System (DART) was used to apply it to the productivity index analysis. However, it targets 24 companies except for companies that are difficult to obtain data from, and if the data is not provided every year, the overall increase or decrease rate of the rest of the companies is digitized and then used as an analysis variable. In addition, among previous studies using MPI analysis,

FGI [20] was conducted on experts in related fields, and the final variable was derived.

Table 2. Theorem of variables in previous studies

A researcher	Subject of Study	Inputs	Output
Lee Joon-woo Park Sung-hoon Oh Jae-kyun Yeo Ki-tae (2012)	18 Freight Forwarding Companies	Total capital Number of employees an overseas branch	Sales
Joo Soo-min Hong Jong-eui (2019)	Top 20 Construction Companies in Construction Capacity Evaluation Ranking	Number of employees capital stock non-current assets	Sales Current profit
Jeon Jong-seop Heo Sik (2020)	104 Arts Centers	Number of employees Operating expenses	Number of users Business revenue
Ahn Kyung-ae (2017)	53 Comprehensive Logistics Certification Companies	Number of employees a fixed asset Operating expenses	Sales Current profit Operating profit
Won Gu-hwan (2007)	7 Projects of Local Public Enterprises	Operating expenses fixed asset input Amount invested in investment	Total return on capital Total turnover of capital

As a result, capital, which is a material resource, and the number of employees, which is a human resource, were derived as input factors, and MPI analysis was conducted using assets, operating income, and net income for the calculation factors. In addition, trend analysis was performed to estimate the degree of change in efficiency over time through productivity index analysis, not just a simple viewpoint. Therefore, relatively recent data, four years of data from 2018 to 2021, were used.

Table 3: Variable selection

Classification	variable (unit)	source
Inputs	Capital (KRW) number of employees (persons)	Data Analysis, Retrieval and Transfer System(DART) (2018-2021, 4 years)
Output	Assets (KRW) Operating revenue (KRW)	
	Net Income (KRW)	

4. Analysis Results

4.1. Basic statistics

For each company, basic statistics as shown in the table below were calculated using capital and number of employees for input factors, assets, operating income, and net income for output factors. Looking at the overall basic statistics, on average, in 2019, capital rose 3.1%, and number of employees 2.1%, assets rose 4.5%, net profit fell 28%, and operating income fell 14.1%, compared to 2018. Compared to 2019, capital rose 3.1% and assets rose 4.9% on average in 2020, but the number of employees fell 11.7%, operating income fell 9.3%, and net profit fell 12.9%. Compared to 2020, on average, capital rose 6.6%, assets rose 8.6%, and operating income rose 4.6%, but the number of employees fell 1.1%, and net profit fell 0.4%.

Table 4: Basic statistics

Year	Classification	Minimum	maximum	mean	standard deviation
2018	Capital (KRW)	-901.83	82918.56	8990.13	17235.03
	number of employees (persons)	5.00	6831.00	1073.58	2103.73
	Assets (KRW)	180.33	180546.09	19993.04	36624.25
	Operating revenue (KRW)	-210.93	10644.89	1226.62	2312.30
	Net Income (KRW)	-9068.02	5874.34	536.95	2033.00
2019	Capital (KRW)	-95.60	87149.82	9272.52	17278.11
	number of employees (persons)	8.00	6926.00	1096.67	2133.03
	Assets (KRW)	183.67	182269.73	20895.82	37576.73
	Operating revenue (KRW)	-251.07	8596.67	992.93	1984.39
	Net Income (KRW)	-2218.77	5733.31	626.91	1463.01
2020	Capital (KRW)	-470.77	87663.78	9875.68	17826.33
	number of employees (persons)	6.00	6588.00	958.88	1882.58
	Assets (KRW)	159.66	179392.74	22675.40	39438.82
	Operating revenue (KRW)	-952.90	7503.98	975.34	1799.41
	Net Income (KRW)	-1710.65	5608.73	575.85	1273.77
2021	Capital (KRW)	-139.09	94292.91	10652.18	19006.63
	number of employees (persons)	6.00	6845.00	969.51	1861.64
	Assets (KRW)	232.10	196372.64	24744.46	42841.12
	Operating revenue (KRW)	-521.87	7535.03	1108.68	1883.71
	Net Income (KRW)	-1337.66	5543.77	685.20	1267.88

