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Analysis of the Efficiency of the U-Healthcare Industry

Kyoungho Choi[1*] and Jiae Kim[2]

[1]Department of Basic Medical Science, Jeonju University, Korea; ckh414@jj.ac.kr
[2]Department of Integrated Bio-resource, Jeonju University, Korea; jiaeblossom@naver.com

Abstract

U-healthcare is a convergence service combining traditional medical industry and Information Technology (IT). It provides a medical service and healthcare which one can access anytime and anywhere, safely and without limit. As the scale of Korea's U-healthcare market having reached 2 trillion Korean won in 2012, the prospects for this area are bright. At this point, this study has analyzed the efficiency of businesses related to Korea's U-healthcare using DEA (Data Envelopment Analysis) and the Malmquist index. The results show business effectiveness was not as high as expected in efficiency analysis which analyzed 2012 cross-sectional data. However, in the results using the Malmquist index, using 5 years of data to analyze longitudinally, 61.3% of businesses related to U-health have increased their productivity. This study has significance in being the first one to measure the change of efficiency and productivity, domestic U-healthcare, and to be considered to contribute to raising the business efficiency of Korea's U-healthcare.

Keywords: Component, DEA, Efficiency, Healthcare, Malmquist Index

1. Introduction

As supply of the Internet and smart devices has increased, the possibilities of improving and advancing to further development in the health medical field by using data and smart technology are being closely looked at. Smart devices' great usability allows the users to access various data services using data communication anytime and anywhere. The merit of increasing service accessibility for the recipient by overcoming time and space limits of the service offered and utilization has great potential in improving effectualness and efficiency in health and medical treatment services offered, while fusing not only the administration of disease, but also in the promotion of health and management service. Furthermore, with smart technology as its background, a new service for a public health project can be created in various ways. In the future, the health medical treatment service environment is also expected to experience lots of changes[21]. Having a great hospital as its center, E-Hospital, which is the information oriented project of hospitals, is being established. The Korean Government has set up the U-healthcare activation plan using the information technology infrastructure. U-healthcare revitalization of a medium and long term comprehensive plan, having the Ministry of Health and Welfare as its center since 2008, has already been established and it is currently in progress[15].

U-healthcare service, a service combining data communication technology and medical technology, is an abbreviation for ubiquitous computing and healthcare. It is a new form of medical service for individual's health management without time or place limits. Generally, U-healthcare can be categorized into U-hospital, Home & Mobile Healthcare, and wellness[18]. If U-healthcare is a common concept in Korea, E-healthcare is a more generally used concept in foreign countries. So in the US, Europe and other countries, terms like E-healthcare, Mobile Healthcare, ICT in Healthcare, Telemedicine, Telecare, Telehealth, Remote Health and Home Health Care are being used instead of U-healthcare. As such, there are various terms used throughout the world and they are different from one another, at least in definition.

**Author for correspondence*

However, they can be considered as the same concept in that they are creating a new added value by grafting information technology onto the traditional medical field[10]. When we distinguish and look into the annual average increase rate of the U-healthcare market in Korea separately, the rate of U-medical has increased by 11.8%; that of U-silver, by 7.7%; that of U-wellness, by 14.1%; and as a whole, 12.5%[23].

Thus, thanks to the rapid growth of sophisticated technical skills having smart devices as a foundation, Korea's U-healthcare industry or market has bright prospects and it is expected to have a great economical ripple effect. At this point, grasping the existence of the U-healthcare industry and its related businesses is significant, but there are not many studies that grasp the point using cross-sectional and longitudinal data. Therefore, the purpose of this study is to examine the actual circumstances using actual materials of businesses related to the U-healthcare industry and to find out relative efficiency of U-healthcare industry businesses. In the best interests of the Korean U-healthcare industry, comparing relative efficiency of related businesses is essential. So this study will provide its basic data. To accomplish this purpose, the data of 'the actual state and trends of business participation in the 2014 Smart Care U-Healthcare Service', all of which were suggested in reference[8], were used to gather efficiency and statistical analysis of the Korean U-healthcare industry using DEA and the Malmquist index.

