EMPIRICAL ANALYSIS OF THE EFFICIENCY IN LOCAL WATERWORKS

By

YUN, Youngmin

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

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Committee in charge:

Professor Jongyearn Lee, Supervisor ____________________

Professor Nahm Chung JUNG ____________________

Professor Taejun LEE 이 태준 ____________________

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Table of Contents

I. Executive Summary

The purpose of this study is to measure the efficiency of local waterworks according to operation types and to derive the factors influencing the efficiency of local waterworks. For the empirical analysis, panel data on waterworks for 10 years from 2006 to 2015 is used for 128 local governments.

As a result of analysis, efficiency analysis by DEA method in 2015 reveals that 26 local governments are efficient. All efficiency indexes of the contracting-out regions are higher than that those of regions operated by local governments, and the difference of efficient indexes according to operation type is statistically significant. Second, the result of dynamic analysis by DEA/Window method also shows a higher efficiency index for trustees during10 years. Last, the research confirms the influence factors such as operation type, population density, pipe length and so on which affect the efficiency of local waterworks by fixed effect model.

Operation type has a positive relationship with efficiency index. It shows that contracting-out areas are more efficient than direct operation by local governments, which is robust results in various models. Pipe length and population density are both positively related to the efficiency index of local waterworks which means the economy of scale affects the efficiency index of local waterworks. Revenue rate of contracting-out regions is higher than that directly operated by local governments and rate of realization cost is also positive related with revenue rate. In the case of the total unit cost, Operation type does not have robustness, and the rate of realization cost, percentage of water produced by local governments and the population density show a significantly negative relationship. Therefore, to reduce the total unit cost, local governments should try to increase rate of realization cost and population density.

II. Introduction

Waterworks business is the representative local public service in Korea, and 161 local governments currently provide water supply services. However, the local waterworks business in Korea is suffering from the inefficiency due to low revenue rate, overlapping investments according to division in a simple administrative district and low rate of realization cost which means the rate of average sale price per 1 ton to total unit cost. According to the waterworks statistics of 2015, the amount of water supplied is about 6.3 billion tons, of which about 680 million tons of water is estimated to have disappeared into the ground. The rate of realization cost is only about 77.5% on average in Korea. 57 local governments are operating at a rate of less than 50%, which is 35% of the total local governments (Ministry of Environment, 2017). 51 local governments had the deficit with waterworks business for the fifth consecutive year in 2016 (Ministry of the Interior and Safety, 2017). As a result, the efficiency of local waterworks has become an important issue.

In order to overcome the problem caused by the inefficient operation of local water supply business, some municipalities introduced contracting-out by specialized public enterprises to increase the efficiency of the water service. Starting in Nonsan in 2004, so far 23 local governments contracted local waterworks out to K-water or Korea Environment Corporation. However, there is controversy as to whether the efficiency of local waterworks business has improved due to contracting-out and the use of multi-regional waterworks. Therefore, it is very important to analyze whether the inefficiency of local waterworks business is overcome by contracting-out and change of operation form.

The purpose of this study is to measure the efficiency of local waterworks according to operation types, to derive the factors influencing the efficiency of local waterworks and to present some policies for improving the efficiency of local waterworks. For the empirical analysis, panel data on waterworks for 10 years from 2006 to 2015 is used for 128 local governments.

Following Chapter 1 Introduction, Chapter 2 covers the overall situation of local water business and literature review. and Chapter3 contains the methodology of the research. The analysis of the efficiency of local waterworks in Chapter 4 and determinants affecting the efficiency in Chapter 5 are covered. Lastly, Chapter 6 focuses on proposals and further direction for local waterworks policies to overcome the inefficiency.

III. Literature Review

1. Status of local waterworks

In 2018, 161 local governments are operating individual local waterworks. Of these, 135 local governments are in operation directly and 26 of them have changed into contracting-out since 2004. The reason why the increase in the number of private trust agency is due to the revision of the water supply and waterworks installation act in 2006. The local government has expanded the operation of specialized institutions such as Korea Water Resources Corporation (K-water), Korea Environment Corporation (KECO) in order to efficiently operate and manage the waterworks business on the basis of the article 23 of the water supply and waterworks installation act as shown in Appendix1. According to the waterworks statistics of 2015 in Appendix2, the overall water supply rate in Korea is 96.5%. The rate of realization cost is close to the total unit cost of 77.5%. However, this is also attributed to the number of metropolitan areas with high population density including 89.6% in Seoul, 102.5% in Incheon and 84.6% in Gyeonggi. Even in Gangwon (56.3%) and Gyeongbuk (59.2%), the rate of realization cost is below 60%, which can be a serious burden on the future sustainability of local waterworks.

The total revenue rate in 2015 is 84.3%, which is 90% higher in most metropolitan city and metropolitan areas, including 95.1% in Seoul, 91.7% in Busan and 89.1% in Gyeonggi. On the other hand, 44.5% of Jeju, 68.5% of Jeonnam (=Jeonbuk), 69% of Gyeongbuk and 70.5% of Gangwon show low revenue rates of around 70%. The low revenue rate means losses that cannot be recovered by charges due to water leakage during the supply process, which increases the financial burden of local governments. Therefore, it can be estimated that the inefficiency is scattered in the financial and the operational aspect of the waterworks business, and it can be predicted that the inefficiency difference is deepen according to the scale of the region.

2. Literature Review

Currently, most of local governments are suffering from the inefficient of waterworks business due to various problems such as a poor finance and low revenue water rate etc. Therefore, in order to overcome the inefficiency of local waterworks, various researches have been actively discussed on the efficiency of local waterworks business

In terms of the methodology, early researches have analyzed the efficiency of the local waterworks business by applying Data Envelopment Analysis (DEA) on the cross-sectional data (Won 1998; Ko 2001) and there was a comparative analysis of the efficiency of local waterworks by operators (Lee 2004; Ko et al. 2008). In recent years, advanced DEA methods like Malmquist analysis (Kim 2011) and Window analysis (Ko 2016; Seo et al. 2016) are shown since gathering a lot of data from early 2000s. In addition to the analysis on the efficiency of local waterworks, studies on affecting factors on the efficiency of local waterworks using the panel regression analysis (Park & Kim 2014) or the panel tobit regression analysis (Yu 2014; Seo et al. 2016).

This research focuses on previous studies on the effects of contracting-out on the efficiency of local waterworks by using DEA/Window analysis method. There is controversy whether the contracting-out is helpful to improve the efficiency of local waterworks. Therefore, studies that analyze the efficiency of local waterworks by operation type have shown significant deviations from results.

Won (2010), Kim (2012) and Ko (2016) showed that the efficiency of contracting-out was higher than that of local governments. Won (2010) estimated the efficiency of 48 cities through data envelopment analysis based on cross-sectional data of 200, analyzed the difference in the efficiency between contracting-out and local governments through T-test and examined the factors influencing the efficiency by using logistic regression analysis. As a result, the efficiency of contracting-out was higher than that of local governments, and the difference in efficiency was attributed to the general administrative expenses. Kim (2012) estimated the efficiency of 70 cities using the Stochastic Frontier Analysis (SFA) method, and then compared the difference in efficiency between contracting-out and local governments. Subsequently, the improvement rate of efficiency of public enterprises was higher than that of local governments. In particular, Ko (2016) measured the relative efficiency of the nationwide waterworks from 2006 to 2012 using Window analysis to examine the efficiency change. Consequently, the change in efficiency has been greater after the implementation of contracting-out. This study is similar to this research in that it analyzed the efficiency of the nationwide local waterworks. However, this study fails to verify whether there is a difference in efficiency between contracting-out regions and areas operated by local governments

On the other hand, research by Lee (2004), Jang & Shin (2009) and You (2014) showed that the contracting-out does not have a statistically significant effect on efficiency. Lee (2004) conducted DEA using cross-sectional data for 71 cities. As a result, it was found that there was no significant effect of contracting-out on efficiency. Jang and Shin (2009) showed that the contracting-out did not always lead to reduction of production cost as a result of analyzing the panel data for six years from 2002 to 2007. Yu (2014) estimated the effectiveness of applying DEA to 91 local governments using data for three years. In order to verify the efficiency by contracting-out, a regression analysis was conducted. Accordingly, it was found that the results did not have a statistically significant effect on the efficiency. This study is very similar to my research in terms of the research procedure. However, as this study is limited to the analysis subject and a short time, it is difficult to generalize the analysis result.

Therefore, the research analyzes the efficiency by applying the quantitative methodology and verify whether there is a difference between the efficiency of contracting-out and local governments based on statistics method. In addition, while previous studies used only limited data for a single year or short period, this research analyzes the efficiency of the past 10 years from 2006 to 2015. It is helpful to increase the generalization of analysis results by reflecting the change in a long time and verifying the difference between the efficiency of regions by contracting out and that of regions by operated by local governments. And the research estimates the determinants to affect the efficiency of local waterworks.

IV. Research Question & Hypothesis

The research question and hypotheses to analyze the efficiency of local waterworks is as follows

1. Research Question

   What is the determinant that affect the efficiency of local water service?"

2. Research Hypothesis

Operation Type would affect increasing the efficiency, revenue rate and total unit cost of local waterworks.

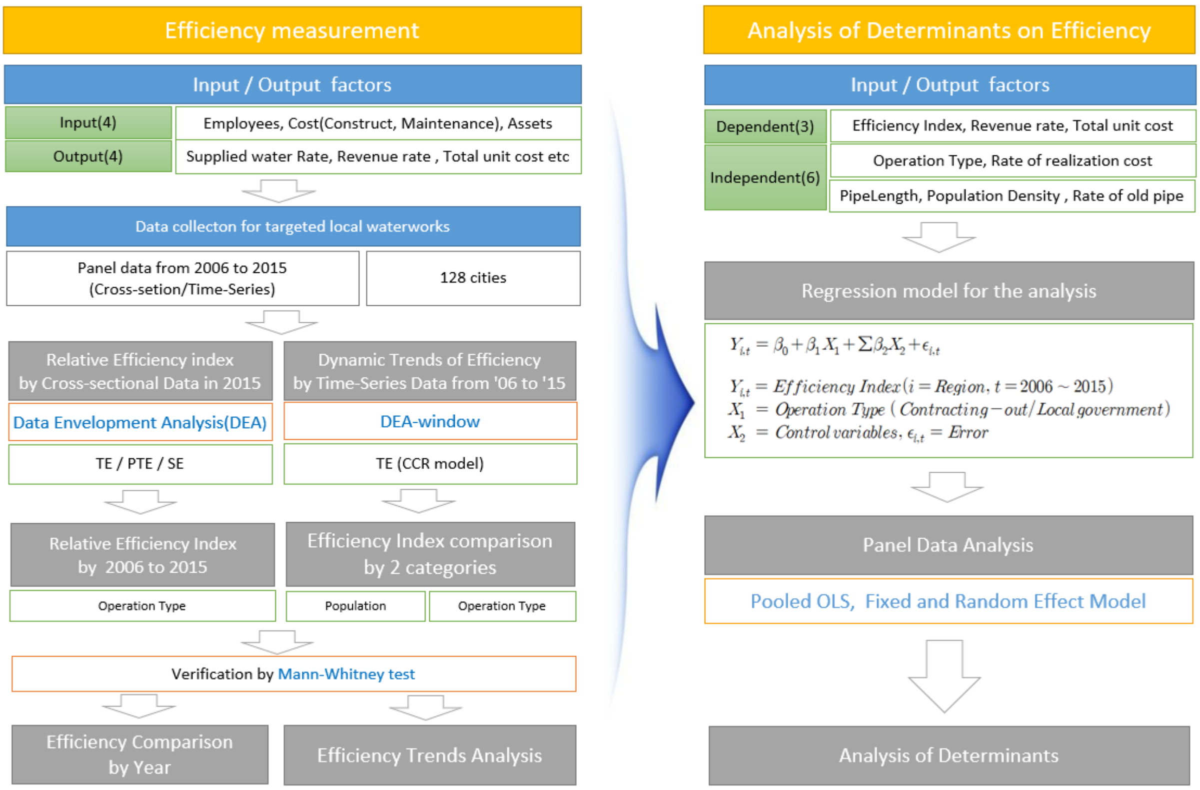
V. Method

1. Research model and method (DEA/Window, Fixed/Random effect)

1) Research model

The purpose of this research is to measure the efficiency of both trust agency and local government providing the water service and to analyze what factors affect the efficiency. To get the purpose. This research consists of two parts: Efficiency measurement, Analysis of determinants. In the efficiency measurement part, the research analyzes technical efficiency, pure technical efficiency and scale efficiency by CCR and BCC model in DEA method. And to check the trend of efficiency, DEA/Window method using input-oriented model are performed, which is an analytical method to estimate the rate at which inputs can be reduced as much as possible while the level of output is fixed in the Decision-Making Unit (DMU). And DEA/Window model is used to analyze the dynamics changes in the efficiency of local government using multi-year data. In the analysis of determinants part, the efficiency index obtained through the DEA/Window method and important factor evaluating the efficiency such as revenue rate and total unit cost are used as dependent variables, and research selects the important independent variables for operation type and water production rate by local government. To find the determinants affecting the efficiency, the research applies pooled OLS, fixed effect and Random effect model with panel data. And the research estimates the optimal model through comparing three model and verifying the results. Finally, the research finds the determinants to affect the efficiency in local waterworks with the optimal regression model. The research flow chart is as follows

< Figure1> Research Flowchart



2) Research method for analysis of efficiency

DEA (Data Envelopment Analysis) methodology was developed by Ferrier, Charnes and Cooper in 1957 and is an analytical technique that measures the efficiency by nonparametric methods. In the meantime, studies using DEA analysis have been applied to public institutions and public service efficiency analysis such as public health centers, public hospitals, water and sewage projects (Kim 2011). The DEA methodology is a kind of linear programming that is used to evaluate the relative efficiency of DMU organized for the purpose of producing multiple outputs using multiple inputs (Ko et al. 2008). Therefore, it can apply to measure the efficiency of nonprofit or government agencies that do not have market prices (Kim and Kim 2001:63). The DEA methodology selects reference groups based on similar input and output structures and measures the relative efficiency. However, since statistical significance tests to verify the validity of the DEA methodology are not discussed, it is necessary to be careful in selecting DMU and selecting input and output factors. In addition, the researcher should raise a fundamental question as to whether the selected input and output valuables can cover the entire administrative agency. In order to utilize the DEA methodology, it is necessary to identify clearly the specific function of the institution (Kim 2000).