As the maximum and average of capital for each company continues to increase from 2018 to 2021, it can be seen that many companies have invested by increasing the input of capital. The number of employees and the minimum, maximum, and average of assets overall increased in 2019, decreased in 2020, and increased again in 2021. If construction investment increased and construction order growth increased from 2018 to 2019, it seems to have decreased due to the worsening construction economy in 2020 due to the aftermath of COVID-19, shrinking construction investment, delaying the realization of investment, and recording negative growth. However, when the government announced plans to intensively foster promising new industries such as PropTech in 2021, it is believed to have increased once again due to expectations for new industries and the possibility of expansion into new businesses despite the recession. The standard deviation of operating income is the lowest in 2020, and this part also showed a decrease in operating income of construction companies due to the sluggish construction economy due to the influence of COVID-19. Finally, it was found that the standard deviation of net profit by company gradually decreased from 2018 to 2021. This seems to have gradually decreased the standard deviation of net profit year by year as large companies, mid-sized companies, and small and medium-sized companies actively invest together and grow together in line with the growth of the domestic proptech market.

4.2. Results of Mamquist productivity index analysis

While analyzing the changes in productivity between different points in time, it should identify changes in efficiency by dividing them into the Technical Efficiency Change Index (TECI), Pure Efficiency Change Index (PECI), and Scale Efficiency Change Index (SECI). MPI represents the change in productivity between each point in time. In other words, when MPI is 1, there is no change in productivity, and if it is greater than 1, it is considered that productivity between time t and t+1 is increased, and if it is less than 1, productivity between t and t+1 is decreased. The results of each year's productivity index analysis are shown in Table 5, Table 6, and Table 7.

Table 5 shows the MPI for the period 2019-2020. Among them, DMUs 3, 5, 6, 7, 9, 14, 18, 20, 21 and 22 were found to be efficient companies with MPI values of 1 or more. In addition, during this period, the average value is 1 or more in the order of TECI, PECI and SECI, indicating that this had a significant impact on the increase in the efficiency of internal factors rather than the development of technology.

Table 5: 2018-2019 productivity index

DMU	TECI	TCI	PECI	SECI	MPI
DMU1	0.8926	0.2553	1	0.8926	0.2279
DMU2	2.5033	0.2653	1.1378	2.2001	0.6641
DMU3	1	1.0706	1	1	1.0706
DMU4	1.503	0.3687	1.2268	1.2251	0.5542
DMU5	1	1.0781	1	1	1.0781
DMU6	2.717	0.526	3.285	0.8271	1.4291
DMU7	1.5017	0.8232	1.1616	1.2928	1.2362
DMU8	1.8968	0.4172	0.8426	2.2511	0.7913
DMU9	2.401	0.4539	1	2.401	1.0898
DMU10	1.9046	0.448	1	1.9046	0.8533
DMU11	1.3645	0.6745	0.9896	1.3789	0.9204
DMU12	1.6504	0.4089	0.9748	1.6931	0.6748
DMU13	1.8432	0.4142	1.324	1.3921	0.7635
DMU14	1.52	0.6808	0.8643	1.7587	1.0348
DMU15	1.3966	0.3012	0.5489	2.5442	0.4207
DMU16	1	0.7397	1	1	0.7397
DMU17	1.9959	0.3801	1.4604	1.3667	0.7586
DMU18	3.6355	0.3239	1.5963	2.2774	1.1775
DMU19	2.0059	0.4428	1	2.0059	0.8882
DMU20	4.0999	0.5834	3.7495	1.0934	2.3919
DMU21	2.7263	0.3829	2.5994	1.0488	1.0439
DMU22	2.586	0.4506	1.173	2.2045	1.1653
DMU23	1.204	0.7591	0.9835	1.2241	0.914
DMU24	1.0073	0.4312	1.2253	0.8221	0.4343
Average	1.7324	0.4878	1.2047	1.438	0.8451

Table 6 shows the MPI for the period 2019-2020. Among them, DMUs 1, 2, 7, 8, 11, 12, 13, 16, 17, 19, 20, 21 and 23 were found to be efficient companies with MPI values of 1 or more. However, it can be seen that DMUs 3, 5, 6, 9, 14, 18 and 22 have changed to inefficient companies by recording MPI values of 1 or less. In addition, when looking at the average value, the average TCI value is 1 or more. During this period, it can be seen that the development of technology had more influence on the increase in productivity than on factors inside the company.