2. Current Trends of the U-Healthcare Industry

The concept of the fusion of the medical industry with IT has changed together with the changes in technology and the environment. This concept is advancing to telemedicine, E-Health, and U-Health, starting with information-oriented medicine which was simply used in medical industry[10]. U-healthcare is a medical environment that provides telemedicine and health management services anytime and anywhere by monitoring patients' health information in real time with network or portable diagnostic sensors. In addition, as the U-health service affects the value chain of medical businesses including medical service providers and consumers, while combining IT with medical health services such as prevention, diagnosis, treatment, rehabilitation, recuperation, and the promotion of health management, it is the complementary service of the previous medical and health services which makes it possible to figure out the health condition of medical consumers anytime and anywhere. They are largely classified into the telemedicine service and telehealth management service. Characteristics of U-healthcare can be arranged as in Table 1.

Meanwhile U-healthcare can be divided into U-medical, U-silver and U-wellness according to users and related services. U-medical provides diagnosis, treatment, management and diagnostic environment support service for high-risk group patients, which is in the range of medical law. U-silver is a field providing services such as safety supervision and independent living support, etc., and it also manages and provides disease diagnosis and treatment to senior citizens who are 65 years old or older. Next, U-wellness is an area that provides the promotion of health and health environment support services intended for citizens. As a health care service for a measure of prevention, it is a new industry field which is not supported by the government's current insurance system. According to prediction data of user numbers of domestic services with such classification standards, it is expected that about 12 million people may use U-healthcare services; among people aged between 20 and 69, 4.0% would use U-medical, U-silver, 3.7%, U-wellness, 16.2%. The total size of the domestic U-healthcare market estimated on the grounds of predicted data of user numbers of U-healthcare is about 3 trillion Korean won, on 2014 standards. In detail, compared with the U-medical

Table 1. Characteristics of U-Healthcare

Service Type	Previous medical service	U-Healthcare
main agent	medical service provider	patients
service time	posterior treatment	emphasis on prevention of illness
type	standardized service	tailored service fit for each patient
expense	same charge for each type	different charge for different quality
medical information	limited information sharing between medical institutes	medical information sharing and its utilization in and outside of the medical institutes
medical treatment	possible only in medical institutes	medical service with no limits of time and space

market having about 560 billion won, the U-silver market recorded 480 billion and the U-wellness market, 2 trillion won. U-wellness is estimated to form the biggest market. Further, prospects of the U-healthcare market abroad seem very optimistic, and it is estimated to reach 250~300 billion dollars in 2013. Also, with figures of 143.1 billion dollars in 2009, the U-healthcare market is projected to show a high growth rate of annual average, 15.7% in the future[8]. Thus, a few examples, currently provided by the U-healthcare industry field which is estimated to have a great economical ripple effect and a high market outlook domestically and internationally, are shown in Table 2.

3. Method of Study

3.1 Data Collection and Variable Selection

The data for this study are from the data of 31 businesses related to the healthcare industry, all provided from reference[8] which organized the current state of the main domestic smart care and U-healthcare businesses in 2014. DEA, which is a static analysis, examined data from 2012. In addition, the Malmquist productivity index analyzed productivity through 5 years, from 2008 to 2012. On the other side, DEA is a non-parametric technique estimating relative efficiency among organizations consuming various input elements and producing various output elements or among DMU (Decision Making Unit). One of the biggest limitations of DEA is that the statistics of efficiency can change dramatically depending on the selection of input and output variables. This means that there is no general guideline for how to set input and output variables which would show the achievement of DMU in the most expressive way. However, if we can grasp which combination among various possible combinations of input and output variables can measure overall achievement of decision making units, we can assume that efforts to improve the efficiency number revealed on the basis of such combination would be the most efficient to improve performances of the overall decision making units[16]. On the basis of reference [11,7,19]etc, this study used capital (a million won) and number of employees for input variables and sales (a million won) for an output variable, because preceding researches commonly use these variables. Furthermore, since business profit, which is used as an output variable in reference[19], has shown the correlation coefficient as 0.988 ($p<0.05$) with sales and the correlation coefficient related to number of employees for cost of sales and cost of sales and management, which are selected as an input variable, are 0.928 ($p<0.05$), 0.978 ($p<0.05$), they should not be considered as input and output variables. In addition, generally the discriminatory power of DEA increases as DMU increases, but it decreases when input and output variables increase[12]. The number of input and output variables is recommended to be a third or less of DMU[13]. In this respect, the number of DMU and selection of input and output variables of this study seems to be appropriate. Next, capital, a selected input variable, and the number of employees are elements related to capital and labor invested for the profit maximization in each and every business, and sales selected as an output variable is an element related to profits. The correlation coefficient among these variables in the data of 2012 is revealed in Table 3. In the case of analysis using the DEA technique, in order for input and output variables to obtain validity, a constant correlation coefficient between variables should be seen reference[9], and Table 3 shows that all the variables seem to have regardful correlation statistically at 5%. The selection of input and output variables is appropriate. Meanwhile, in this study, for data analysis to achieve efficiency, it uses EnPAS (Efficiency and Productivity Analysis System)