The basic DEA model is divided into two major methods depending on assumptions about returns to scale. One model developed by of Charnes, Cooper and Rhodes (1978) is to assume unchanged return to scale and is called constant return to scale DEA or CCR model. Another model developed by Banker, R.D., Charnes, A. & Cooper, W.W. (1984) is to assume variable return to scale and is called a variable return to scale DEA or BCC model. And DEA model is divided into input-oriented or output-oriented models depending on the purpose. An input - oriented model aims at producing a given output using a minimum input, while an output - oriented model is designed to maximize outputs with a given input. CCR model measures the technical efficiency (TE) under the assumption of constant return to scale (CRS). This means that the output changes at a constant rate even with the increase in inputs. On the other hand, the BCC model reflects the variable returns to scale (VRS) and measures the pure technical efficiency (PTE) obtained from a given production scale. In other words, considering the change of efficiency in operation and technology, it means that the rate of increase and decrease in the output varies with those in the input. Alternatively, the Scale Efficiency (SE) is calculated by dividing PTE by TE value, which can be correlated with the appropriate scale and efficiency of the scale (Seo et al. 2016). Among the various models of DEA, technical efficiency is analyzed based on input-oriented CCR model. In addition, PTE and SE are also compared together. After measurement, it estimates the relative efficiency according to each population, population density, and operation types. The results are verified by rank-sum test which is nonparametric difference test developed by Wilcoxon Mann-Whitney (Park 2008).

Second, this research uses the DEA/Window model to analyze the dynamics and stability of the efficiency changes by using the data from 2006 to 2015. DEA can measure the efficiency of DMU without the need for a separate conversion process between each input and output variables with different units of measurement. In addition to provide information on the DMU to be benchmarked, DEA is recognized as a useful efficiency measurement model. But DEA reveals the limitation that it cannot observe the change in the efficiency of time-series. To overcome the shortcomings of DEA, Charnes, Clark, Cooper, and Golany in 1985 proposed a DEA-window model to track DMU's time-series efficiency changes. The DEA/Window method is based on the DEA model. But it can confirm trends and stability. And it has the advantage to analyze the efficiency at various points such as time-series periods (Mun 2009: 67). DEW/Window method divides the time series data into specific sections by window and analyzes data by considering DMU in window as the same DMU (Seo et al. 2016). For example, after collecting data over k periods for n DMU, the width of the window, the number of windows, and the number of DMU for each window can be calculated as shown in Appendix3. This Research measures technology efficiency using input - oriented CCR model with DEA/Window.

3) Research method for determinants affecting the efficiency of local waterworks

After measuring efficiency, the research uses Panel analysis model to analyze the factors affecting efficiency. Panel analysis is one of the regression analysis methods that performs time-series and cross -sectional analysis at the same time using panel data. In particular, panel data covered by panel analysis provides multidimensional information. Panel data has time-series data information as well as cross-sectional data information, so that additional information cannot be obtained from the time-series or cross-sectional analysis alone. Panel analysis model settings vary depending on how the heterogeneity effect, i.e., individual effect and time effect, is considered among remaining error terms which is not observed and explained. Panel analysis model is expressed as regression model as follows.

<Figure 2> Simple panel regression

$Y_{i \cdot t} = a + X_{i \cdot t}\beta + \epsilon_{i \cdot t}$

($\epsilon_{i \cdot t} = \mu_i + \lambda_t + \nu_{i \cdot t}$, i (Region) = 1, 2....N , t (Year) = 1, 2....T)

μ_i = unobservable individual effect

λ_t = unobservable time effect

$\nu_{i \cdot t}$ =remainder stochastic disturbance term

The panel analysis model assumes that unobserved heterogeneity effects such as individual effect and time effect is probabilistic and considers them as fixed parameters. The former is referred to as the random effect model and the latter as the fixed effect model. In the panel analysis, the choice of the fixed effect and the random effect model depends on whether there is a correlation between the individual effect and the independent variables. In other words, if there is a correlation between the individual effect and the independent variables, a fixed effect model should be selected. If there is no correlation between the individual effect and the independent variables, the random effect model should be selected. Therefore, this research analyzes both the fixed effect panel regression model and the random effect panel regression model as an analytical tool for the effect of the operation type of local waterworks on the efficiency and estimates the better model through the Hausman test, which is a hypothesis test for the selection of the fixed effect and the random effect model by analyzing the correlation between individual effect and independent variables. The regression model to be analyzed in this study is as follows.

<Figure 3> Regression Model in the research

$$Eff_{i,t} = \beta_0 + \beta_1 ContO_{i,t} + \beta_2 LongP_{i,t} + \beta_3 CostR_{i,t} + \beta_4 OwnP_{i,t} + \beta_5 Old + \beta_6 Log(DenP_{i,t}) + YearN_t + \epsilon_{i,t}$$

- $Eff_{i,t} = Percentage\,of\,Efficiency\ (i = Region,\ t = 2006 \sim 2015)$
- $ContO_{i,t} = Contracting - Out\ (Dummy\ Variable)$
- $LongP_{i,t} = Length\,of\,Pipe$
- $CostR_{i,t} = Rate\,of\,Realization\ Cost$
- $OwnP_{i,t} = Rate\,of\ water\,Production\,by\,Local\,governmnet$
- $OldP_{i,t} = Rate\,of\ Oldpipe\,by\,annual$
- $DenP_{i,t} = Population\ Density$
- $YearN_t = Year\,of\,Dummy$
- $\epsilon_{i,t} = Error\ term$

2. Research Target and Variables

1) Analysis target and data collection

In order to compare the efficiency among local governments and analyze determinants affecting the efficiency, this research selects 128 cities with less than 300 thousand people based on 2015 and excludes metropolitan cities due to the considerable size, labor and financial differences. This research is based on the quantitative study. Since the local waterworks project has a large efficient fluctuation depending on the capital investment and contracting-out, it is necessary to analyze through the balanced panel data from 2006 to 2015. Data collection period is set to 10 years from 2006 to 2015. In order to maintain the objectivity of the analysis data, this research uses 'The Statistics of Waterworks' published by the ministry of environment, 'The Local Public Enterprise Balance sheet and Management Analysis' published by the ministry of government administration and home affairs and 'population census' in Korean statistical Information service. The research uses Win4Deap2 (ver2.1) and EMS (ver1.3) to measure the efficiency index with this data and the research analyze the regression model by STATA 14.2.

2) Variables for DEA and regression model

Selecting input and output variables to measure and evaluate efficiency using DEA method is an important basis of the research. It should not be underestimated that the relative efficiency values of Decision-Making Unit (DMU) may vary depending on the variables used in the DEA method. Especially, waterworks, which is one of representative public goods, should be carefully selected because it depends on how to select and analyze various input and output variables. For the relative efficiency analysis, the input and the output variables used in the previous studies are as follows.

< Table 1> Measurement variables used in previous studies (Kim et al. 2015)

Variables for measuring Efficiency Index	
Input	Labor cost, Goods cost, Depreciation cost, Capital cost, Operating cost(construct&maintenance), Non-operating cost, Total unit cost, Facility capacity, Number of employees, Operating facility assets, Total expenditure, Water pipe extension
Output	Population serverd, Production quantity, Water supply rate, Adjustment amount, Stability ratio, Revenue rate, Profitability ratio, Facility utilization rate,Total unit cost, Operating profit, Total Revenue, Water taps number, Water pipe extension

In previous studies, indicators for efficiency analysis or performance measurement have similar characteristics. For the efficiency analysis, manpower and capital indicators are used as input variables and indexes standing for income and performance are used as output variables. In the research, input and output variables are selected based on these indicators as follows.

< Table 2> Variables for measuring the efficiency

I/O	Meaning	Measurement Variables
Input (4)	Manpower	Number of Employees
	Capital	Construction Cost, Maintenance Cost
		Total Operating Facility Assets
Output (4)	Publicness	Water Supply Rate , Population Served
	Continuity	Total Unit Cost
	Stability	Revenue Rate

For the research, input variables consist of the number of employees, construction cost maintenance cost and total operating facility assets. The number of employees is a factor for determining the efficiency of manpower management. The construction cost refers to the total cost for the construction of facilities such as expansion and improvement in the process of water production by waterworks. Maintenance cost includes power, labor costs, Water Treatment Chemicals, purchase of water, repair and maintenance, and commission. And Total operating facility assets is used as capital indicators. The output variables consist of water supply rate, population served, total unit cost and revenue rate. The water supply rate and population served represent the improvement of services to residents and is representative of the public indicators of the waterworks business. In terms of continuity, the total unit cost means the upper limit of the price that local governments can collect for the final consumer as a charge, measures the rate of realization cost compared to average water price and the total unit cost is an index to have characteristics that indicate the financial soundness, adequacy of facility investments, and provision of necessary expenses for waterworks business (Ko 2016). And in terms of stability, the revenue rate is the most commonly used indicator of water management performance, which is the percentage of total water supply that can be charged from the quantity that the water service recognized as valid. In other words, the high revenue rate means that the water provider is managing the leaks efficiently because it manages the leakage.

At the analysis of determinants part, this research determines the variables in order to examine determinants that affect the efficiency of local waterworks business. The efficiency index derived from DEA method, revenue rate and total unit cost as well-known as main indicators of performance are used as the dependent variable in order to analyze the effect of operation type and water supply method, which are the interest of this research. The independent variables are whether the local waterworks are contracting out and whether the local waterworks uses the multi-regional water which is considered to affect the efficiency. And other independent variables include pipe length, rate of realization cost, percentage of old pipe by annual and population density taking into account the characteristics of the local waterworks business.

< Table 3> Variables of Regression in the research

Variables.		Explanation
Dependent Variables (3)	Efficiency index / Revenue rate / Total Unit Cost	Efficiency Index by DEA/Window method , Revenue Rate and Total Unit Cost : Technical Efficiency (CCR model)
Independent Variables (6)	Operation type	Contracting-out or Local Government
	Percentage of water produced by Local	Water quantity producedby local government divided by Toal Water Supply
	Pipe length	Total Pipe Length
	Rate of realization cost	Average price divided by Total unit cost
	Percentage of old pipe by annual	Percentage of pipe length Over 20yr divided by Total pipe length
	Population density	Logarithm of Population density

VI. Result of Efficiency Analysis

1. Descriptive Statistics (Periods: 2006 - 2015)

The descriptive statistics of the input and output variables used in the research from 2006 to 2015 are as follows in Table4. When it comes to input variables, the mean of number of employees are 31, the mean of construction cost is 6,044,420 thousand won, and the mean of maintenance cost is 6,014,305 thousand won. The mean of total operating facility assets is 61,420,895 thousand won. Especially, In the case of construction cost, Jeongseon shows 0 won in 2014 and 2015, and maintenance cost shows 0 won in 2012 in Andong. In the case of output variables, the mean of total unit cost is 1,377 won, water supply rate is 74%, the revenue rate is 66.6% and the Population Served is 76,104 people. The difference between the maximum and minimum values of Total unit cost is more than 10 times, and the revenue rate also shows large deviation by regions.

<Table 4> Descriptive Statistics (2006 to 2015)

Variables		N	Min	Max	Mean	SD
Input Variables	Number of Employees (people)	1280	4	112	31	18
	Construction Cost (thousand won)	1280	0	59,471,700	6,044,420	5,788,236
	Maintenance Cost (thousand won)	1280	0	77,250,281	6,014,305	6,481,760
	Total Operating Facility Assets (thousand won)	1280	5553,612	251,600,000	61,420,895	40,383,057
Output Variables	Total Unit Cost (won)	1280	404	4,661	1,377	605
	Water Supply Rate (%)	1280	27.9	100.0	74.0	17.9
	Revenue Rate (%)	1280	25.7	95.7	66.6	12.8
	Population Served (people)	1280	8,520	294,933	76,104	70,626

2. Comparison of Means according to operation type in 2015

When looking at the descriptive statistics of 2015, the mean of input and output variables except number of employees increases compared to the total mean from 2006 to 2015. This means quantitative growth in waterworks. The research verifies whether the difference of each mean according to the operation types is significant. Since the size of the sample is less than 30, the Shapiro-Wilk test is performed for normality verification. As all variables are statistically significant ($p < 0.05$), they do not follow the normal distribution. Then, the difference between two groups is tested using the Mann-Whitney U test for non-parametric statistics rather than t-test.