Table 6: 2019-2020 productivity index

DMU	TECI	TCI	PECI	SECI	MPI
DMU1	1.1203	1.2211	1	1.1203	1.368
DMU2	1.1216	0.9751	1.302	0.8614	1.0937
DMU3	0.2947	0.6502	0.3305	0.8917	0.1916
DMU4	0.5509	1.1316	0.8826	0.6242	0.6234
DMU5	1	0.7149	1	1	0.7149
DMU6	0.5417	1.0312	0.462	1.1725	0.5586
DMU7	1	1.0338	1	1	1.0338
DMU8	0.8932	1.2742	0.8703	1.0262	1.1381
DMU9	0.5271	1.0738	0.874	0.6031	0.566
DMU10	0.5593	1.1912	1	0.5593	0.6662
DMU11	0.9912	1.0168	1.0004	0.9909	1.0079
DMU12	1.1471	1.1916	1.0785	1.0636	1.3669
DMU13	0.9407	1.3028	1.0117	0.9299	1.2255
DMU14	0.7671	0.6301	0.8615	0.8904	0.4833
DMU15	0.7978	1.021	1.0255	0.778	0.8146
DMU16	1	1.0127	1	1	1.0127
DMU17	1.12	1.1168	1.1186	1.0012	1.2508
DMU18	0.7375	1.1758	1.0178	0.7246	0.8672
DMU19	0.8098	1.2709	0.8963	0.9035	1.0292
DMU20	1.024	1.3468	1	1.024	1.3791
DMU21	1	1.3614	1	1	1.3614
DMU22	0.7283	1.2383	1.0898	0.6683	0.9019
DMU23	1.3391	0.7697	1.4182	0.9442	1.0307
DMU24	0.8396	1.1773	1.0941	0.7674	0.9885
Average	0.8277	1.0577	0.9392	0.8812	0.8754

Table 7: 2020-2021 productivity index

DMU	TECI	TCI	PECI	SECI	MPI
DMU1	0.745	1.431	1	0.745	1.0661
DMU2	0.7475	0.9903	0.6342	1.1788	0.7402
DMU3	2.1313	1.1857	2.0239	1.0531	2.5271
DMU4	1.2413	1.1461	0.7008	1.7712	1.4227
DMU5	1	1.4866	1	1	1.4866
DMU6	0.8618	1.0672	0.892	0.9661	0.9197
DMU7	0.9776	0.9666	1	0.9776	0.9449
DMU8	0.808	1.2517	0.9138	0.8842	1.0114
DMU9	0.6283	1.0005	0.474	1.3255	0.6286
DMU10	3.6903	1.372	1	3.6903	5.0631
DMU11	0.867	1.3286	0.5365	1.6159	1.1519
DMU12	0.6196	1.2236	0.5002	1.2386	0.7581
DMU13	0.6587	1.1709	0.544	1.2108	0.7713
DMU14	1.0242	1.4101	0.9232	1.1094	1.4442
DMU15	0.9992	1.3333	0.8722	1.1456	1.3322
DMU16	1	1.0223	1	1	1.0223
DMU17	0.755	1.5151	0.5737	1.3159	1.1439
DMU18	0.8202	1.1527	1.1444	0.7167	0.9454
DMU19	1.0284	1.0202	1.0916	0.9421	1.0492
DMU20	1	1.2331	1	1	1.2331
DMU21	1	1.5194	1	1	1.5194
DMU22	0.8976	0.9255	0.5683	1.5795	0.8307
DMU23	0.8127	1.2766	0.6487	1.2529	1.0375
DMU24	0.8084	1.2491	0.5162	1.566	1.0098
Average	0.9532	1.207	0.8055	1.1833	1.1505

Table 7 shows the MPI for the 2020-2021 period. Among them, DMUs 1, 3, 4, 5, 8, 10, 11, 14, 15, 16, 17, 19, 20, 21, 23 and 24 were found to be efficient companies with MPI values of 1 or more. However, it can be seen that DMUs 2, 7, 12 and 13 have changed to inefficient companies by recording MPI values of 1 or less. In addition, when looking at the average value, the average value of TCI and SECI is 1 or more. During this period, it can be seen that the development of technology and optimization of scale influenced the productivity index.