Table 2. Cases of U-Healthcare Services

Businesses	Service contents
RobopoilisWithings	• smart device connected type weight management service • portable blood pressure measuring instrument utilizing smart phone apps
Fotofinder Systems	skin diagnosis service using smart phone apps and optically equipped lens
Apple and Nike	Nike + running service using multi devices
Intel	Health guide PHS6000 service managing patients' chronic diseases
MobiSante	portable ultrasonography diagnosis service using SP1 system
Konkuk Univ. Medical Center	ECG management service using digital patches

Table 3. Correlation Coefficient between Input and Output Variables (*$P<0.05$)

	worker	total sales	capital
worker	1	.788*	.391*
total sales	.788*	1	.638
capital	.391	.638*	1

v1.10, developed by reference[17], R 3.1.0 and IBM SPSS21 for statistical analysis.

3.2 DEA Analysis

DEA is a way to evaluate relative efficiency of other DMUs putting productivity 1 of the most efficient DMU as criteria. Since the DEA technique was first proposed by reference[6], the CCR model was proposed by reference[3] and so was the BCC model by reference[1]. Meanwhile the DEA technique uses DMU as a unit for production of various outputs using various input variables and the DMU of this study was ten cosmetic businesses which were selected as the subjects of the analysis.

The following information could be found when looking further into the CCR model and the BCC model based on reference[14]. First, the input standard CCR model among other CCR models is an efficiency measuring model, which pulls out the ratio for the minimum input while fixing the standard of output in production possibility set satisfying CRS, provided that n stands for subscript to signify the output element; m stands for output element; and j is DMU. Objective function θ^{k*} is a ratio reducing k-th input element of DMU. If input decreases equally with θ^{k*} on all input elements, k-th DMU can reach production change and meanwhile S_m^- and S_n^+ mean the surplus portion of input and output.

$$\theta^{\kappa *} = \min_{\theta,\lambda,s\_,s} + \left[\theta^k - \in\left(\sum_{m=1}^{M} S_m^- + \sum_{n=1}^{N} S_n^+\right)\right]$$

subject to

$$\theta^k x_m^k = \sum_{j=1}^{J} x_m^j \lambda^j + s_m^- \, (m=1,2,3,\cdots,M)$$

$$y_n^k = \sum_{j=1}^{J} y_n^j \lambda^j + s_n^- \, (n=1,2,3,\cdots,N) \qquad 3.1$$

$$y^j \geq 0\left(j=1,2,3,\cdots,J\right)$$

$$s_m^- \geq 0 \, (m=1,2,3,\cdots,M)$$

$$s_n^- \geq 0 \, (n=1,2,3,\cdots,N)$$

Next, in the case of dissatisfaction in the assumption of constant returns to scale among a public interest production possibility set, a production possibility set satisfying VRS can be achieved. The BCC model for input standards is as the following in equation 3.2.

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

subject to

$$\theta^k x_m^k \geq \sum_{j=1}^{J} x_m^j \lambda^j \, (m=1,2,3,\cdots,M)$$

$$y_n^k \leq \sum_{j=1}^{J} y_n^j \lambda^j \, (n=1,2,3,\cdots,N) \qquad 3.2$$

$$\sum_{j=1}^{J} \lambda^j = 1 \;, \quad \lambda^j \geq 0\left(j=1,2,3,\cdots,J\right)$$

Meanwhile pure efficiency value of scale can be achieved by finding SE of equation 3.3. SE can be obtained by dividing the result of efficiency value from the CCR model by the efficiency value.

$$\mathrm{SE} = \frac{\theta^{k^*}(CCR)}{\theta^{k^*}(BBC)} \qquad 3.3$$

Next, the procedure to achieve efficiency from the CCR model and the BCC model, and efficiency of scale and returns to scale based on it is as the following in Table 4[17].