<Table 5> Descriptive Statistics and Comparison of Mean difference in 2015

Variables		Total			Local Gov.			Contracting-out			Mann- whitney test	
		N	Mean	SD	N	Mean	SD	N	Mean	SD	Z-value	P-value
Input Variables	Number of Employees	128	29	17	104	33	16	24	12	8	6.22	.000
	Construction Cost	128	725,1703	7,257,624	104	7,334,538	747,1159	24	6892751	6,380,683	0.39	.701
	Maintenance Cost	128	811,1885	7,842,595	104	7,837,611	8,080,202	24	9300405	6,739,689	-1.50	.133
	Operating facility assets	128	80,549,926	44,408,313	104	78,575,195	42,959,490	24	89107093	5,030,5671	-0.86	.388
Output Variables	Total Unit Raw Cost	128	1607	723	104	1554	647	24	1837	970	-1.20	.232
	Supplied Water Rate	128	82.5	13.5	104	81.6	14.0	24	86.1	10.7	-1.26	.206
	Revenue Rate	128	69.2	12.3	104	67.6	12.0	24	76.5	10.8	-3.50	.000
	Population Served	128	85,708	77,219	104	85,722	77,807	24	85,650	76,253	0.14	.888

Table 5 shows the results of examining the differences between two groups which is divided by operation type. The number of employees in local government group is higher than that of contracting-out group. In terms of revenue rate, the contracting-out group is higher than the local government group. Those two variables have a statistically significant difference. And all other variables are not statistically significant. As this result is simple comparison, the significance should be further discussed.

3. Cross-sectional analysis of Efficiency Index in 2015

The result of the efficiency analysis in 2015 using the DEA method for 128 local waterworks business is shown in Appendix 4-1. This table compares the efficiency indexes such as technical efficiency (TE, CCR model), pure technical efficiency (PTE, BCC model) and scale efficiency (SE, TE/PTE) with the reference group to determine the relative inefficiency. And Appendix4-1 also contains comprehensive results such as reference groups, which are used as a basis for measuring the efficiency, and the weight (λ, lambda), which is the reflection ratio of the reference groups. The average technical efficiency index of local waterworks in 2015 was 0.7204. 26 of 128 regions are efficient, accounting for 20%. In addition, 17 local waterworks areas with low efficiency index less than 0.5 are 13%. The efficiency index is distributed as shown in Table 6.

<Table 6> Distribution of Technical efficiency in 2015

E=Technical Efficiency	E=1	1>E>0.9	0.9>E>0.8	0.8>E>0.7	0.7>E>0.6	0.6>E>0.5	0.5>E>0.4	0.4>E>0.3	0.3>E>0.2
Freq.	26	12	8	19	16	30	12	4	1
(%)	20%	9%	6%	15%	13%	23%	9%	3%	1%

However, even if the efficiency is 1, it is difficult to say that it is a totally efficient region. Because the efficiency in DEA analysis means relative efficiency, it can be said that the agency is efficient depending on how much it contributes to the reference group. Table 7 lists the regions with the number of reference groups used to evaluate the inefficiency in the local waterworks. This means that the more frequently used reference group are, the more efficient they are.

<Table 7> Reference Counts of DMU

DMU	Reference Count	DMU	Reference Count
E6	88	H15	9
E11	55	C1	8
B5	38	C13	6
B4	31	I4	6
G3	31	B10	4
D8	25	F5	4
D10	20	B1	1
H18	20	C4	1
C9	19	D6	1
H9	17	C11	0
G13	14	F6	0
I1	12	G19	0
I6	10	G21	0

Among 26 efficient regions, E6(Gyeryong) is the most efficient, which is the highest reference counts at 88 counts. Next, it shows the number of references is higher in order of E11(Cheongyang, 55 counts), B5 (Gunpo, 38 counts), B4 (Osan, 31 counts), and G3 (Suncheon, 31 counts). Of these, 10 regions are contracting-out regions in red color. However, a detailed analysis of these areas such as B1, C4, D6, C11, F6, G19, and G21 is needed.

When analyzing by DEA models and operation type, the average technical efficiency index of the contracting-out regions in CCR model is 0.8735, which is higher than the total average (0.7204). In other models, contracting-out regions are estimated to be more efficient than regions operated by local governments. The mean difference of efficiency index between two groups is verified to be significant. First, the test of normality is performed using the Shapiro-Wilk test. As a result, the overall efficiency index does not follow the normal distribution because null hypothesis that the population is normally distributed is rejected at the 0.001 significant level. Therefore, the research tests the mean difference between the two groups using the Mann-Whitney U test for non-parametric statistics rather than t-test. As result of the efficiency comparison between the two groups as shown in Table 8, there is a significant difference in all efficiency indexes between the two groups ($p<.001$). Therefore, it shows that the average efficiency is different according to operation type, and the efficiency index of contracting-out regions is higher than that of regions operated by local governments.

<Table 8> Comparison of Efficiency index by Operation type

Model	Operation Type	N	Efficiency index		Mann-Whitney Test	
					z-value	p-value
TE(CCR)	Local gov.	104	0.7204	0.6851	-4.046	0.0001
	Contracting-out	24		0.8735		
PTE(BCC)	Local gov.	104	0.8232	0.8015	-2.189	0.0048
	Contracting-out	24		0.9172		
SE	Local gov.	104	0.8784	0.8618	-3.193	0.0014
	Contracting-out	24		0.9500		

Table 9 shows the efficiency index of contracting-out regions in 2015.

<Table 9> Reference Group of the Contracting-out regions

DMU	CCR Models (TE, CRS)	BCC Models (PTE, VRS)	SE (Scale Eff.)	Reference Group(Benchmarks)
B1	1	1	1	1
B10	1	1	1	4
B11	0.801	1	0.801	B4 (0.06) D10 (0.03) I1 (0.55) I4 (0.44)
C4	1	1	1	1
C9	1	1	1	19
C10	0.959	1	0.959	C9 (0.85) D8 (0.53)
C11	1	1	1	0
D10	1	1	1	20
E4	0.826	0.827	0.999	B4 (0.35) D10 (0.40) I4 (0.27)
E5	0.923	0.988	0.934	D10 (0.23) E6 (0.10) H15 (0.11) I1 (0.58) I4 (0.02)
E8	0.915	0.929	0.985	B1 (0.17) D10 (0.21) H15 (0.25) H18(0.29) I4 (0.01)
F2	0.698	0.853	0.818	B4 (0.30) D8 (0.10) D10 (0.26) E6 (0.09) H15 (0.10) I1 (0.25)
G4	0.72	0.738	0.976	B4 (0.25) C9 (0.12) D10 (0.39) H15 (0.24) I4 (0.03)
G12	0.893	0.91	0.981	B4 (0.01) D8 (0.35) D10 (0.09) H15 (0.46) H18 (0.10) I1 (0.02)
G17	0.806	0.876	0.92	E6 (0.07) E11 (0.08) H15 (0.74) H18 (0.03)
G20	0.514	0.721	0.712	B4 (0.01) C9 (0.30) D10 (0.05) E6 (0.99)
G21	1	1	1	0
H15	1	1	1	9
H18	1	1	1	20
H19	0.396	0.403	0.982	C13 (0.21) E6 (0.24) E11 (0.05) G13 (0.07) H9 (0.04) I6 (0.24)
I1	1	1	1	12
I2	0.788	0.799	0.987	B4 (0.32) C9 (0.07) D10 (0.05) H15 (0.49) 117 (0.09)
I4	1	1	1	6
I9	0.724	0.968	0.747	D8 (0.04) E6 (0.80) E11 (0.62) B2 (0.01)

Table 9 shows that 7 regions of B10, C9, D10, H15, H18, I1 and I4 are efficient among 24 contracting-out cities and 13 regions of B11, C10, E4, E5, E8, F2, G4, G12, G17, G20, H19, I2 and I9 are found to be inefficient. B1, C4, C11, and G21 which is scored by 1 require detailed analysis. D10 (Danyang) and H18 (Yecheon) were the most efficient cities in terms of reference count number, and H19 (Bonghwa) recorded the lowest level at 0.396.

4. The efficiency index using DEA method in 2006 to 2015

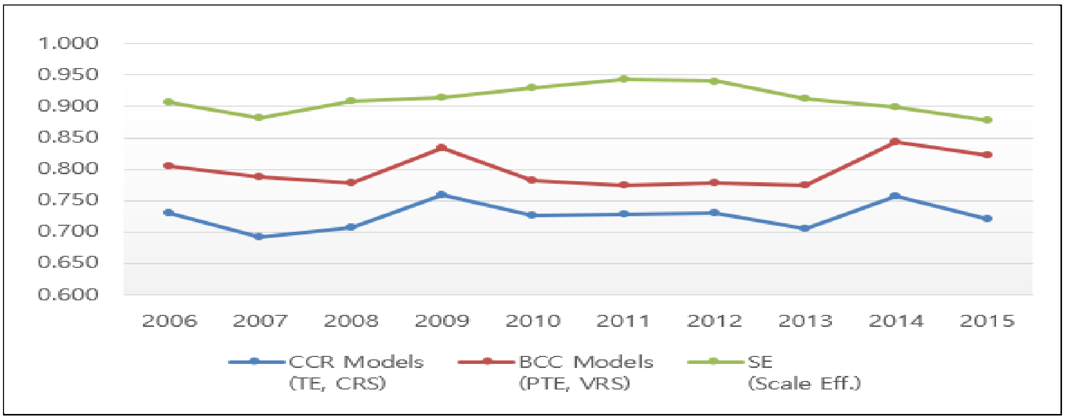
The research analyzed the annual efficiency trends of 129 local water supply operators from 2006 to 2015. The 10-year average of technical efficiency was 0.726, the highest efficiency index was 0.7592 in 2009, and the lowest was 0.6914 in 2007.

<Table 10> Efficiency Index by Year using DEA method

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
CCR Models (TE, CRS)	0.7302	0.6914	0.7080	0.7592	0.7260	0.7287	0.7292	0.7061	0.7564	0.7204	0.726
BCC Models (PTE, VRS)	0.8059	0.7885	0.7782	0.8339	0.7827	0.7740	0.7776	0.7748	0.8436	0.8232	0.798
SE (Scale Eff.)	0.9072	0.8824	0.9081	0.9142	0.9301	0.9438	0.9403	0.9133	0.8992	0.8784	0.912

The total technological efficiency (TE) for10 years is divided into pure technical efficiency and scale efficiency. The average of pure technical efficiency is 0.798 and the scale efficiency is 0.912. As shown in the figure, the trend of technical efficiency and pure technical efficiency is similar. Overall, the scale efficiency is higher than the other efficiencies.

<Figure 4> Trend of Efficiency Index by Year



The difference in the average efficiency index by operation type every year is tested using the Mann-Whitney test like that in 2015. As results, all TE index is statistically significant with a significance level of 0.05. However, PTE was not statistically significant in 2008 (p-value: 0.1035) and 2007 (p-value: 0.1002). SE was not statistically significant in 2006 (p-value: 0.3197), 2012 (p-value: 0.0825) and 2013 (p-value: 0.2961).

5. Time-series analysis using DEA/Window from 2006 to 2015

The CCR and BCC model of DEA methods have limitations that they do not measure changes in efficiency when time goes by and determine the relative efficiency of DMUs only at a single point in time. In other words, DEA has a disadvantage that it cannot consider the dynamic trend of efficiency according to the change of environment. To overcome these shortcomings, DEA / Window analysis is used to measure time-series efficiency change by using moving average. Therefore, DEA window analysis method can provide the overall dynamic trend and stability of efficiency. The analysis period in this research is 10 years from 2006 to 2015, window depth is set to 5 years (w=6, k=10, p=5) and the number of windows is 6 according to Appendix 3.

This research shows the average efficiency from 2006 to 2015 using the DEA / Window method in table9. Specific results on this are included in Appendix 4-2. Looking at Table 11 as a summary, the overall efficiency is 0.567 and increases from 0.452 in 2006 to 0.616 in 2007. However, the figures are similar in general except for 2006 and 2007. In addition, the overall result is a 0.159 decline compared with the average technical efficiency index (0.726) using DEA in Table 8,

<Table 11> Technical Efficiency index measured by DEA/Window

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Avg
Average Eff.	0.452	0.616	0.597	0.562	0.564	0.577	0.582	0.567	0.580	0.579	0.567

Looking at the overall distribution of the efficiency index, as shown in Table 10, there are no more efficient local waterworks region. 52 local governments with the efficiency index of less than 0.5 are found to account for 40 percent of the total, indicating low efficiency. According to each local government, Goryeong with the highest average efficiency for 10 years is 0.999 and the lowest efficiency is 0.180 in Yangsan.

< Table 12> Distribution of Efficiency Index

E=Technical Efficiency	E=1	1>E>0.9	0.9>E>0.8	0.8>E>0.7	0.7>E>0.6	0.6>E>0.5	0.5>E>0.4	0.4>E>0.3	0.3>E>0.2	0.2>E>0.1
Freq.	0	12	10	10	27	17	13	26	12	1
(%)	0%	9%	8%	8%	21%	13%	10%	20%	9%	1%

The research conducts an analysis of mean difference between groups based on the operation type and population served obtained by the DEA/Window method from 2006 to 2015. The results are shown in Table 13.

First of all, analysis of the mean difference according to operation type shows that the mean efficiency index of contracting-out regions is 0.758 and that of regions operated by local governments was 0.540. As a result of testing the mean difference by operation type using Mann-Whitney test, the difference is statistically significant ($z=-10.154$, $p=0.000$) at a significant level of 0.001. This shows that there is the mean difference between two groups, and it means that the water supply business is more efficient in local governments to entrust the operation and management affairs of waterworks. it is the same result obtained from the DEA analysis.

In addition, analysis of the mean difference of efficiency index by local governments based on the water supply population of 100,000 people from 2006 to 2015 are as follows. Local governments with population of 100,000 or more have 0.40213, and below 100,000 people was 0.64847. The results of validating the significance of the mean difference between two groups is statistically significant ($z=18.206$, $p=0.000$). This shows that the efficiency of small cities is higher than that of large cities. This is contrary to the original idea that large cities will have economies of scale and be more efficient than small towns. This is probably because Maintenance cost($r=0.7565$) and total operating facility assets ($r=0.7329$) have a strong positive correlation with population, compared to other variables. Then when the population increases, two input variables increases and the efficiency decreases. or it may be the effect of excluding the metropolis from target samples.

