Exploring Effects of Water Price on Residential Water Demand in Korea

By

SEO, Giwon

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

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Professor Lee, Jinsoo ______________________

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ABSTRACT

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Management of water resource is pivotal issue globally, while it is getting difficult due to climate change. The purpose of this study is to explore water resource management in terms of demand and suggest efficient residential water demand management in Korea with price elasticity. This study applied data of water usage and water price of 15 regions in four major river basins by considering up and downstream locations from 1997 to 2017. This study applied regression analyses and ANOVA to verify claims. The results of this study found that there are relationships between water usage and price in Korea by revealing positive elasticity. The results also show that there are significant differences based on location and river basins. Findings provide important policy and management implications for the improvement of water resources management in terms of demand. The results of this study also provide signal for the water price that should be reconsidered by comparing water price level of OECD countries. Further the results implied that water management in Korea needs to be improved in terms of supply aspects to cope with climate change.

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I. Introduction

Have you ever thought about where your water came from? According to a report of a Ministry of the Republic of Korea (Korea), 32.8% of your water comes from the river, 56.2% from dams, and remains from ground water (Ministry of Land, Infrastructure and Transportation, 2016). By definition of dam, “a structure . . . built, by blocking the flow of a river, to be used as tap water, water for industrial use, water for agriculture . . . environmental water, power generation, flood control . . .” (Ministry of Environment, 2017b), The 89% of water for Korean is originally from surface water including rivers and dams.

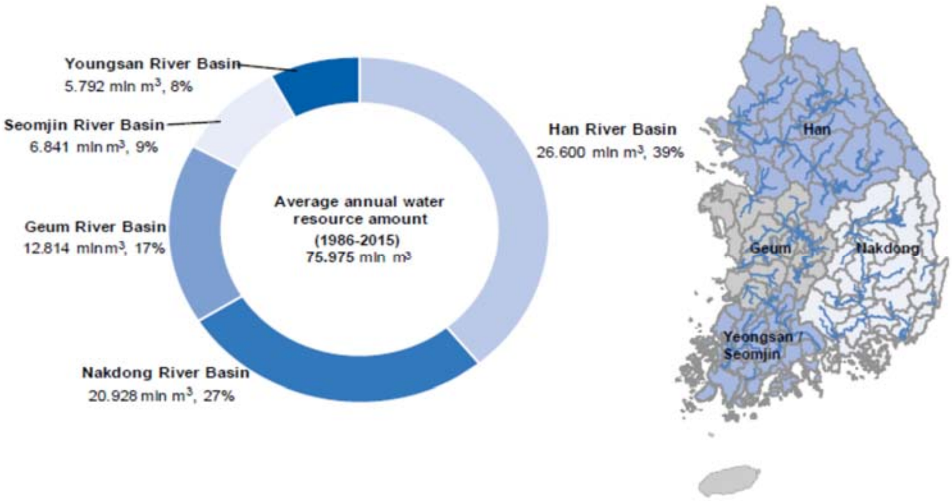
In worldwide the climate change is non-doubtable future threat. According to the Paris Agreement (2015), 195 parties agreed that recognizing the need for an effective and recognized necessity of an effective and progressive response to the urgent threat of climate change (UNFCCC, 2015). The 8th World Water Forum approved the ministerial declaration, which “encourage governments to establish or strengthen national integrated water resources management policies and plans, including strategies for adaptation to climate change . . .” (The ministerial declaration, 2018). The crisis of in terms of water area is also increasing in global context due to the threat of climate change.

In Korea, frequency and impact of floods and droughts by climate change make condition difficult to manage than before (Ministry of Land, Infrastructure and Transportation, 2016). For examples, there were two cases: Kangnam station flooding from 2010 to 2012 and local drought of west Chungcheongnam-do from 2012 to 2015 (Ministry of Environment, 2017a). In addition, the surface water is weaker for flood and drought rather than ground water since there is no barrier for rainfall or evaporation. Korea is the 6th in OECD countries on the water stress index, the ratio of total abstraction to total water in a country, which is one way to reveal the vulnerability of water security (OECD, 2017). The water management condition in Korea is highly affected by the climate change, while water resource management is getting unstable and unstainable.

This research will focus on demand perspectives with approaches on water resources and management. Statistics showed that in the case of Seoul, the capital city and the biggest city of Korea, has the lowest water price among selected major cities (OECD, 2015). However, Korea abstracted 400 liter of water a day (Ministry of Land, Infrastructure and Transportation, and K-water, 2015). However, other countries have lower amounts of water abstraction, such as 345 liters (Japan), 318 liters (Swiss), 282 liters (UK) and 173 liters (Germany) day (Ministry of Land, Infrastructure and Transportation, and K-water, 2015). In this regard, this paper explores ways to respond to water instability caused by the climate change from demand control aspect.