3.3 Malmquist Productivity Analysis

The purpose of the CCR model and other related models, when analyzing efficiency, is to compare the relative ratio

Table 4. Relation between the CCR Nodel, the BCC Model and Returns to Scale

CCR TE	BCC PTE	scale index
θ^*_{CCR}	θ^*_{BCC}	$\sum_{j=1}^{J} \lambda^{*j}$
	inefficiency cause	
SE	PT	scale
$\frac{\theta^*_{CCR}}{\theta^*_{BCC}}$	PTE <PT	PTE >PT
	return to scale	
DRS	CRS	IRS
$\sum_{j=1}^{J} \lambda^{*j} > 1$	$\sum_{j=1}^{J} \lambda^{*j} = 1$	$\sum_{j=1}^{J} \lambda^{*j} < 1$

of output with the input of various observational stations in a similar situation at a specific point in time. Furthermore, the increase and decrease in the ratio of output compared with input as time goes on can be tracked when data are achieved by crossing over at different points. It is called productivity growth. However, productivity analysis that uses DEA among many other ways to analyze productivity change is the Malmquist productivity index. It calculates the ratio of common technique with distances of each observational station of different viewpoints. In addition, after comparing the time sequence of productivity, it divides the cause of change into technical efficiency and change of technology and then divides technical efficiency into change of pure technical efficiency and that of efficiency of scale. It also finds the factors that changed productivity by defining them[4]. Productivity we mention here is defined as a value of output divided by input. Its concept is similar to that of efficiency. However, the concept of efficiency often shows relative efficiency which is an efficiency of observed value of the analyzed subject compared to the maximum efficiency, while productivity is generally defined as an output value compared with input. The change index of productivity is an index that shows how much productivity has changed over in between two points. It is usually expressed as a productive ratio of the current state compared with the previous one. If the Malmquist productivity change index is higher than 1, it means the ratio of output compared with input at *t* point has increased comparing to the ratio at *t*+1 point. Therefore, productivity is increased. In order to read the productivity change index intuitively, we can look into the change of percentage of productivity using. $(M_0 - 1) \cdot 100$ Meanwhile, expressing the productivity change index on the basis of production possibility set at a certain point is not always correct. Therefore, it is proper to define it with the Malmquist productivity index by calculating the Malmquist productivity change index in geometric average on the basis of each point like equation 3.4[14].

$$M_0^{t,t+1}\left(x^t, x^{t+1}, y^{t+1}\right)$$

$$= \left[M_0^t \cdot M_0^{t+1}\right]^{1/2} = \left[\left[\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right] \cdot \left[\left[\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right]\right]\right]^{1/2} \quad 3.4$$

Meanwhile, the Malmquist index of geometric average of output standard of equation 3.4 can be divided into rate of efficiency change (EC) and rate of technical change (TC).

If EC is more than 1 (EC>1), it means it has moved closer to productivity change at *t*+1 point compared to that at *t* point. On the other hand, if EC is lesser than 1 (EC<1), it has moved further away from productivity change at *t*+1 compared to that at *t*. Next if productivity change enlarges, the possibility to produce more output with the same input level increases. It is called technological advances (TC>1), and it is called technical regression (TC<1), if it is in the inverse case.