<Table 13> Comparison by Operation type and Population

Cat.	Variables	N	Mean	SD	Min	Max	Mann- whitney test	
							Rank-sum	z-value
Operation Type	Local gov	1,121	0.54	0.231	0.089	1	673718	-10.154 (p=0.0000)
	Contracting-Out	159	0.758	0.221	0.241	1	146121	
Population	less than 100,000 people	865	0.646847	0.21951	0.193	1	153129	18.206 (p=0.000)
	More than 100,000 people	415	0.40213	0.19449	0.089	1	666711	

VII. Result of Panel Data Analysis

In orders to analyze the determinants affecting the efficiency of local waterworks, this research selects the average efficiency index analyzed by DEA/Window method, Revenue rate and total unit cost as dependent variables, operation type as independent variables and pipe length, population density, and rate of realization cost etc. as control variables. First, the descriptive statistics are analyzed. Second, the research is performed by pooled OLS, fixed effect model, and random effect model. After doing that, the validity of each model is tested.

1. Descriptive statistics

Table 14 shows the descriptive statistics such as the mean and standard deviation of the main variables used in this study. The variance inflation factor (VIF), which is the degree to which individual independent variables are explained by other independent variables, is smaller than the cut-off threshold of 10. Therefore, there seems to be no multicollinearity problem in regression analysis. The research uses the population density data except 12 datasets because of new city and change of city name.

<Table 14> Variables for Regression Analysis

Variables		N	Mean	SD	Min	Max	VIF
Dependent Variable	Percentage of Efficiency Index	1,280	56.8	24.1	8.9	100	
Independent Variables	Contracting-Out(0 : local 1 : contracting)	1,280	0.124	0.330	0	1	1.05
	Percentage of Water produced by Local gov(%)	1,280	61.4	40.8	0	100	1.21
	Pipe Length (Km)	1,280	583.3	401.1	10.6	2553.0	1.12
	Rate of Realization Cost(%)	1,280	60.7	20.5	15.0	156.0	1.22
	Percentage of Old pipe by annual(%)	1,280	34.0	19.0	0	89	1.21
	Population Density(per 1000 people)	1,266	0.420	1.043	0.000	7.916	1.20

2. Result of the Pooled OLS

The pooled OLS is a pooled linear regression without fixed or random effects. It assumes a constant intercept and slopes regardless of group and time-periods. In pooled OLS method, most coefficients of independent variables are statistically significant when the dependent variable is the efficiency index ($p<0.001$). In terms of operation type, when dependent variables are efficiency index and revenue rate, it has a significantly positive relation. It can expect that the efficiency index of contracting-out regions is about 23% higher than that of regions operated by local governments and revenue rate of contracting-out areas is 6% higher than others. When it comes to total unit cost, operation type is statistically insignificant in model (5) and (6). In case of model (1), about 25% of the change in the efficiency index is explained by the change of independent variables through adj. R-squared. However, this pooled OLS method has the most important drawback, which is that we would have to assume that the unobserved effect is uncorrelated with independent variables for pooled OLS to produce a consistent estimator. In this case, there are some unobserved factor like employees' skills, policy of local governments and so on. As a result of that, signs of the coefficients appeared in contrast to those initially expected, specially pipe length and population density which represents economies of scale in model (1) and (2).

Model (2), (4) and (6) are controlled by time effect. These models have a little larger R-squared than others. As a result of checking the standardized coefficient, operation type is the factor to have the great influence on efficiency in model (1) and (2). And population density has the biggest impact on revenue rate in model (3) and (4). As expected, the rate of realization cost is a biggest value of a coefficient in model (5) and (6).

<Table 15> Pooled OLS with Three Dependent Variables

	(1)	(2)	(3)	(4)	(5)	(6)
	Efficiency Index		Revenue Rate		Total Unit Cost	
Operation Type(0:local, 1:contracting-out)	23.22708***	22.95159***	6.11852***	5.94868***	41.42314	22.84481
	(1.80770)	(1.79363)	(0.91416)	(0.91233)	(44.24210)	(42.35206)
Pipe Length(Km)	-0.01297***	-0.01346***	0.00198*	0.00134	0.10804***	0.06792**
	(0.00154)	(0.00159)	(0.00078)	(0.00081)	(0.02435)	(0.02449)
Rate of Realization Cost(%)	-0.21466***	-0.22050***	0.04659**	0.04631**	-21.19327***	-20.77788***
	(0.03377)	(0.03371)	(0.01708)	(0.01715)	(0.78891)	(0.77804)
Percentage of of Water produced by Local Gov(%)	-0.07809***	-0.08004***	0.04223***	0.04361***	-1.37358***	-1.52315***
	(0.01617)	(0.01602)	(0.00818)	(0.00815)	(0.29280)	(0.28844)
Percentage of Old pipe by annual(%)	0.13400***	0.15418***	-0.18365***	-0.17243***	-1.94782***	-0.71594
	(0.03473)	(0.03664)	(0.01757)	(0.01864)	(0.57710)	(0.60398)
Log(Population Density) (per 1000people)	-4.36270***	-4.31174***	5.78262***	6.08693***	-41.57842***	-45.81827***
	(0.61589)	(0.61931)	(0.31146)	(0.31501)	(9.67026)	(9.72121)
Time Dummy	N	Y	N	Y	N	Y
N	1266	1266	1266	1266	1266	1266
adj. R-sq	0.249	0.271	0.318	0.330	0.590	0.597

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001"
(Model(5)(6) Robust Standard errors

As a result of Breusch-Pagan / Cook-Weisberg test for heteroskedasticity, Null Hypothesis (= Constant variance) is not rejected at a 0.05 significant level in case of model (1) and model (2). However, in the case of model (3), Null hypothesis is rejected(chi2=401.70). Therefore, this research is carried out the heteroskedasticity-robust inferences.

3. Result of Panel Regression with Fixed effect and Random effect

1) Fixed effect model

The effect of operation types on the efficiency index is analyzed by the fixed effects panel model as shown in Table 14. First, model (1) is a model to analyze the effect on a dependent variable when all independent variables in this study are included. According to result of Model (1), operation type is statistically significant at the significance level of 0.001 ($t = 3.63$, $p = 0.000$), which means that operation type affects the efficiency of local waterworks. When operation type is contracting-out, it can expect that Efficiency index is 13.6% point higher than that of regions operated by local government holding other variables, which is consistent with the result of Table 11. If pipe length is increased by 10Km, Efficiency index will be increased by 0.22% point. And when population density is increased by 1%, efficiency index will be increased by about 0.04% point in model (1). most independent variables except the percentage of water produced by local government have statistically significant influence on the efficiency index in model (1).

Pipe length and population density show a significant positive relationship with efficiency in all models. This implies that if the population is concentrated in the unit area, infrastructure construction in a small area can provide public services to the large number of people, thus positively affecting economic efficiency. Rate of realization cost has a significant negative correlation with the efficiency index. That is because rate of realization cost has a negative relationship with total unit cost to be used by output variable to measure the efficiency index. Percentage of old pipe by annual is positively related to the efficiency index at 0.001 significance level. The increase in percentage of old pipe is likely to result in more efficiency-enhancing efforts internally to achieve the same output goal and consequently increases efficiency.

<Table 16> Result of Fixed Effect Model with Efficiency Index

Fixed Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable : Efficiency Index (%)											
Operation Type(0:local, 1:contracting-out)	13.60821***	13.73881***	13.53451***	12.98690***	12.87016***	13.14201***	13.68401***	13.04881***	12.86106***	13.68025***	13.56624***	13.60821*
	(1.79971)	(1.81617)	(1.80126)	(1.80423)	(1.80649)	(1.81927)	(1.81608)	(1.81952)	(1.83383)	(1.88827)	(1.90898)	(4.73418)
Pipe Length(Km)	0.02177***	0.02251***	0.02147***	0.02047***	0.02005***	0.02125***	0.02228***	0.02091***	0.02184***			0.02177**
	(0.00222)	(0.00223)	(0.00222)	(0.00221)	(0.00220)	(0.00222)	(0.00223)	(0.00221)	(0.00220)			(0.00417)
Rate of Realization Cost(%)	-0.14603***		-0.13832***	-0.14113***	-0.13175***							-0.14603
	(0.03119)		(0.03095)	(0.03136)	(0.03112)							(0.05690)
Percentage of of Water produced by Local Gov(%)	0.05441	0.03635		0.06403*		0.04610						0.05441
	(0.02914)	(0.02915)		(0.02922)		(0.02919)						(0.04247)
Percentage of Old pipe by annual(%)	0.18588***	0.17701***	0.19330***				0.18237***					0.18588**
	(0.04730)	(0.04770)	(0.04719)				(0.04752)					(0.02437)
Log(Population Density) (per 1000people)	4.06952***	3.62538***	4.18003***	4.33074***	4.47408***	3.88877***	3.71647***	4.01546***		4.58404***		4.06952*
	(0.79390)	(0.79552)	(0.79257)	(0.79618)	(0.79483)	(0.79683)	(0.79236)	(0.79331)		(0.82147)		(1.01804)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266
adj. R-sq	0.177	0.162	0.176	0.167	0.164	0.153	0.162	0.151	0.143	0.085	0.070	0.261

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001"

In addition to these analysis results, the research subtracts explanatory variables one by one and analyzes the robustness of operating type in estimation of coefficient. As a result, all models (1) to (12) show that the coefficient of the operation type is very robust because it is statistically significant at 0.01 level of significance. In terms of adj. R-squared, Model (12) to be clustered by same province is the best, which is that about 26% of the change in efficiency index is explained by the change of independent variables. As standard errors of coefficients in model (12) is larger than model (1), t-statistic in model (12) is smaller than model (1). Then coefficient of rate of realization cost in model (12) is not statistically significant anymore. In addition, all variables retained significance and correlation even from model (1) to (11). It means that most variables except the percentage of water produced by local government are statistically significant below the 0.05 significance level even for the change of the model. When fixed effect model is compared with pooled OLS, the signs of the coefficients of pipe length, percentage of water produced by local government and population density are changed and adj R-square is smaller. Time dummy variable is tested by F-test to confirm significance. Since the p-value is less than 0.01, it is significant at 0.01 significance level. Therefore, it can be interpreted that there is a time characteristic effect of time dummy variable.

As shown in Table 17, the research analyzes the effect of operation type on the revenue rate. In models (1) to (11), Operation type has a statistically significantly positive correlation with the revenue rate and means that operation type has robustness about revenue rate. It can be expected that the revenue rate of contracting-out regions is 8.47% higher compared to regions operated by local governments holding other variables in model (1).

<Table 17> Result of Fixed Effect Model with Revenue rate

Fixed Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable :Revenue rate(%)											
Operation Type(0:local, 1:contracting-out)	8.46534***	8.41723***	8.45088***	8.61360***	8.59831***	8.55576***	8.39110***	8.52530***	8.59962***	8.54059***	8.58888***	8.46534
	(0.96664)	(0.97052)	(0.96618)	(0.96378)	(0.96306)	(0.96740)	(0.97034)	(0.96686)	(0.98756)	(0.96586)	(0.98642)	(3.37681)
Pipe Length(Km)	0.00060	0.00033	0.00054	0.00091	0.00085	0.00062	0.00022	0.00051	-0.00033			0.00060
	(0.00119)	(0.00119)	(0.00119)	(0.00118)	(0.00117)	(0.00118)	(0.00119)	(0.00117)	(0.00119)			(0.00205)
Rate of Realization Cost(%)	0.05379**		0.05531***	0.05262**	0.05385**							0.05379
	(0.01675)		(0.01660)	(0.01675)	(0.01659)							(0.02520)
Percentage of of Water produced by Local Gov(%)	0.01068	0.01733		0.00838		0.01507						0.01068
	(0.01565)	(0.01558)		(0.01561)		(0.01552)						(0.02998)
Percentage of Old pipe by annual(%)	-0.04435	-0.04109	-0.04290				-0.03853					-0.04435
	(0.02541)	(0.02549)	(0.02531)				(0.02539)					(0.07938)
Log(Population Density) (per 1000people)	0.48790	0.65151	0.50958	0.42556	0.44433	0.59037	0.69494	0.63177		0.64554		0.48790
	(0.42641)	(0.42511)	(0.42513)	(0.42530)	(0.42373)	(0.42372)	(0.42336)	(0.42155)		(0.42019)		(0.53902)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266
adj. R-sq	0.014	0.006	0.014	0.012	0.013	0.004	0.006	0.004	-0.003	0.005	-0.002	0.114

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001"

Rate of realization cost have positive relationship with the revenue rate as well. It means that when rate of realization cost will be increased by 1% point, the revenue rate will be expected to increase 0.05% point in model (1). However, when applying cluster with same province, all coefficients of explanatory variables are not statistically significant due to increasing the standard errors in model (12). As a result, in terms of the revenue rate, it would be more accurate to compare clusters in the same drainage system rather than clusters in the same administrative districts

In terms of total unit cost in Table 18, operation type has statistically significant effects on total unit cost in model (1). However, operation type is not robust through other models. Rate of realization cost, percentage of water produced by local government and population density has statistically significantly negative relations with total unit cost in model (1) and they are robust. It means that if rate of realization cost is increased by 1% point, it can expect that total unit cost will be decreased by 21.7 won.