The purpose of this paper is to investigate the price elasticity of residential water demand (e_{dw}) in cities of Korea. "The price elasticity of demand measures how much the quantity demanded responds to a change in price" (Mankiw, 2008). Residential water demand is applied as it less sensitive than other demands such as agriculture or industrial water demand (Espey, Espey & Shaw, 1997). This study also considers river basin approach due to reasons such as policy movement and political aspects. Cities are chosen from four major river basins, Han, Nakdong, Geum and Yeongsan-Seomjin, with consideration of upstream and downstream.

Figure 1. The Four Major River Basins of Korea and the Quantity of Water Resources in Each River Basin



Source: The 4th Long-term Comprehensive Plan of Water Resources (2001-2020) 3rd revision plan. (Ministry of Land, Infrastructure and Transportation, The 4th Long-term Comprehensive Plan of Water Resources (2001-2020), 3rd revision) [Modified by OECD]

Based on consideration, this paper aims to provide answers to four research questions:

i) Are there significant effects of water price on residential water demand in cities of Korea?;

ii) Are there significant effects of water price on e_{dw} in Korea?;

iii) Are there any different effects of e_{dw} based on river basins and location?; and

iv) Are there any different effects of water usage based on river basins and location?

The paper consists with five parts. Chapter 2 will cover the literature review in the field, chapter 3 about hypothesis development, chapter 4 about methodology, chapter 5 about data analysis, and chapter 6 about conclusion with findings, policy implications and future research suggestions.

II. Literature Review

2.1 Price Elasticity of Water Demand

2.1.1 Definition of Price Elasticity of Demand

Mankiw (2008) defined "the price elasticity of demand measures how much the quantity demanded responds to a change in price" in his book. And the formula of price of elasticity of demand (e_d) is as below.

$$e_d = \frac{\Delta Q\%}{\Delta P\%} = \frac{\partial \ln Q}{\partial \ln P}$$

Normally, demand is decreased when price is increasing, so the elasticity is almost always negative value and four cases are possible to occur: perfect inelastic (ed = 0), inelastic (-1 < ed <0), unitary elastic (ed = -1) and elastic (ed < -1). Unusually, elasticity is positive value, Veblen and Giffen Goods. Veblen Goods means that demand is risen with price increase, and Giffen Goods means that demand is reduce when price decrease.

2.1.2 Price Elasticity of Residential Water Demand with Case Studies

The table is about price elasticity of residential water demand in other countries summarized by Hortová and Krištoufek (2014), and Espey, Espey & Shaw (1997).

Some of these studies showed that e_{dw} has a difference between short and long term. Hortová and Krištoufek (2014) also stated the e_{dw} is affected by consumption, price and income, not temperature, aging and waterfall. And Grafton, Ward, To and Kompas (2011) argued that water is inelastic goods, residential water demand is more sensitive than others and environmental concerns effects the elasticity. But Espey, Espey and Shaw (1997) observed e_{dw} was only affected by season and interpreted that the equilibrium state is reached as the absolute value of e_{dw} increase in long term although the short term e_{dw} is small against the price increase. Espey, Espey and Shaw also states that family members, income and seasons cannot directly affect to the demand, but these effect to the pattern of water use indirectly.

Table 1. Summary of Price Elasticity of Residential Water Demand in 9 Countries (Hortová and Krištoufek, 2014, and Espey, Espey and Shaw, 1997)

Literatures	e_{dw}	Period	Countries
Musolesi and Nosvelli (2007)	-0.27 (short term) -0.47 (long term)	1998-2001	Italy
Bartczak (2009)	-0.22	2001-2005	Poland
Schleich and Hillenbradn (2009)	-0.25		Germany
Worthington (2009)	-0.1	1994-2004	Australia
Arbues et al. (2010)	-1.32 (single member) -0.26 (more than 5 members)	1996-1998	Spain
Ciomos (2012)	-0.70	2010	Romania
Rinaudo et al. (2012)	-0.18		South France
Hortová and Krištoufek (2014)	-0.20 (short term) -0.54 (long term)	2000-2011	Czech
Espey, Espey & Shaw (1997)	-0.38 (short term) -0.64 (long term)	1963-1993	U.S.A

About previous Korean case, Moon (2010) summarized that e_{dw} were -0.82 in 1991, -0.496 or -0.011 in 1996, -0.179 in 1999, and -0.2677 in 2010 with insufficient statistical data, and these results show that the absolute value of e_{dw} has decrease, while the previous study rarely analyzed whether the e_{dw} of Korea is affected by income, season or number of family members And Moon (2010) also examine that the water use does not decrease even if the water rate increases. Table 2 summarized case studies on Price elasticity of residential water demand in Korea modified from Moon (2010). Ministry of Land, Transport and Maritime Affairs (2010) studied demand elasticity of residential water use in 16 metropolitan cities and provinces of Korea in improvement feasibility research. The research uses water usage (m^3) and water rate (KRW) during 1985 to 2008. And the result of the research shows the lowest, -0.09 in Jeju and the biggest, -0.56 in Chungnam (Table 3).