$$M_0^{t,t+1}\left(x^t, y^t, x^{t+1}, y^{t+}\right) = EC \times TC \quad 3.5$$

4. Analysis and Conclusion

4.1 Efficiency Analysis

There are three ways to evaluate management efficiency: weighted average method, measurement model, DEA analysis. This study uses DEA analysis which is a non-parametric method according to linear programming. DEA analysis is distinguished into the input oriented model and the output oriented model. While fixing the value of output, this study obtained the value of efficiency using equation 3.1 and 3.2 and measured the efficiency of scale using equation 3.3. DMU showed above average efficiency. 12 DMUs in CRS, which is 45.2%, and 9 DMUs in the VRS model, which is 29.0% showed above average efficiency. However, since 14 businesses (45.2%) including ISU showed efficiency of scale below average, it indicates that management efficiency of Korean U-healthcare businesses is not relatively high. On the contrary, both 'im' and 'Osstem' showed 1 in the value of efficiency. Of course such consequence may be caused by the limit of data envelopment analysis, the result of which changes depending on DMU's selection and comparison of input and output variables. Therefore, it is necessary to caution on its generalization. However, when we look at into profit size in Table 5, the results show that only two businesses in CRS state run at optimum size which has the same increase rate in input and output, and as the remaining 17 businesses which are in IRS state have a greater increase rate of output than that of input, their achievement can be lifted if more investment is made. On the contrary, 'Celltrion' and 'CHA' that are in DRS state cannot obtain greater achievement in output products even if they are invested more than optimal size because the increase rate of output is lesser than that of input. Next, in CCR and BCC model analysis using the

Table 5. Relative Efficiency of 31 DMUS

DMU	CRS	VRS	SE	return to scale
Insung	0.9324	0.9406	0.9913	IRS
UBcare	0.2631	0.3290	0.7997	IRS
Bit	0.3223	0.5779	0.5577	IRS
NanoEnTek	0.1578	0.6738	0.2342	IRS
DIO	0.6102	0.6718	0.9083	IRS
Lutronic	0.6287	0.8031	0.7828	IRS
MacroGen	0.8971	1	0.8971	IRS
Medipost	0.5598	0.9552	0.5861	IRS
Binex	0.3388	0.4159	0.8146	IRS
Bioneer	0.2220	0.5290	0.4197	IRS
Bioland	0.7499	0.7837	0.9569	IRS
Biospace	0.2749	0.6192	0.4440	IRS
Vartech	0.9081	0.9236	0.9832	IRS
Vieworks	0.7417	1	0.7417	IRS
Seowoon	0.7127	0.8330	0.8556	IRS
Cellumed	0.2847	0.6072	0.4689	IRS
Celltrion	0.4130	1	0.4130	DRS
SOLCO	0.1918	0.3800	0.5047	IRS
Seegene	0.6048	0.7430	0.8140	IRS
isens	0.8776	0.9328	0.9408	IRS
im	1	1	1	CRS
Oscotec	0.2508	1	0.2508	IRS
Osstem	1	1	1	CRS
Winnova	0.3912	0.7302	0.5357	IRS
ISU	0.0813	0.7036	0.1155	IRS
infopia	0.8478	0.9075	0.9342	IRS
Infinitt	0.2881	0.3786	0.7610	IRS
IlShin	0.2525	1	0.2525	IRS
CHA	0.5348	0.7576	0.7059	DRS
Theracen	0.2970	0.4212	0.7051	IRS
Huvitz	0.8889	0.9524	0.9333	IRS
mean	0.5330	0.7603	0.6873	

DEA technique, the number of reference for benchmarking and value of reference which is required for certain DMU to satisfy efficiency can be calculated. Among 31 DMU concerned in this study, 'MacroGen', which has been referred to 16 times, shows the greatest benchmarking, and the following are 'im', 17 times, and 'Vieworks', 13 times.

Table 6 shows the portion of excessive input in order to correct inefficiency. As the target value of input is always less than or the same as the real value, the number for input shows the degree of current surplus[22]. For example, in the case of 'Insung', it can enhance its efficiency by reducing 10 employees from its current employees. However, since it is a result which does not concern other variables and conditions, it can be used only as a reference but nothing more.