Table 8. Average Productivity Index by DMU

DMU	TECI	TCI	PECI	SECI	MPI
DMU1	0.9065	0.7641	1	0.9065	0.6927
DMU2	1.2803	0.6351	0.9794	1.3073	0.8131
DMU3	0.8564	0.938	0.8746	0.9793	0.8033
DMU4	1.0092	0.782	0.9121	1.1064	0.7892
DMU5	1	1.0464	1	1	1.0464
DMU6	1.0825	0.8334	1.1062	0.9785	0.9021
DMU7	1.1365	0.937	1.0512	1.0812	1.0649
DMU8	1.1104	0.873	0.8751	1.2688	0.9694
DMU9	0.9264	0.7871	0.7455	1.2428	0.7292
DMU10	1.5782	0.9013	1	1.5782	1.4225
DMU11	1.0545	0.9695	0.8098	1.3021	1.0224
DMU12	1.0546	0.8416	0.8072	1.3066	0.8876
DMU13	1.0453	0.8581	0.8999	1.1616	0.897
DMU14	1.0609	0.8457	0.8825	1.2021	0.8972
DMU15	1.0364	0.7429	0.7889	1.3138	0.77
DMU16	1	0.9149	1	1	0.9149
DMU17	1.1906	0.8632	0.9786	1.2166	1.0277
DMU18	1.3004	0.76	1.2297	1.0575	0.9883
DMU19	1.1865	0.8311	0.9927	1.1952	0.9862
DMU20	1.6132	0.9895	1.5535	1.0384	1.5963
DMU21	1.397	0.9252	1.375	1.016	1.2925
DMU22	1.1913	0.8023	0.899	1.3252	0.9558
DMU23	1.0943	0.9069	0.9672	1.1314	0.9924
DMU24	0.881	0.8591	0.8845	0.996	0.7568
Average	1.1098	0.854	0.9696	1.1446	0.9477

Table 8 shows the average values of TECI, TCI, PECI, SECI and MPI calculated from 2018 to 2021. Each average value was derived using a geometric mean. There are 7 companies with MPI values of 1 or more, followed by DMU 20, 10, 21, 7, 5, 17, and 11, and on average, it can be seen that the productivity index is efficient. All seven companies with an MPI value of 1 or more have a TECI value of 1 or more, which can be said that internal factors of the company had a greater impact on the increase in efficiency than factors outside the company. The

following Table 9 is the rate of change in the Mamquist productivity index, which shows the flow and width of the change in the productivity index for each section.

Table 9. Mamquist productivity index change rate

Classification	TECI	TCI	PECI	SECI	MPI
t2(2018-2019)	1.7324	0.4878	1.2047	1.438	0.8451
t3(2019-2020)	0.8277	1.0577	0.9392	0.8812	0.8754
t4(2020-2021)	0.9532	1.207	0.8055	1.1833	1.1505
Average	1.1098	0.854	0.9695	1.1446	0.9477