<Table 18> Result of Fixed Effect Model with Total Unit Cost

Fixed Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable : Total Unit Cost(won)											
Operation Type(0:local, 1:contracting-out)	76.18275*	95.56089	78.56510*	78.59721*	81.87222*	102.43381	102.25265	111.63424*	109.43672*	114.15953*	111.48539*	76.18275
	(37.59678)	(52.94063)	(37.71048)	(37.44366)	(37.55647)	(52.75958)	(53.54014)	(53.38116)	(54.09796)	(53.36085)	(54.05621)	(104.07782)
Pipe Length(Km)	-0.07485	0.03526	-0.06519	-0.06981	-0.05816	0.04977	0.06332	0.08361	0.06346			-0.07485
	(0.04635)	(0.06511)	(0.04638)	(0.04582)	(0.04581)	(0.06438)	(0.06564)	(0.06486)	(0.06497)			(0.06583)
Rate of Realization Cost(%)	-21.66838***		-21.91765***	-21.68746***	-21.95034***							-21.66838***
	(0.65150)		(0.64787)	(0.65084)	(0.64698)							(1.42088)
Percentage of of Water produced by Local Gov(%)	-1.75902**	-4.43893***		-1.79639**		-4.55125***						-1.75902
	(0.60865)	(0.84960)		(0.60637)		(0.84657)						(2.32384)
Percentage of Old pipe by annual(%)	-0.72234	-2.03848	-0.96224				-2.69356					-0.72234
	(0.98813)	(1.39045)	(0.98785)				(1.40088)					(2.97177)
Log(Population Density) (per 1000people)	-52.07390**	-117.97560***	-55.64665***	-53.08903**	-57.11037***	-121.00892***	-129.09959***	-133.51550***		-131.24163***		-52.07390
	(16.58504)	(23.18918)	(16.59291)	(16.52338)	(16.52435)	(23.10849)	(23.35956)	(23.27421)		(23.21407)		(30.30681)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266
adj. R-sq	0.599	0.205	0.597	0.600	0.597	0.205	0.187	0.185	0.165	0.184	0.165	0.640

If the local government reduces water production by 1%point, total unit cost will be increased by 1.76 won. When population density is increased by 1%, total unit cost will be decreased by about 0.52 won. this indicates that the economies of scale affect total unit cost. However, when applying the cluster with same province, rate of realization cost is only statistically significant value in model (12). In terms of adj. R-squared, Model (12) is that 64% of the change in total unit cost is explained by the change of independent variables, which is the best in entire models.

2) Random effect model

The effect of the operation type on the efficiency index of local waterworks is analyzed by the random effects model as shown in Appendix 5. Operation type, pipe length, rate of realization cost and percentage of old pipe by annual are statistically significant($p<0.01$) in all models which means that four variables are robust. Like the fixed effect model, the efficiency index of contracting-out regions is higher than that of regions operated by local governments. Most of population density is not robust compared to fixed effect model. All variables have the same direction compared to fixed model. When a dependent variable is revenue rate as shown in Appendix 5, Operation type is statistically significant in all model. That is the same result compared to fixed effect model. However, Population density has a strong positive relationship to revenue rate significantly compared to fixed effect model. And when a dependent variable is total unit cost as shown in Appendix 5, The signs of the coefficients are the same across fixed and random effect model, and the same variables are statistically significant in both models.

4. Analysis of goodness of fit (pooled OLS, Fixed effect/Random effect models)

In the first step, F-test and Breusch-Pagan test are conducted to determine goodness of fit between pooled OLS and panel model. The former is required for selecting between Pooled

OLS and fixed effect model, and the latter is necessary for selecting between pooled OLS and random effect model. F-test is to check whether the fixed individual characteristic of the error term needs to be considered. As result of F-test, null hypothesis is rejected at 0.01 significance level. Therefore, the fixed effect model considering the individual characteristics of the panel is more appropriate than the pooled OLS. The Breusch-Pagan test results showed that the null hypothesis was rejected at the 0.1 significance level because the p-value is less than 0.001. Therefore, it is necessary to estimate the random effect model considering the individual characteristics of the panel rather than the pooled OLS model. Second, the Hausman test is used to select between fixed effect model and random effect model. As a result, the null hypothesis is rejected at 0.01 level and the validity of the fixed effect model is supported as shown in Table 19.

< Table 19> Comparison of Model with Efficiency Index

Dependent Variable : Efficiency Index	(1) Pooled OLS	(2) Fixed Effect	(3) Random Effect
Operation Type(0:local, 1:contracting-out)	22.95159***	13.60821***	14.66071***
	-1.79363	-1.79971	-1.78555
Pipe Length(Km)	-0.01346***	0.02177***	0.01317***
	-0.00159	-0.00222	-0.00206
Rate of Realization Cost(%)	-0.22050***	-0.14603***	-0.18554***
	-0.03371	-0.03119	-0.03086
Percentage of Water produced by Local(%)	-0.08004***	0.05441	0.04827*
	-0.01602	-0.02914	-0.02448
Percentage of Old pipe by annual(%)	0.15418***	0.18588***	0.12786**
	-0.03664	-0.0473	-0.04459
Log(Population Density) (per 1000people)	-4.31174***	4.06952***	1.87464*
	-0.61931	-0.7939	-0.73701
Time Dummy	Y	Y	Y
F-test	F(127, 1123) = 30.45, Prob > F = 0.0000		
Breusch-Pagan test	chibar2(01) = 2322.97, Prob > chibar2 = 0.0000		
Hausman test	chi2(8) = 116.27, Prob>chi2 = 0.0000		
Choice		O	

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001"

VIII. Conclusion

Water service not only has a direct effect on the welfare level and quality of life, but also is a very important factor in the production activities of companies. Therefore, the government has limited the waterworks business to the unique area of local government in view of the public interest. However, this resulted in a lack of scale and expertise in local water supply, and reduced efficiency, failing to secure competitiveness. Therefore, the research examines the relative efficiency of local water supply business by using DEA method for 128 local governments with a population of less than 300,000 and checks the difference of efficiency between the contracting-out areas and regions directly operated by the local governments. DEA/Window method confirms the dynamic trend of efficiency and performs the efficiency analysis based on 100,000 people. Based on the results of this efficiency analysis, the research analyzes the determinants affecting the efficiency of local waterworks using fixed effect model which is best among pooled OLS, fixed effect model and random effect model. The results of the empirical analysis are as follows.

First of all, efficiency analysis in 2015 reveals that 26 local governments are efficient. All efficiency indexes of the contracting-out regions are higher than that those of regions operated by local governments, and the difference of efficient indexes according to operation type is statistically significant. Second, the research also shows a higher efficiency index for trustees by DEA/Window method. And small cities with a population of less than 100,000 are more efficient than cities with more than 100,000 people. Last, the research confirms the influence factors such as operation type, population density, pipe length and so on which affect the efficiency of local waterworks by the fixed effect model. Operation type has a positive relationship with efficiency index. It shows that contracting-out areas are more efficient than direct operation by local governments, which was robust results in various models. This result is same as those of DEA/Window method. Pipe length and population density are both positively related to the efficiency index of local waterworks, and the coefficients of them are statistically significant. It means the economy of scale affects efficiency of local waterworks. However, percentage of water produced by local governments does not have a statistically significant relationship with efficiency index.

As a result of analyzing the influence of a variables on the revenue rate and total unit cost, which are representative of local waterworks efficiency, revenue rate of contracting-out regions is higher than that directly operated by local governments and coefficients of it is statistically significant and robust. Rate of realization cost is also positive related with revenue rate. However, the explanatory variables like pipe length, rate of realization cost, percentage of old pipe, percentage of water produced by local governments and population density are not statistically significant. In the case of the Total unit cost, the operation type does not have robustness. And the rate of realization cost, percentage of water produced by local governments and the population density show a significantly negative relationship. To reduce the total unit cost, local governments try not to import water but to produce water by themselves and they try to increase rate of realization cost and population density.

In order to analyze the efficiency of local waterworks, clustering was performed by same province, but clustering in the simple administrative area did not yield meaningful results. Therefore, it is likely that the region should be clustered in the same drainage system for more accurate analysis.

The implications of the analysis result are as follows. First, it is revealed that the contracting-out in local waterworks has contributed greatly to the efficiency improvement of water supply business. However, it is difficult to conclude that contracting-out type is efficient because most local governments maintain the form of direct business. Nevertheless, it can be said that contracting the local waterworks out helps to improve the efficiency through slimming of the organization and scientific operation. Second, the contracting-out in local waterworks has positive effect on the revenue rate. The contracting-out helps improve revenue rate by systematic operation of pipes, proper pipe network replacement, and maintenance. Third, it is estimated that the local waterworks business can be economically effective by economy of scale. In other words, if the business scale is expanded, the total unit cost is expected to decrease. Therefore, to improve the inefficient operation of small-scale areas, it is necessary to reduce costs by expanding the scale of integration with nearby waterworks providers and to apply the integrated water management through the vertical integration between local and wide-area waterworks.

However, the research seems to have the following limitations. It is difficult to use diverse variables such as the geographical conditions and the specificity of local governments in analyzing the efficiency of local waterworks. This research also measures the efficiency by using only quantitative variables in data collections such as 'The Statistics of Waterworks' and 'The Local Public Enterprise Balance sheet and Management Analysis'. However, non - quantitative factors such as the customer satisfaction and internal employee job satisfaction may also affect the efficiency. In addition, there are limitations to the analytical methodology. The result of using DEA and panel regression analysis can be very different depending on the variables used. Therefore, in order to increase the validity of variables, it is important to review the previous studies more carefully and to select variables that can represent the production process of the waterworks business. In the future, it will be necessary to further consider whether there are other observable variables that are correlated with independent variables and dependent variables, and if so, to include those variables in the model.

IX. References

Hyun, Seunghyun and Kim, Jeonglyeol (2017), 'A Comparative Analysis of the Efficiency of Local Waterworks Utilizing DEA Model'

Jang, Deokhee and Shin, Youl (2009). 'A Comparative Analysis on the Effectiveness of Local Water Supply System', Journal of Policy Studies, 13 (3): 145-165.

Kim, Sang-moon (2012), 'Evaluation of Local Water Efficiency Using SFA', Water Policy and Economy, 19: 73-89.

Kim, Naeyun, Kim, Sunduck, and Lee, Manhyung (2015), 'An Analysis of Efficiency of Waterworks Project Using Data Envelopment Analysis: Focused on the Chung-cheong North province', Urban Administration research, 28 (4): 269-288.

Kim, Geonwi, Lee, Byungki and Hyun, Seunghyun (2008), 'Changes in Productivity and Determinants of Regional Economic Capital: Focused on the Metropolitan Organizations', Journal of Public Administration Research, 22 (4): 69-99.

Kim, Jaehong and Kim, Taeil (2001), 'Evaluation and Measurement of Public Sector Efficiency'

Kim, Seok (2004), 'A study on the Efficiency Evaluation of Water supply Projects using the DEA'

Kim, Taeil (2000), 'A Critical Discussion on Productivity Evaluation of Local Government Administration by Data Envelopment Analysis Technique', Policy Analysis and Evaluation Science Bulletin, 10 (1): 185-207.

Kim, HyoJoo (2011), 'Data Envelopment Analysis of Delivery Alternatives for Local Public Services in Korea'

Ko, Gwanghee, Lee, Dongkyu and Lee, Soohee (2008), 'Performance analysis of DEA for Efficient Operation Management of Water Supply Business' Accounting Research, 13 (1): 123-150.

Ko, Sujeong (2016), ‘A Comparative Analysis on the Efficiency of Operators of Local Waterworks Projects’, Daegu Gyeongbuk Study, 15 (1): 1-23.

Lee, Youngbum (2004), ‘An Empirical Study on the Relationship between Efficiency and Equity of Providing Public Services’, Korea Institute of Public Administration, 13 (3): 236-262.

Mun, Gyeongju (2009), ‘Measuring and Evaluating the Efficiency of Public Libraries: Focusing on 21 Public Libraries’, 20(2).

Park, Gwayoung and Kim, Kabsung (2014), ‘An appropriate urban scale analysis for efficient supply of urban public services: Focusing on the local water service’, Journal of the Korean Urban Management Association.

Park, Manhee (2008), ‘Efficiency and Productivity Analysis’, Korean Academic Information.

Seo, Seonjae, Lee, Sunho and Han, Changmook (2016), ‘Study on Effects of Efficiency of Local Public Water Utilities Enterprises on Market and Production Structure in Local Government: Focusing on Economies of Scale, Economies of Density, and Economies of Scope’, Local Administration Research, 30 (1): 281-320.

Won, Kohwan (1998), ‘Measuring Cost Efficiency of Public Utilities Using SFA’, Korean Association for Policy Studies 7(3): 287-306.

Won, Kohwan (2010), ‘Analysis of Contracting Efficiency of Specialized Institutions in Local Waterworks Projects’, Korea Local Government Research 12 (3): 91-110.

Yeo, Younghyun and Ko, Jongwook (2010), ‘A Study on the Privatization Policy of Waterworks and Decision Factors of Private Trust’, Korea Policy Institute Research 19(4): 441-468.

Yu, Jiyeon (2014), ‘A Study on the Effect of Consignment Operation of Local Public Water Companies on Cost Efficiency’, Korean Local Finance Review, 19 (2): 101-130.