Table 6. Improvement Target of Inefficiency

DMU	capital	worker
Insung	503.829	10.184
UBcare	13516.796	188.562
Bit	3509.218	61.217
NanoEnTek	3173.662	28.708
DIO	1957.234	88.634
Lutronic	1001.841	36.431
MacroGen	0	0
Medipost	160.193	6.353
Binex	6979.49	186.321
Bioneer	2952.666	131.398
Bioland	1622.632	43.05
Biospace	2605.825	50.659
Vartech	567.279	20.094
Vieworks	0	0
Seowoon	731.712	35.408
Cellumed	51018.746	41.634
Celltrion	0	0
SOLCO	16853.453	108.494
Seegene	1682.952	46.769
isens	271.352	29.684
im	0	0
Oscotec	0	0
Osstem	0	0
Winnova	20789.621	25.086
ISU	1666.35	29.64
infopia	401.983	22.305
Infinitt	7560.456	210.661
IlShin	0	0
CHA	14335.175	62.534
Theracen	7887.658	122.702
Huvitz	250.025	8.338

4.2 Malmquist Productivity Analysis

There are various analyzing methods such as functional approach, ratio analysis, etc. Malmquist productivity analysis is an analysis based on the DEA model suggested by S. Malmquist, an economic scholar from Sweden. Later this analysis was advanced to an analysis based on metric function by reference[2] and reference[5] contributed to its becoming a useful measuring tool for analyzing productivity change by dividing by the productivity index[14]. This study looked over the productivity change of 31 businesses related to the domestic U-healthcare industry using Malmquist productivity index analysis. The period of the data is between 2008 and 2012. The productivity related index can be organized with efficiency change rate (ec), technical change rate (tc), and productivity change rate (pc).

Taking Insung in Table 7, for instance, pc decreased a little to 0.9213 from 2008 (T=1) to 2009(T=2), but it slowly increased as time passed afterward, achieving 1.1306 in 2010 (T=3), 1.1858 in 2011 (T=4) and 1.2213 in 2012 (T=5). In 2012, MacroGen (1.3336), which was founded with a DNA sequence analysis service, gene transplantation, and knockout mouse supply service as its main business, showed a high pc. On the other hand, Theracen (0.6524), selling FPD manufacturing machines and healthcare items, showed the lowest pc. Meanwhile, U-healthcare industry related businesses having greater than value 1 in geometric average of productivity index, PI are shown in bold, and 19 businesses including Insung, which are 61.3% of 31 businesses, are marked bold. Seegene (1.4468) showed the highest geometric average of pc, and Biospace (0.9036) had the lowest one. Low pc means that the rate of output compared with output decreased as time passed, and particularly businesses having pc lower than average (1.0597) need to put more effort to increase their productivity.

4.3 Statistical Analysis

Analysis in order to determine whether the location of the U-Healthcare businesses affects its efficiency or not, we used the non-parametric Mann-Whitney test to verify that the industries' efficiency difference according to their locations is valid statistically[20]. As shown in Table 9, Seoul's efficiency average is higher than other regions' average. In CRS and CE, however, all of CRS, VRS, and SE showed a significance level of about 5%, which means that the difference between the two regions is not very significant. Therefore, in the perspective of efficiency, the site of the U-Healthcare industry does not have a big influence.

5. Conclusion

The development of the information technology in the special environment, where population aging becomes consistent and the medical service is rapidly being advanced, makes the realistic realization of U-Healthcare