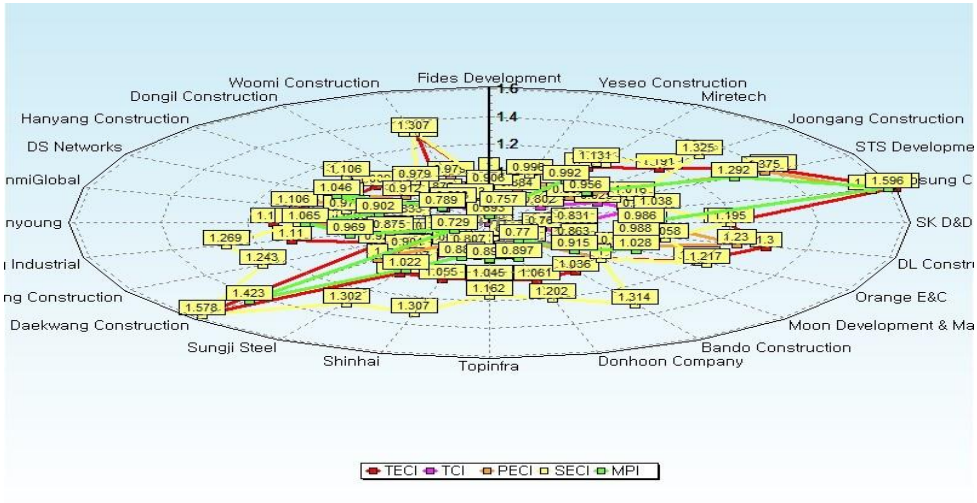

Fig. 1: Productivity change radar chart

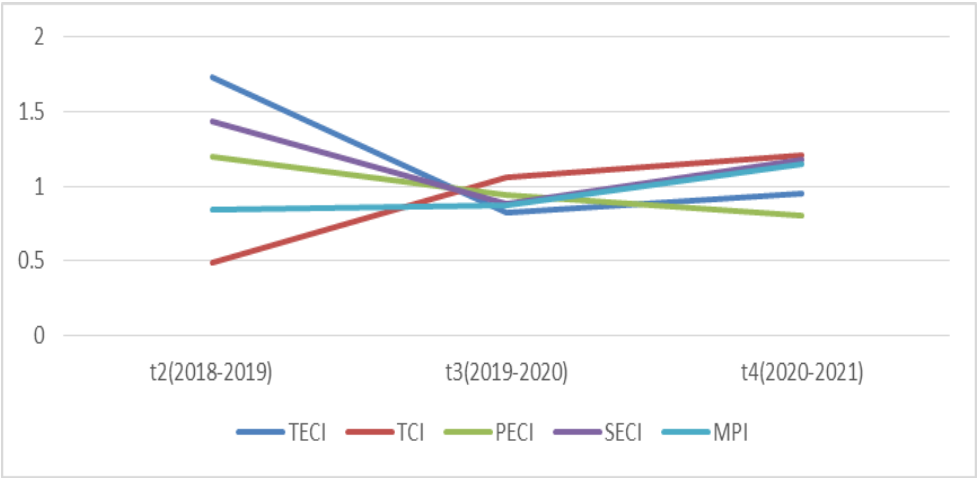

Fig. 2: Flow changes in TECI, TCI, PECI, SECI and MPI

First, looking at the MPI index, it can be seen that overall productivity tends to increase. Although there is a difference in the rate of change by part, the MPI (0.8754) index in 2020 increased compared to 2019, and also increased during the 2020-2021 (1.1505). Overall, the trend is increasing, and based on t4, the most recent point, productivity has increased by about 36% compared to 2018, the starting point of the analysis. It is also shown that the factor indicates an increasing trend in the same the factor that showed an increasing trend in the same direction along with MPI during the entire period is TCI. In other words, TCI is rising, while TECI is decreasing. This gradually indicates that the development of technology has a greater impact on the productivity index than on factors inside the company. In addition, the decline in the level of TECI from 1 or more to 1 or less led to the decline in the overall index. As a result, it can be said that the increase in productivity has a greater impact on efficiency in the order of technology development, scale optimization, and systematic operation. This suggests similar analysis results supporting the claims of this study in the previous study, "A Study on the Relative Operational Efficiency of PropTech Companies" [21] by Kim Tae-geun (2022). This is because the DEA analysis showed that the technical efficiency (TE) value was the lowest in 2021, and the overall figure of the analysis result is similar to the analysis figure of this study. Finally, Figure 1 shows the trend of productivity change by DMU as a radar chart, and Figure 2 shows the change in flow for each index.

5. Conclusion

This study aims to increase operational efficiency and provide basic data on improvement of companies with poor operational efficiency by grasping the operational status of construction companies belonging to the Korea PropTech Forum and seeking ways to improve productivity. Accordingly, the productivity index was measured by the Technical Efficiency Change Index (TECI), the Pure Efficiency Change Index (PECI), and the Scale Efficiency Change Index (SECI) through trend analysis of 24 proptech construction companies from 2018 to 2021. The Mamquist productivity index analysis was used for the measurement model, and capital, which is a material resource, and the number of employees, which is a human resource, were used for the input factors, and assets, operating income, and net income were used for the output factors. When looking at the indicators of each company's analysis factors repeatedly rising and falling, it can be seen as being sensitive to the situation of the construction industry that changes every year. In addition, it can be said that the proptech company's aggressiveness in investing in proptech and whether the government supports related policies also affected the operation and productivity of the company.

The implications of this study are as follows.

First, the proptech-related construction market is an industry in various sizes and forms, including large companies, mid-sized companies, and small and medium-sized enterprises. Therefore, since each company has different operating conditions and different factors that cause inefficiency in operation, it is necessary to reconsider efficiency by supplementing the strengths and weaknesses of each company. It is necessary to recognize the difference in productivity by the size of each company and make efforts to improve corporate operation efficiency. Second, as a result of Mamquist analysis, construction companies showed different and inconsistent TECI, TCI, PECI, and SECI by period. This indicates that due to the nature of the construction market, each company is sensitively affected not only by the development of technology but also by external situations such as the internal environment of the company and the construction economy. Therefore, it is analyzed that if the competitiveness of each company is reconsidered and the government's efficient policy support is supported, it will lead to more stable operational efficiency and productivity increase. However, it did not reflect the fact that the analysis was conducted on a small number of companies due to the limitation of data acquisition, and that the result value may vary as other construction companies were added. In addition, it remains a limitation that the difference in size and type of investment between companies is considerable, and all the effects on the analysis figures are not considered. It is further recommended that in future studies, it will be a high-quality study if companies are subdivided by size to analyze factors affecting operational efficiency and productivity growth, identify the importance of each variable, and reflect the weight of the variables.

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