X. Appendix

< Appendix 1> Status of Trustees

Trustees	Local Government		
K-water	Gyeongi Province	4	Dongduchan, Yangju, Paju, Kwangju
	Chungcheong Province	5	Nonsan, Seosan, Cheonan, Geumsan, Danyang
	Jeolla Province	6	Jeongeup, Naju, Hampyeong, Wando, Jindo, Jangheung
	Kyungsang Province	7	Yecheon, Goryeong, Bonghwa, Sacheon, Geoje, Goseong, Tongyeong
KECO	Gangwon Province	4	Youngwol, Jeongseon, Pyeongchang, Taebaek

< Appendix 2> Descriptive Statistics of Regional waterworks

Region	Total Population (people)	Population served (People)	Water Supply Rate (%)	Total Unit cost (won)	Realization Cost Rate (%)	Revenue Rate (%)
Total	52,672,425	50,804,120	96.5	881.7	77.5	84.3
Seoul	10,297,138	10,297,138	100	639.0	89.6	95.1
Busan	3,553,768	3,553,768	100	908.0	79.1	91.7
Daegu	2,513,970	2,512,107	99.9	683.0	93.9	91.2
Incheon	2,983,484	2,940,926	98.6	656.8	102.5	89.1
Gwangju	1,490,654	1,487,423	99.8	634.0	90	85.9
Deajeon	1,535,191	1,533,553	99.9	539.0	97.5	92.3
Ulran	1,199,717	1,176,323	98.1	857.0	101	89.9
Seojong	214,365	188,058	87.7	1161.9	63.7	80.1
Gyeongi	12,892,271	12,626,376	97.9	780.9	84.6	89.1
Gangwon	1,564,615	1,401,287	89.6	1499.7	56.3	70.5
Chungbuk	1,616,589	1,458,754	90.2	971.4	72.8	83.8
Chungnam	2,134,232	1,801,865	84.4	1181.3	65.2	79.9
Jeonnam	1,895,905	1,812,644	95.6	1216.2	75.4	68.5
Jeonbuk	1,939,562	1,680,268	86.6	1321.4	62.4	68.5
Gyeongbuk	2,752,591	2,483,956	90.2	1252.3	59.2	69
Gyeongnam	3,447,018	3,208,319	93.1	1090.3	76.2	73.6
Jeju	641,355	641,355	100	926.0	83.4	44.5

< Appendix 3> Equation of DMU

Elements	Equation
Number of Window	w=k-p+1
Total number of DUM for each Window	np
Total Number of DMU	npw
Window Depth	p=(k+1)/2 , If k is odd
	p=(k+1)/2 ± 1/2 , If k is even

< Appendix 4> Result of efficiency indexes in 2015

ID	DMU	TE (CCR Model)	PTE (BCC Model)	SE (Scale Eff.)	Benchmarks (TE)
1	A	0.733	0.780	0.940	5 (0.13) 6 (0.38) 50 (0.27) 63 (0.50)
2	B1	1.000	1.000	1.000	1
3	B2	0.957	1.000	0.957	5 (0.12) 6 (0.03) 50 (0.62) 55 (0.56)
4	B3	0.913	0.996	0.917	6 (0.55) 18 (0.03) 50 (0.21) 83 (0.36)
5	B4	1.000	1.000	1.000	31
6	B5	1.000	1.000	1.000	38
7	B6	0.904	1.000	0.904	5 (0.01) 6 (0.46) 50 (0.35) 55 (0.43)
8	B7	0.974	1.000	0.974	6 (0.05) 50 (0.50) 73 (0.49)
9	B8	0.732	0.837	0.875	5 (0.48) 6 (0.24) 50 (0.57)
10	B9	0.570	0.601	0.949	5 (0.49) 6 (0.16) 50 (0.51)
11	B10	1.000	1.000	1.000	4
12	B11	0.801	1.000	0.801	5 (0.06) 44 (0.03) 114 (0.55) 117 (0.44)
13	B12	0.586	0.610	0.961	6 (0.25) 50 (1.34)
14	B13	0.701	0.707	0.992	50 (1.28) 73 (0.17)
15	B14	0.355	0.452	0.786	50 (1.01) 55 (0.20)
16	B15	0.441	0.591	0.746	5 (0.00) 26 (0.00) 42 (0.51) 44 (0.03) 50 (0.87)
17	B16	0.574	0.763	0.752	6 (0.03) 11 (0.10) 55 (1.10) 73 (0.05) 83 (0.20)
18	C1	1.000	1.000	1.000	8
19	C2	0.755	0.791	0.956	6 (0.63) 50 (0.43)
20	C3	0.537	0.814	0.659	5 (0.28) 50 (0.61) 55 (0.16) 63 (0.09)
21	C4	1.000	1.000	1.000	1

22	C5	0.764	1.000	0.764	6 (0.16) 18 (0.01) 50 (0.55) 83 (0.52)
23	C6	0.511	0.629	0.813	50 (1.29) 55 (0.10) 73 (0.04)
24	C7	0.420	0.518	0.810	42 (0.25) 50 (0.39) 55 (0.68) 73 (0.07)
25	C8	0.553	0.798	0.693	26 (0.05) 42 (0.84) 50 (0.20) 55 (0.35)
26	C9	1.000	1.000	1.000	19
27	C10	0.959	1.000	0.959	26 (0.85) 42 (0.53)
28	C11	1.000	1.000	1.000	0
29	C12	0.411	0.456	0.902	11 (0.03) 50 (0.66) 55 (0.31) 73 (0.01) 83 (0.11) 110 (0.05)
30	C13	1.000	1.000	1.000	6
31	C14	0.951	1.000	0.951	30 (0.80) 50 (0.11) 55 (0.24) 101 (0.08)
32	C15	0.378	0.506	0.748	26 (0.02) 42 (0.30) 50 (0.33) 55 (0.65)
33	C16	0.764	0.964	0.793	26 (0.12) 44 (0.05) 50 (0.41) 55 (0.71)
34	C17	0.696	0.886	0.785	42 (0.16) 50 (0.43) 55 (0.35) 101 (0.17) 119 (0.11)
35	D1	0.735	0.744	0.988	6 (0.58) 50 (0.45)
36	D2	0.710	0.735	0.966	6 (0.11) 18 (0.26) 50 (0.26) 55 (0.05) 83 (0.46)
37	D3	0.532	0.638	0.834	42 (0.04) 50 (0.19) 55 (0.54) 119 (0.05)
38	D4	0.576	0.720	0.800	44 (0.08) 50 (0.41) 55 (0.54) 114 (0.15)
39	D5	0.624	0.889	0.703	50 (0.43) 55 (1.04) 73 (0.03)
40	D6	1.000	1.000	1.000	1
41	D7	0.518	0.519	0.998	5 (0.13) 26 (0.00) 50 (0.46) 107 (0.26) 110 (0.14)
42	D8	1.000	1.000	1.000	25
43	D9	0.538	0.538	0.999	6 (0.21) 26 (0.04) 42 (0.18) 50 (0.45) 110 (0.08)
44	D10	1.000	1.000	1.000	20
45	E1	0.468	0.571	0.820	6 (0.04) 50 (1.49) 73 (0.06)
46	E2	0.523	0.574	0.911	6 (0.08) 18 (0.01) 50 (0.26) 55 (0.70) 73 (0.14)
47	E3	0.672	1.000	0.672	6 (0.97) 50 (0.20)
48	E4	0.826	0.827	0.999	5 (0.35) 44 (0.40) 117 (0.27)
49	E5	0.923	0.988	0.934	44 (0.23) 50 (0.10) 107 (0.11) 114 (0.58) 117 (0.02)
50	E6	1.000	1.000	1.000	88
51	E7	0.454	1.000	0.454	5 (0.10) 55 (0.32) 114 (0.74)

52	E8	0.915	0.929	0.985	2 (0.17) 44 (0.21) 107 (0.25) 110 (0.29) 117 (0.01)
53	E9	0.658	0.770	0.855	6 (0.10) 50 (0.15) 55 (0.86) 101 (0.08) 110 (0.02)
54	E10	0.512	0.515	0.994	6 (0.05) 11 (0.00) 50 (0.25) 73 (0.02) 83 (0.12) 101 (0.51)
55	E11	1.000	1.000	1.000	55
56	E12	0.593	0.598	0.993	5 (0.29) 26 (0.05) 42 (0.09) 44 (0.33) 50 (0.22) 110 (0.03)
57	E13	0.762	0.901	0.845	6 (0.10) 55 (1.14) 83 (0.37)
58	E14	0.569	0.576	0.988	5 (0.09) 26 (0.48) 50 (0.43)
59	F1	0.430	1.000	0.430	5 (1.19) 63 (0.31)
60	F2	0.698	0.853	0.818	5 (0.30) 42 (0.10) 44 (0.26) 50 (0.09) 107 (0.10) 114 (0.25)
61	F3	0.613	0.674	0.908	50 (0.37) 55 (0.56) 73 (0.18) 83 (0.15) 119 (0.01)
62	F4	0.695	1.000	0.695	6 (0.15) 50 (0.51) 55 (0.68) 73 (0.05) 110 (0.06)
63	F5	1.000	1.000	1.000	4
64	F6	1.000	1.000	1.000	0
65	F7	0.691	0.884	0.781	26 (0.01) 42 (0.22) 50 (0.22) 55 (0.90)
66	F8	0.938	0.956	0.981	26 (0.09) 42 (0.22) 44 (0.08) 50 (0.36) 110 (0.21)
67	F9	0.722	1.000	0.722	42 (0.81) 50 (0.09) 101 (0.25) 110 (0.06) 119 (0.04)
68	F10	0.652	0.673	0.968	50 (0.23) 55 (0.40) 101 (0.34) 110 (0.06)
69	F11	0.541	1.000	0.541	5 (0.07) 42 (0.19) 44 (0.05) 50 (0.92) 55 (0.12)
70	F12	0.596	1.000	0.596	40 (0.00) 50 (0.36) 55 (0.98) 114 (0.22)
71	G1	0.550	0.696	0.790	5 (0.56) 63 (1.61)
72	G2	0.652	0.876	0.745	6 (0.83) 50 (0.56)
73	G3	1.000	1.000	1.000	31
74	G4	0.720	0.738	0.976	5 (0.25) 26 (0.12) 44 (0.39) 107 (0.24) 117 (0.03)
75	G5	0.748	0.748	1.000	6 (0.15) 18 (0.24) 50 (0.38) 73 (0.01) 83 (0.21)
76	G6	0.649	0.654	0.991	50 (0.36) 73 (0.04) 101 (0.53) 110 (0.04)
77	G7	0.582	0.610	0.953	30 (0.06) 50 (0.55) 101 (0.29)
78	G8	0.782	0.901	0.868	50 (0.09) 55 (0.94) 101 (0.12)

79	G9	0.767	0.798	0.961	5 (0.13) 50 (0.11) 55 (1.01) 114 (0.00)
80	G10	0.806	0.816	0.987	50 (0.06) 73 (0.02) 83 (0.83)
81	G11	0.653	0.887	0.735	5 (0.02) 26 (0.14) 42 (0.22) 44 (0.01) 50 (1.09)
82	G12	0.893	0.910	0.981	5 (0.01) 42 (0.35) 44 (0.09) 107 (0.46) 110 (0.10) 114 (0.02)
83	G13	1.000	1.000	1.000	14
84	G14	0.931	0.966	0.964	73 (0.11) 101 (0.20) 110 (0.54)
85	G15	0.359	0.376	0.956	5 (0.08) 44 (0.06) 50 (0.46) 55 (0.44) 114 (0.06)
86	G16	0.707	0.812	0.872	5 (0.10) 26 (0.04) 50 (1.34)
87	G17	0.806	0.876	0.920	50 (0.07) 55 (0.08) 107 (0.74) 110 (0.03)
88	G18	0.762	0.879	0.866	42 (0.07) 50 (0.76) 55 (0.33) 73 (0.06)
89	G19	1.000	1.000	1.000	0
90	G20	0.514	0.721	0.712	5 (0.01) 26 (0.30) 44 (0.05) 50 (0.99)
91	G21	1.000	1.000	1.000	44 (1.12) 50 (0.16) 55 (0.06) 114 (0.01)
92	G22	0.429	0.610	0.703	50 (0.44) 55 (1.00) 73 (0.03)
93	H1	0.529	0.558	0.948	6 (0.73) 50 (0.70)
94	H2	0.671	0.671	1.000	6 (0.14) 18 (0.09) 50 (0.35) 73 (0.14) 83 (0.29)
95	H3	0.273	1.000	0.273	5 (0.50) 6 (0.06) 50 (0.75)
96	H4	0.764	0.764	1.000	6 (0.02) 18 (0.05) 50 (0.57) 55 (0.16) 73 (0.20)
97	H5	0.418	0.542	0.770	6 (0.07) 50 (1.90)
98	H6	0.610	0.691	0.882	42 (0.03) 50 (0.18) 55 (0.88) 73 (0.21)
99	H7	0.468	0.562	0.833	6 (0.06) 18 (0.04) 50 (0.51) 55 (0.62) 73 (0.04)
100	H8	0.646	0.725	0.891	5 (0.32) 6 (0.62) 50 (0.26)
101	H9	1.000	1.000	1.000	17
102	H10	0.582	1.000	0.582	26 (0.76) 50 (0.11) 55 (0.87)
103	H11	0.860	0.883	0.974	30 (0.05) 50 (0.18) 55 (0.08) 101 (0.51) 119 (0.10)
104	H12	0.529	0.657	0.805	30 (0.11) 50 (0.49) 55 (0.24) 101 (0.28) 119 (0.06)
105	H13	0.476	1.000	0.476	6 (0.01) 50 (0.34) 55 (1.12) 101 (0.07) 110 (0.00)
106	H14	0.559	0.622	0.899	5 (0.02) 42 (0.04) 50 (0.44) 55 (0.09) 107 (0.24)
107	H15	1.000	1.000	1.000	9
108	H16	0.825	1.000	0.825	26 (0.70) 42 (0.16) 44 (0.03) 50 (0.03) 55 (0.39)