Table 7. Malmquist Productivity Index

DMU	T=2			T=3		
	ec	tc	pc	ec	tc	pc
Insung	0.7896	1.1667	0.9213	1.4502	0.7796	1.1306
UBcare	0.7523	1.4242	1.0715	1.4940	0.7579	1.1324
Bit	0.8874	1.1700	1.0384	1.4720	0.7808	1.1494
NanoEnTek	1.0542	1.4242	1.5015	1.2421	0.7579	0.9414
DIO	.0.8536	1.2137	1.0361	1.2399	0.8340	1.0341
Lutronic	1.0659	1.2008	1.2799	1.1841	0.8337	0.9872
MacroGen	0.4511	1.1418	0.5151	2.3349	0.8127	1.8977
Medipost	0.7836	1.1902	0.9327	1.8149	0.8110	1.4719
Binex	0.7073	1.1913	0.7527	1.6260	0.8174	1.3291
Bioneer	1.5527	1.1981	1.8605	1.7763	0.8336	0.6471
Bioland	1.1328	1.2045	1.3646	0.8361	0.8174	0.6835
Biospace	1.3218	1.1842	1.5728	1.6050	0.7905	0.4783
Vartech	1.0258	1.1867	1.2174	1.0000	0.8275	0.8275
Vieworks	0.8370	1.1745	0.9830	1.4352	0.7884	1.1316
Seowoon	0.5142	1.1555	0.5942	1.3644	0.8430	1.1503
Cellumed	3.0199	1.4242	4.3012	0.9799	0.7579	0.7427
Celltrion	1.1374	1.4242	1.6200	1.2143	0.7579	0.9204
SOLCO	0.7860	1.4242	1.1195	1.2620	0.7579	0.9565
Seegene	2.4762	1.1784	2.9180	1.0848	0.7881	0.8550
isens	1.8155	1.0314	1.87725	1.1617	0.8154	0.9473
im	1.0000	1.2856	1.2856	1.0000	0.7590	0.7590
Oscotec	0.7623	1.1665	0.8892	1.5110	0.7654	1.1566
Osstem	0.8348	1.0380	0.8665	1.1223	0.8145	0.9142
Winnova	1.5104	1.2878	1.9451	1.4497	0.7657	1.1101
ISU	0.4993	1.1730	0.5857	1.7166	0.7767	1.3333
infopia	0.6137	1.1984	0.7355	1.5238	0.8226	1.2536
Infinitt	0.9216	1.1815	1.0889	1.2144	0.7901	0.9595
IlShin	1.0449	1.1704	1.2231	1.3650	0.7793	1.0637
CHA	0.5056	1.3788	0.6972	1.0334	0.7601	0.7856
Theracen	0.5202	1.4242	0.7409	1.3634	0.7610	1.0375
Huvitz	1.0216	1.1812	1.2067	1.4252	0.7994	1.1394
DMU	**T=4**			**T=5**		
	ec	tc	pc	ec	tc	pc
Insung	1.4960	0.7926	1.1858	1.1286	1.0821	1.2213
UBcare	1.4016	0.6546	0.9176	0.9015	1.2568	1.1330
Bit	1.2506	0.7707	0.9639	0.9158	1.1355	1.0399
NanoEnTek	0.9673	0.6262	0.6058	0.7756	1.2598	0.9772
DIO	1.1449	0.8443	0.9667	1.0424	1.0088	1.0516
Lutronic	1.0785	0.8528	0.9198	1.0739	0.9923	1.0658

Continued

Table 7. *Continued*

MacroGen	1.3805	0.9123	1.2595	1.2728	1.0486	1.3336
Medipost	1.3900	0.8715	1.2115	1.0815	0.9924	1.0733
Binex	1.1803	0.8683	1.0249	0.8118	0.9783	0.7942
Bioneer	1.2398	0.8521	1.0566	0.9099	1.0114	0.9203
Bioland	1.2103	0.8697	1.0527	1.0934	0.9752	1.0663
Biospace	1.1665	0.7513	0.8765	0.9071	1.1147	1.0112
Vartech	1.0000	0.8638	0.8638	0.9080	0.9820	0.8917
Vieworks	1.0000	0.7950	0.7951	1.1291	1.0853	1.2255
Seowoon	1.3602	0.7593	1.1553	1.1267	1.0152	1.1439
Cellumed	1.4650	0.6262	0.9175	0.6331	1.2598	0.7976
Celltrion	1.8503	0.6417	1.1874	0.7528	1.2598	0.9484
SOLCO	1.5669	0.6262	0.9813	0.9047	1.2598	1.1398
Seegene	1.9101	0.7758	1.4820	1.1543	1.0264	1.1849
isens	0.7676	1.0377	0.7966	1.1433	1.0789	1.2335
im	1.0000	0.6500	0.6500	1.0000	1.2744	1.2744
Oscotec	1.4262	0.6262	0.8932	0.7707	1.2598	0.9702
Osstem	1.0672	1.0635	1.1350	1.0000	1.1274	1.1274
Winnova	2.5754	0.6262	1.6129	0.6034	1.2598	0.7603
ISU	1.4713	0.7538	1.1092	0.9207	1.1504	1.0592
infopia	1.1103	0.8816	0.9789	0.9754	1.0303	1.0050
Infinitt	1.1642	0.8389	0.9766	0.8926	0.9903	0.8840
IlShin	0.7964	0.7850	0.6252	1.1596	1.1465	1.3295
CHA	1.9963	0.6472	1.2921	1.1756	1.2598	1.4811
Theracen	2.0828	0.7114	1.4818	0.5516	1.1828	0.6524
Huvitz	1.3140	0.8700	1.1432	1.0707	0.9813	1.0508

Table 8. Geometric Mean of Productivity Index

Insung	UBcare	Bit	NanoEnTek	DIO	Lutronic	MacroGen	Medipost
1.1082	**1.0598**	**1.0458**	0.9564	0.9564	**1.0549**	**1.1320**	**1.1559**
Binex	Bioneer	Bioland	Biospace	Vartech	Vieworks	Seowoon	Cellumed
0.9771	**1.0402**	**1.0115**	0.9036	0.9386	**1.0204**	0.9749	**1.2365**
Celltrion	SOLCO	Seegene	isens	im	Oscotec	Osstem	Winnova
1.1383	**1.0462**	**1.4468**	**1.1490**	0.9482	0.9716	**1.0034**	**1.2765**
ISU	infopia	Infinitt	IlShin	CHA	Theracen	Huvitz	mean
0.9787	0.9759	0.9745	**1.0198**	**1.0118**	0.9258	**1.1337**	1.0597

come true. Thus, it is creating more new businesses and making potential growth of these industries possible. Ubiquitous computing, which means an 'anywhere, any-time' computing environment, happens when various computers become one of us and the environment, and get connected so that it can provide convenient computing anywhere. U-Healthcare can be classified into U-Hospital, Home & Mobile Healthcare and Wellness. According to ETRI's (Electronics and Telecommunications Research Institute) expectation, the size of the U-Healthcare

Table 9. Mann-Whitney Test of Efficiency (Seoul vs. Other Regions)

	mean	U	p-value
CRS	0.538(seoul) 0.529(other)	111.5	0.921
VRS	0.729 0.779	97.0	0.509
SE	0.707	105.5	0.743

market after 2014 will be over 1.8 trillion Korean won if we add the whole of the expenses of U-Health service, Individual U-Healthcare Service, and the money people spend on buying their smart devices. Like this, because of the rapid development of IT based on smart devices, Korea's U-Healthcare is expected to develop over time and have a huge impact on our economy. In this study, we researched U-Healthcare industries' state longitudinally and cross-sectionally. As a result, we discovered the following things.

First, according to cross-sectional analysis with DEA, 45.2% of CRS models, which was 12, and 29.0% of DMUs, which was 9, showed an over average efficiency. However, since 14 industries (45.2% of all) showed a managing efficiency below than average, Korea's U-Healthcare industries' management efficiency is not very high. Next, with regards to returns to scales, only 2 industries in CRS state are managing their business in a perfect condition in which the increase in the rate of input and output is identical. The other 17 IRS state businesses have a higher increased rate of output than the increased rate of input, so these businesses' results can be improved with more investment. We strongly recommend these businesses to invest more for their future. Third, according to the geometric average of Malmquist PI, there were 19 of 31, which are 61.3% of them, businesses that scored over 1 including Insung. The DMU that had the highest geometric average of PI is Seegene (1.4468) and the one with the lowest geometric average of PI is Biospace (0.9036). Low PI means a decreased outcome ratio with the same input, so industries that showed a PI of below average (1.0597) need to work hard in order to boost their productivity. Fourth, as we have used the non-parametric Mann-Whitney test to see that industries' efficiency difference between regions is valid statistically, all of CRS, VRS, and SE showed a significance level of about 5%, which means that the difference in location does not mean much to industries' efficiency.

As written above, the prospects of the U-healthcare industry in and out of Korea are believed to advance more over time. However, as our study shows, Korea's U-Healthcares' efficiency is not that high. So, for these industries' efficiency boost, the government's medium and long-term U-Healthcare plans' smooth implementation, plans for the activation of the U-Healthcare industry, new businesses that merge IT and U-Healthcare and U-Healthcare's connection with public health should be provided. This study showed the efficiency of Korea's U-Healthcare industry, but caution should be taken when generalizing our results. This is because relative efficiency analysis's results may differ when you change the comparison objects or input/output variables. Although this is true, this study has its own significance to be the first study to measure the change of efficiency and productivity of domestic U-Healthcare businesses through the Malmquist index and DEA and to be considered to contribute to raising the efficiency of the U-Healthcare industry in Korea.

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