109	H17	0.603	0.605	0.998	6 (0.18) 50 (0.71) 73 (0.12)
110	H18	1.000	1.000	1.000	20
111	H19	0.396	0.403	0.982	30 (0.21) 50 (0.24) 55 (0.05) 83 (0.07) 101 (0.04) 119 (0.24)
112	H20	0.516	0.519	0.995	42 (0.36) 50 (0.15) 55 (0.39) 73 (0.04) 110 (0.14)
113	H21	0.972	0.976	0.995	30 (0.04) 50 (0.81) 55 (0.12)
114	I1	1.000	1.000	1.000	12
115	I2	0.788	0.799	0.987	5 (0.32) 26 (0.07) 44 (0.05) 107 (0.49) 117 (0.09)
116	I3	0.585	0.663	0.882	6 (0.15) 50 (0.96) 55 (0.15) 73 (0.01)
117	I4	1.000	1.000	1.000	6
118	I5	0.472	1.000	0.472	5 (1.29) 21 (0.01) 114 (0.11)
119	I6	1.000	1.000	1.000	10
120	I7	0.592	0.708	0.836	6 (0.00) 11 (0.05) 50 (0.54) 55 (0.58) 73 (0.08) 110 (0.02)
121	I8	0.531	0.807	0.659	6 (0.04) 50 (0.77) 55 (0.45) 73 (0.04) 110 (0.17)
122	I9	0.724	0.968	0.747	42 (0.04) 50 (0.80) 55 (0.62) 73 (0.01)
123	I10	0.528	0.543	0.973	42 (0.37) 50 (0.34) 55 (0.11) 73 (0.02) 110 (0.05)
124	I11	0.517	0.555	0.932	50 (0.23) 55 (0.44) 73 (0.03) 101 (0.02) 110 (0.08) 119 (0.03)
125	I12	0.943	0.944	0.999	55 (0.65) 83 (0.19) 101 (0.16) 119 (0.00)
126	I13	0.870	0.977	0.891	55 (0.65) 73 (0.02) 83 (0.25) 101 (0.12) 119 (0.07)
127	I14	0.490	0.584	0.840	5 (0.01) 26 (0.01) 42 (0.24) 44 (0.09) 50 (0.94)
128	I15	0.539	1.000	0.539	42 (0.00) 55 (1.49) 114 (0.01)

< Appendix 4-2 > Efficiency index using DEA/Winodw for 10 years

ID	DMU	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
1	A	0.2353	0.31915	0.3494667	0.3197	0.34156	0.33908	0.24735	0.2283667	0.23465	0.2219	0.2837
2	B1	0.224	0.94985	0.9473	0.93615	0.9178	0.91602	0.922825	0.8763	0.8691	0.8553	0.8415
3	B2	0.381	0.4234	0.4655667	0.456175	0.5669	0.68116	0.926325	0.9225	0.8504	0.7059	0.6379

4	B3	0.2464	0.3075	0.3295333	0.234275	0.2924	0.30258	0.2641	0.2746	0.3322	0.2701	0.2854
5	B4	0.5127	0.4982	0.5864	0.44735	0.46006	0.5218	0.475475	0.5671	0.4952	0.5258	0.5090
6	B5	0.2288	0.228	0.2705333	0.28635	0.29698	0.28818	0.334025	0.2943667	0.26525	0.2579	0.2750
7	B6	0.2715	0.2807	0.2930667	0.287775	0.28354	0.33416	0.31965	0.3339667	0.30795	0.3343	0.3047
8	B7	0.2642	0.2762	0.3690667	0.285675	0.36936	0.34466	0.317525	0.3046333	0.35975	0.3123	0.3203
9	B8	0.1879	0.2914	0.3326333	0.327825	0.26918	0.32968	0.29275	0.4819667	0.5888	0.5616	0.3664
10	B9	0.2186	0.3015	0.2996667	0.328125	0.20852	0.2825	0.234875	0.2659333	0.3069	0.3148	0.2761
11	B10	0.1307	0.2004	0.1913667	0.373625	0.3688	0.3191	0.3078	0.3158	0.336	0.3468	0.2890
12	B11	0.1236	0.19295	0.2346	0.241375	0.46442	0.47446	0.34555	0.3452667	0.3699	0.5315	0.3324
13	B12	0.1573	0.3489	0.2214	0.2098	0.20442	0.23136	0.278975	0.3089	0.3266	0.3536	0.2641
14	B13	0.2474	0.3936	0.2715333	0.444175	0.42426	0.37644	0.410275	0.4189667	0.4033	0.3909	0.3781
15	B14	0.4154	0.5034	0.3377333	0.37695	0.37724	0.46124	0.355075	0.3612333	0.3024	0.2938	0.3784
16	B15	0.2512	0.33455	0.3061333	0.305225	0.30718	0.29992	0.320625	0.3184	0.3194	0.308	0.3071
17	B16	0.3825	0.45435	0.4409667	0.306825	0.3281	0.32432	0.2946	0.3091667	0.35045	0.3435	0.3535
18	C1	0.1612	0.3818	0.4022	0.38265	0.37324	0.30794	0.299	0.3165667	0.331	0.3362	0.3292
19	C2	0.1183	0.3131	0.3339	0.29005	0.32528	0.47756	0.4557	0.4031333	0.37025	0.3779	0.3465
20	C3	0.2811	0.4518	0.4000667	0.3607	0.37486	0.45268	0.413425	0.4082667	0.3955	0.4087	0.3947
21	C4	0.6563	0.63255	0.6958333	0.558225	0.53552	0.58628	0.615375	0.6587333	0.71735	1	0.6656
22	C5	0.3642	0.4885	0.5427333	0.434175	0.90988	0.76796	0.872425	0.6875	0.4903	0.4631	0.6021
23	C6	0.2775	0.53505	0.5466667	0.4199	0.42668	0.43828	0.421075	0.4482333	0.4971	0.4763	0.4487
24	C7	0.3969	0.3375	0.306	0.296325	0.32306	0.30974	0.33935	0.3422333	0.325	0.2727	0.3249
25	C8	0.3671	0.4725	0.4950667	0.451775	0.423	0.44722	0.363425	0.3967333	0.4865	0.4714	0.4375
26	C9	0.7049	0.558	0.5027	0.450125	0.44312	0.53912	0.806175	0.7956	0.828	0.8559	0.6484
27	C10	0.433	0.5352	0.4628	0.498375	0.41622	0.43068	0.667475	0.7166	0.7405	0.5837	0.5485
28	C11	0.3911	0.4739	0.4096333	0.5007	0.52516	0.51272	1	0.5871667	1	1	0.6400
29	C12	0.457	0.455	0.3551333	0.3719	0.37728	0.3663	0.3488	0.5045333	0.38085	0.3214	0.3938
30	C13	1	1	0.9455667	0.871925	1	0.76552	0.699075	0.7071667	0.65705	0.6264	0.8273
31	C14	0.5278	0.74065	0.6936	0.67675	0.61722	0.58894	0.5829	0.5589333	0.5403	0.559	0.6086
32	C15	0.3101	0.33725	0.3595333	0.342625	0.3294	0.34016	0.317875	0.3472667	0.3157	0.3196	0.3320
33	C16	0.4415	0.4949	0.4974	0.524875	0.59198	0.63346	0.585725	0.6022	0.64055	0.6715	0.5684
34	C17	0.3453	0.4518	0.6173333	0.53195	0.37632	0.42568	0.4538	0.4948667	0.5253	0.549	0.4771
35	D1	0.1867	0.4529	0.4114667	0.415075	0.40248	0.3796	0.34355	0.3666	0.394	0.4062	0.3759
36	D2	0.204	0.38475	0.3292333	0.377875	0.3394	0.33168	0.3346	0.3576	0.3963	0.3707	0.3426
37	D3	1	1	0.7507333	0.7896	0.5609	0.7254	0.593575	0.5099333	0.502	0.4889	0.6921

38	D4	0.5133	0.7606	0.6299667	0.4979	0.65924	0.57662	0.560275	0.6414667	0.6636	0.542	0.6045
39	D5	0.5981	1	0.5897667	0.62955	0.68614	0.63712	0.57955	0.5711667	0.58655	0.5925	0.6470
40	D6	0.7402	0.80155	0.777	0.730875	0.7818	0.72026	0.92115	1	0.9187	0.9597	0.8351
41	D7	0.5114	0.42545	0.4254333	0.42965	0.3945	0.37174	0.490825	0.5188333	0.52785	0.4754	0.4571
42	D8	0.4281	1	0.7445333	0.6332	0.63808	0.64322	0.55785	0.6504	0.8548	0.8528	0.7003
43	D9	0.2853	0.3474	0.3288	0.33985	0.37534	0.36878	0.3556	0.3738	0.3877	0.4161	0.3579
44	D10	0.3623	0.516	0.7947333	0.975125	0.99824	0.9544	1	1	1	1	0.8601
45	E1	0.2027	0.31415	0.3217	0.317425	0.2907	0.32258	0.305675	0.5396667	0.3657	0.3376	0.3318
46	E2	0.2276	0.39735	0.5455333	0.440375	0.41168	0.41164	0.407075	0.4379667	0.48415	0.4814	0.4245
47	E3	0.1309	0.213	0.2059333	0.1915	0.28182	0.26016	0.2837	0.2709667	0.2775	0.2741	0.2390
48	E4	0.3628	0.5352	0.4346333	0.543775	0.53856	0.593	0.578175	0.7339	0.7677	0.8033	0.5891
49	E5	0.3674	0.51215	0.5479333	0.53695	0.35966	0.8286	0.7644	0.7494333	0.77305	0.9386	0.6378
50	E6	1	1	1	0.9628	0.95052	1	1	0.9984	1	1	0.9912
51	E7	0.2903	0.33985	0.4286	0.31535	0.5325	0.54686	0.75515	0.5446	0.5632	0.5101	0.4827
52	E8	0.9193	0.89675	0.9927333	0.8526	0.96266	1	0.971025	0.9415667	0.9988	0.9135	0.9449
53	E9	0.331	0.73165	0.8549667	0.620825	0.59182	0.59946	0.6581	0.5628	0.55995	0.5889	0.6099
54	E10	0.2491	0.4181	0.4064667	0.382575	0.35422	0.35684	0.40235	0.4519	0.4502	0.4678	0.3940
55	E11	1	1	0.9624333	0.99775	1	0.97278	1	1	1	1	0.9933
56	E12	0.3983	0.5856	0.5341	0.483675	0.54014	0.65706	0.60105	0.629	0.6473	0.6136	0.5690
57	E13	0.4243	0.60915	0.5713	0.5689	0.65572	0.55776	0.68365	0.6538667	0.7437	0.758	0.6226
58	E14	0.2732	0.3485	0.3712333	0.354525	0.3246	0.37836	0.3832	0.3765333	0.4407	0.4157	0.3667
59	F1	0.0889	0.3045	0.2601333	0.24715	0.35942	0.35472	0.33195	0.3631	0.3366	0.3307	0.2977
60	F2	0.4577	0.8434	0.6269	0.560975	1	0.99088	1	1	1	1	0.8480
61	F3	0.2534	0.5207	0.4902333	0.4837	0.55594	0.53448	0.431325	0.4388	0.49265	0.4988	0.4700
62	F4	0.2524	0.82605	0.8092667	0.5744	0.6319	0.73334	0.87595	0.6882333	0.73525	0.865	0.6992
63	F5	0.6618	1	0.8429333	1	0.83298	0.96414	1	1	0.98495	1	0.9287
64	F6	0.5006	0.6284	0.6499	1	0.68218	0.50136	0.59985	0.55	0.63	0.6501	0.6392
65	F7	0.6976	0.8819	0.7655	0.877575	0.78928	1	0.894175	0.6922	0.6536	0.53	0.7782
66	F8	0.733	0.8312	0.7015667	1	0.86474	1	1	0.9313333	0.8397	0.7304	0.8632
67	F9	0.944	1	0.8274667	0.891975	0.78976	0.99854	0.6099	0.6058	0.5835	0.695	0.7946
68	F10	0.9615	0.931	0.9969	0.8012	0.57254	0.41914	0.413025	0.4614333	0.5514	0.633	0.6741
69	F11	0.2673	0.88205	0.7891667	0.672475	0.82304	0.76054	0.747225	0.7116	0.8079	0.7582	0.7219
70	F12	0.246	0.9382	0.5641	0.54295	0.71478	0.73452	0.624575	0.7033	0.7454	0.8663	0.6680
71	G1	0.1146	0.32715	0.2837333	0.235625	0.25712	0.34936	0.354925	0.2949	0.2917	0.2812	0.2790

72	G2	0.1436	0.24825	0.0941333	0.103875	0.19306	0.1913	0.255375	0.2696333	0.29875	0.2747	0.2073
73	G3	0.154	0.3122	0.3309	0.316975	0.2487	0.24914	0.26375	0.2708667	0.2613	0.2887	0.2697
74	G4	0.4602	0.53445	0.5805667	0.51645	0.54572	0.59142	0.6063	0.5169333	0.5865	0.8611	0.5800
75	G5	0.2165	0.4649	0.5882333	0.409675	0.40116	0.4163	0.362975	0.3776333	0.37435	0.382	0.3994
76	G6	0.7368	1	1	0.83735	0.66152	0.71316	0.496025	0.5523	0.67715	0.4434	0.7118
77	G7	0.8197	0.73285	0.7124333	0.71865	0.61034	0.57208	0.62795	0.5982	0.4863	0.4702	0.6349
78	G8	1	0.9942	1	0.973725	0.93318	0.87828	0.98605	0.8489333	0.84565	0.8619	0.9322
79	G9	0.428	1	0.9654	0.852325	0.7243	0.80808	0.9662	0.7675	0.9734	0.9727	0.8458
80	G10	0.6183	0.78895	0.6991333	0.556375	0.57824	0.59548	0.354625	0.4766333	0.4931	0.4823	0.5643
81	G11	0.3323	0.547	0.7453667	0.7566	0.72084	0.62318	0.68765	0.3776667	0.5297	0.5698	0.5890
82	G12	1	0.6719	0.9368	0.5732	0.82402	0.74316	1	0.6664	0.6745	0.7395	0.7829
83	G13	0.7022	0.796	0.7133333	0.765275	0.73788	0.69194	0.669425	0.7550333	0.7446	0.8654	0.7441
84	G14	0.633	0.83385	0.7561333	0.6106	0.46414	0.52902	0.605475	0.7056667	0.70815	0.6852	0.6531
85	G15	0.1929	0.6212	0.6017667	0.3472	0.33942	0.39742	0.38535	0.3729333	0.3967	0.4295	0.4084
86	G16	0.3759	0.6578	0.5460667	0.57435	0.52062	0.53642	0.58155	0.5196333	0.48425	0.4895	0.5286
87	G17	0.7328	0.84465	0.8514667	1	0.99104	0.96026	1	0.8803667	0.79445	0.8313	0.8886
88	G18	0.7571	0.79855	0.9958667	0.922	0.90028	1	1	0.9446	0.9125	0.9182	0.9149
89	G19	1	1	1	0.8982	0.8541	1	1	0.9403333	0.9717	1	0.9664
90	G20	0.4663	0.744	0.5260333	0.499675	0.54534	0.5203	0.501875	0.4177667	0.4567	0.4632	0.5141
91	G21	0.3574	0.5679	0.6408333	0.7724	0.88576	1	0.68855	0.9677667	1	0.8572	0.7738
92	G22	0.2265	0.5976	0.9980667	0.58295	0.51576	0.46484	0.46315	0.4645333	0.51105	0.4147	0.5239
93	H1	0.0914	0.3233	0.3463	0.2844	0.32412	0.35696	0.36015	0.3299667	0.33605	0.3393	0.3092
94	H2	0.2081	0.48065	0.4465333	0.324825	0.36526	0.3904	0.3909	0.4156333	0.39905	0.3747	0.3796
95	H3	0.193	0.69055	0.3603333	0.421675	0.3885	0.25568	1	0.2167333	0.2606	0.2558	0.4043
96	H4	0.2938	0.63315	0.5690667	0.49855	0.50602	0.57952	0.5294	0.4395667	0.48305	0.5626	0.5095
97	H5	0.1665	0.37645	0.361	0.326	0.3165	0.33934	0.2728	0.2926667	0.3361	0.3375	0.3125
98	H6	0.2332	0.638	0.6236	0.547625	0.58216	0.68024	0.616275	0.6473	0.526	0.5409	0.5635
99	H7	0.2352	0.72375	0.7164333	0.5267	0.5331	0.4852	0.426275	0.4888667	0.4813	0.4585	0.5075
100	H8	0.1079	0.33855	0.2974333	0.271525	0.26476	0.26494	0.300575	0.2986	0.3653	0.3155	0.2825
101	H9	0.5717	0.9118	1	1	0.99506	0.989	0.957625	0.9409	0.90995	1	0.9276
102	H10	0.398	0.5537	0.587	0.516675	0.35684	0.34722	0.47335	0.4755667	0.53625	0.4794	0.4724
103	H11	0.8569	0.79415	0.8219	0.7232	0.65838	0.68494	0.629925	0.6693	0.65875	0.6633	0.7161
104	H12	0.5726	0.7607	0.8063667	0.74465	0.74316	0.7014	0.759825	0.4556	0.4381	0.4307	0.6413
105	H13	0.3822	0.6309	0.9882667	0.730525	0.6335	0.54322	0.719575	0.7662	0.7069	0.6959	0.6797

106	H14	0.4941	0.7332	0.6461	0.59565	0.63184	0.68988	0.61145	0.6093	0.6725	0.6177	0.6302
107	H15	1	1	1	1	0.99884	0.99632	1	1	1	1	0.9995
108	H16	0.8468	0.8713	1	0.8776	0.9677	1	0.94005	0.7459	0.726	0.5993	0.8575
109	H17	0.1491	0.34835	0.2993	0.3024	0.43318	0.4135	0.452675	0.3764333	0.3763	0.3884	0.3540
110	H18	0.8671	1	0.9163333	0.968925	1	0.97118	1	1	0.91885	1	0.9642
111	H19	0.7745	0.9317	0.8324667	0.79925	0.75062	0.72858	0.479925	0.5190667	0.563	0.3829	0.6762
112	H20	0.2973	0.4307	0.4432333	0.48415	0.4261	0.40196	0.429225	0.3781	0.3921	0.2914	0.3974
113	H21	1	1	1	0.933175	1	1	0.9235	0.9127	0.9868	0.9249	0.9681
114	I1	1	1	0.6082333	0.822975	0.95422	1	1	1	0.97485	1	0.9360
115	I2	0.4404	0.7106	0.7502333	0.8579	0.77534	0.71318	0.69095	1	0.64405	0.6902	0.7273
116	I3	0.2189	0.5173	0.6023333	0.54945	0.58084	0.57698	0.56555	0.5295667	0.5442	0.5491	0.5234
117	I4	0.2284	0.5174	0.5419667	0.52515	0.53644	0.57328	0.540675	0.5239	0.625	0.6329	0.5245
118	I5	0.1261	0.1677	0.1811333	0.1776	0.17612	0.19884	0.207425	0.2152333	0.18405	0.1678	0.1802
119	I6	0.7663	0.9375	0.9163	0.93145	0.55084	0.56498	0.48625	0.4963333	0.5226	0.5379	0.6710
120	I7	0.253	0.4827	0.4470333	0.471325	0.54032	0.60268	0.565025	0.5315	0.5213	0.4403	0.4855
121	I8	0.3616	0.6217	0.6880667	0.571125	0.66442	0.6523	0.665	0.6367333	0.63355	0.6648	0.6159
122	I9	0.4587	0.79395	0.6377667	0.583025	0.58176	0.51668	0.57545	0.4973333	0.7687	0.8868	0.6300
123	I10	0.3683	0.6121	0.5930333	0.472275	0.46982	0.3655	0.3885	0.3729	0.41	0.4688	0.4521
124	I11	0.7672	0.8781	0.5239	0.5553	0.51094	0.50092	0.4939	0.4627	0.4507	0.4063	0.5550
125	I12	1	0.9113	0.7417	0.72105	0.72434	0.90356	0.7311	0.8421	0.88095	0.8689	0.8325
126	I13	0.7451	0.92895	0.9175667	0.6468	0.59228	0.60786	0.516975	0.5358	0.5765	0.5355	0.6603
127	I14	0.4319	0.69135	0.8018	0.592225	0.56618	0.38574	0.3854	0.3056667	0.3988	0.3678	0.4927
128	I15	0.6783	0.6341	0.7615667	0.59135	0.5825	0.62336	0.547325	0.6976333	0.6457	0.6261	0.6388

< Appendix 5-1> Random Effect with Efficiency Index

Random Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable : Efficiency Index(%)											
Operation Type(0:local, 1:contracting-out)	14.66071***	14.72281***	14.45474***	14.30566***	14.04730***	14.40664***	14.55169***	14.18779***	13.91819***	14.69009***	14.46213***	14.66071**
	(1.78555)	(1.81063)	(1.78361)	(1.78626)	(1.78569)	(1.80992)	(1.80738)	(1.80772)	(1.79999)	(1.83036)	(1.82815)	(4.67238)
Pipe Length(Km)	0.01317***	0.01357***	0.01298***	0.01258***	0.01208***	0.01304***	0.01347***	0.01265***	0.01386***			0.01317***
	(0.00206)	(0.00209)	(0.00205)	(0.00206)	(0.00204)	(0.00208)	(0.00208)	(0.00207)	(0.00204)			(0.00301)
Rate of Realization Cost(%)	-0.18554***		-0.18036***	-0.18061***	-0.17468***							-0.18554***
	(0.03086)		(0.03078)	(0.03090)	(0.03085)							(0.04844)
Percentage of of Water produced by Local Gov(%)	0.04827*	0.03868		0.05730*		0.04690						0.04827
	(0.02448)	(0.02476)		(0.02436)		(0.02461)						(0.03290)
Percentage of Old pipe by annual(%)	0.12786**	0.11327*	0.14045**				0.12401**					0.12786*
	(0.04459)	(0.04515)	(0.04431)				(0.04481)					(0.06265)
Log(Population Density) (per 1000people)	1.87464*	0.98660	1.89543*	2.16322**	2.17018**	1.26503	1.04263	1.30646		1.89501**		1.87464
	(0.73701)	(0.73228)	(0.73812)	(0.73275)	(0.73441)	(0.72606)	(0.73342)	(0.72742)		(0.73509)		(1.03314)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266

Standard errors in parentheses * p<0.05 ** p<0.01 *** p<0.001"

< Appendix 5-2>   Random Effect with Revenue Rate

Random Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable : Revenue rate(%)											
Operation Type(0:local, 1:contracting-out)	7.99939***	7.97510***	8.00033***	8.19516***	8.19300***	8.15619***	7.96334***	8.13928***	8.32570***	8.17582***	8.35190***	7.99939**
	(0.92941)	(0.93493)	(0.92775)	(0.92814)	(0.92636)	(0.93319)	(0.93329)	(0.93139)	(0.95219)	(0.93022)	(0.95050)	(2.66979)
Pipe Length(Km)	0.00085	0.00072	0.00080	0.00111	0.00111	0.00095	0.00063	0.00090	0.00051			0.00085
	(0.00107)	(0.00107)	(0.00106)	(0.00107)	(0.00106)	(0.00107)	(0.00107)	(0.00106)	(0.00109)			(0.00199)
Rate of Realization Cost(%)	0.06336***		0.06355***	0.06078***	0.06084***							0.06336***
	(0.01607)		(0.01602)	(0.01605)	(0.01600)							(0.01895)
Percentage of of Water produced by Local Gov(%)	0.00475	0.00783		0.00082		0.00434						0.00475
	(0.01264)	(0.01267)		(0.01271)		(0.01273)						(0.01460)
Percentage of Old pipe by annual(%)	-0.05732*	-0.05254*	-0.05564*				-0.05010*					-0.05732
	(0.02315)	(0.02324)	(0.02298)				(0.02306)					(0.07457)
Log(Population Density) (per 1000people)	1.80003***	2.12200***	1.75464***	1.57850***	1.57555***	1.89055***	2.07291***	1.88819***		1.92969***		1.80003*
	(0.38244)	(0.37637)	(0.38270)	(0.38147)	(0.38133)	(0.37498)	(0.37695)	(0.37489)		(0.37240)		(0.80049)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266

Standard errors in parentheses   * p<0.05   ** p<0.01   *** p<0.001"

< Appendix 5-3 >   Random Effect with Total Unit Cost

Random Effect	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Dependent Variable : Total Unit Cost(won)											
Operation Type(0:local, 1:contracting-out)	70.01104*	73.78873	76.42911*	71.40518*	79.31697*	79.50500	83.68238	92.29273	92.66103	94.52616	93.25008	70.01104
	(35.32832)	(49.72582)	(35.46661)	(35.24250)	(35.37638)	(49.66887)	(49.94217)	(49.90950)	(51.19887)	(49.83090)	(51.11187)	(102.14863)
Pipe Length(Km)	-0.03421	0.00690	-0.01659	-0.03150	-0.01131	0.01706	0.03482	0.05086	0.01022			-0.03421
	(0.04047)	(0.05659)	(0.04041)	(0.04024)	(0.04013)	(0.05635)	(0.05639)	(0.05610)	(0.05755)			(0.06376)
Rate of Realization Cost(%)	-21.45403***		-21.58896***	-21.47404***	-21.63306***							-21.45403***
	(0.61086)		(0.61288)	(0.60976)	(0.61169)							(1.40289)
Percentage of of Water produced by Local Gov(%)	-1.75896***	-2.64613***		-1.79805***		-2.81174***						-1.75896
	(0.47595)	(0.66021)		(0.47120)		(0.65364)						(1.66466)
Percentage of Old pipe by annual(%)	-0.54403	-2.25440	-0.97455				-2.94986*					-0.54403
	(0.87693)	(1.22656)	(0.87401)				(1.21975)					(2.53606)
Log(Population Density) (per 1000people)	-48.87521***	-156.62884***	-46.51789**	-50.10378***	-48.68629***	-162.53408***	-153.61624***	-161.07117***		-159.10666***		-48.87521
	(14.47914)	(19.80230)	(14.54618)	(14.33174)	(14.42101)	(19.56161)	(19.86497)	(19.66132)		(19.50214)		(26.60710)
Time Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster Province	N	N	N	N	N	N	N	N	N	N	N	Y
N	1266	1266	1266	1266	1266	1266	1266	1266	1280	1266	1280	1266

< Appendix 6> Result of Hausman Test

Variables	(b) Fixed Effect	(B) Random Effect	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
Operation Type(0:local, 1:contracting-out)	13.60821	14.66071	-1.052503	0.6001336
Pipe Length(Km)	0.0217664	0.0131714	0.0085949	0.0010687
Percentage of Realization Cost(%)	-0.146033	-0.1855399	0.0395069	0.0106414
Percentage of Producing Water by Local(%)	0.0544125	0.0482714	0.0061411	0.0181886
Percentage of Old pipe by annual(%)	0.1858787	0.1278625	0.0580163	0.0215054
Log(Population Density) (per 1000people)	4.069516	1.874641	2.194875	0.383804

b = constistent under Ho and Ha ; obtained from xtreg
B = inconsistent under Ha efficient under Ho; obtained from xtreg

Test Ho difference in conefficients not systematic

chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 116.27
Prob>chi2 = 0.0000