Table 2. Summary of Other Case Studies on Price Elasticity of Residential Water Demand in Korea (modified from Moon (2010))

Literatures	e_{dw}	Variables
Kim (1991)	-0.82	Annual water usage in Seoul
Yoo (1996)	-0.496	Annual multi-region water usage
Kim (1996)	-0.011	Water usage
Kim et al. (1997)	Local waterworks -0.229 (short term) -0.379 (long term)	Water usage of local waterwork
ME (1999)	-0.179	Water usage
Kim and Park (2001)	-0.13	Water usage, and water rate
MoLTMA (2010)	-0.2571	Water abstraction rate and volume

Table 3. Demand Elasticity of Residential Water Use in Korea during 1985 – 2008

Region	e_{dw}	Method
Overall	-0.2571	CORC
Seoul	-0.1744	CORC
Busan	-0.3175	CORC
Daegu	-0.4437	ML
Incheon	-0.1754	CORC
Gwangju	-0.4803	ML
Daejeon	-0.2021	CORC
Ulsan	-0.3321	CORC
Kyeongki	-0.1987	ML
Kangwon	-0.3499	OLS
Chungbuk	-0.4184	OLS
Chungnam	-0.5606	CORC
Gyeongbuk	-0.2505	CORC
Gyeongnam	-0.2997	CORC
Jeonbuk	-0.2247	ML
Jeonnam	-0.2062	CORC
Jeju	-0.0924	CORC

Source: Ministry of Land, Transport and Maritime Affairs, 2010

2.2 Water Price in the Republic of Korea

A water bill of common Korean household consists with water rate, sewerage rate, water use charge and charges for using groundwater (groundwater charge). Seoul Waterworks Ordinance (www.law.go.kr) define that water rate in Seoul consists with two parts, Diameter Rate and Water Use Rate. The Ordinance defines that the diameter rate is charged a constant rate according to the diameter of supply pipe and water use rate charge is charged in proportion to water usage. And the more people use, the more charged it is. It means that water rate is accumulatively charged. Water rate of other cities has the same system but different rate (Table 4). Lim and Han (2016) informed that the water rate is a type of public utility bill paid to the government in exchange for using supplied water at home or in the office, and the water supply system divided into multi- and local waterworks. Also, Kwak, Lee and Kim (2004) pointed out problems by rate system below production cost with case study in Seoul and suggested a solution to secure fiscal soundness and water saving by realizing the water rate. In this vein, Ryu and Jang (2012) argued that the water rate is a meaningful way to be able to change consumer behavior.

Table 4. Summary of Detailed Water Rates of Seoul, Busan, Daejeon and Gwangju from Ordinances of Four Major Cities

City	Diameter Rate		Residential Water Use Rate (KRW/m^3)	
	Diameter (mm)	Rate (KRW)		
Seoul (2012~)	15	1,080	Below 30	360
	20	3,000	More than 30 to below 50	550
	25	5,200	More than 50	790
Busan (2018~)	15	1,200	Below 10	540
	20	2,200	More than 10 to below 20	620
	25	3,400	More than 20	880
Daejeon (2017~)	15	860	Below 20	430
	20	2,420	More than 20 to below 40	720
	25	3,890	More than 40	950
Gwangju (2017~)	13	1,000	Below 20	530
	20	2,000	More than 20 to below30	600
	25	3,000	More than 30	700

Source: www.law.go.kr

2.2.2 Sewerage Rate

Structure of sewerage rate is summarized in Table 5. And Seoul, Busan, Daejeon, Gwangju Sewerage usage Ordinance (www.law.go.kr) define that sewerage rate is charged on water usage, quantity measured by house water meter, not disposal amount of sewage. Oh, Kim, Park, Park and Park (2014) argued that sewerage utility authority of Seoul needs to raise its sewerage rate due to facing financial independent from central government to local government and suggested to realization of sewerage rate. Also, Yun, Choi and Hong (2009) said that the low sewerage rate could help to press the inflation, but there are heavy water usage and old infrastructure issues. Saal and Parker (2001) introduced result of privatization of water and sewerage of England and Wales, and insisted that more regulation causes fewer marginal returns.

Table 5. Summary of Residential Public Sewerage Rate of Seoul, Busan, Daejeon and Gwangju from Ordinances of Four Major Cities

City	Sewerage Rate (KRW/m^3)	
Seoul (2019~)	Below 30	400
	More than 30 to below 50	930
	More than 50	1,420
Busan (2019~)	Below 10	450
	More than 10 to below 20	580
	More than 20 to below 30	620
	More than 30	870
Daejeon (2018~)	Below 20	370
	More than 20 to below 40	600
	More than 40	860
Gwangju (2019)	Below 20	574
	More than 20 to below 30	689
	More than 30	1,318

Source: www.law.go.kr

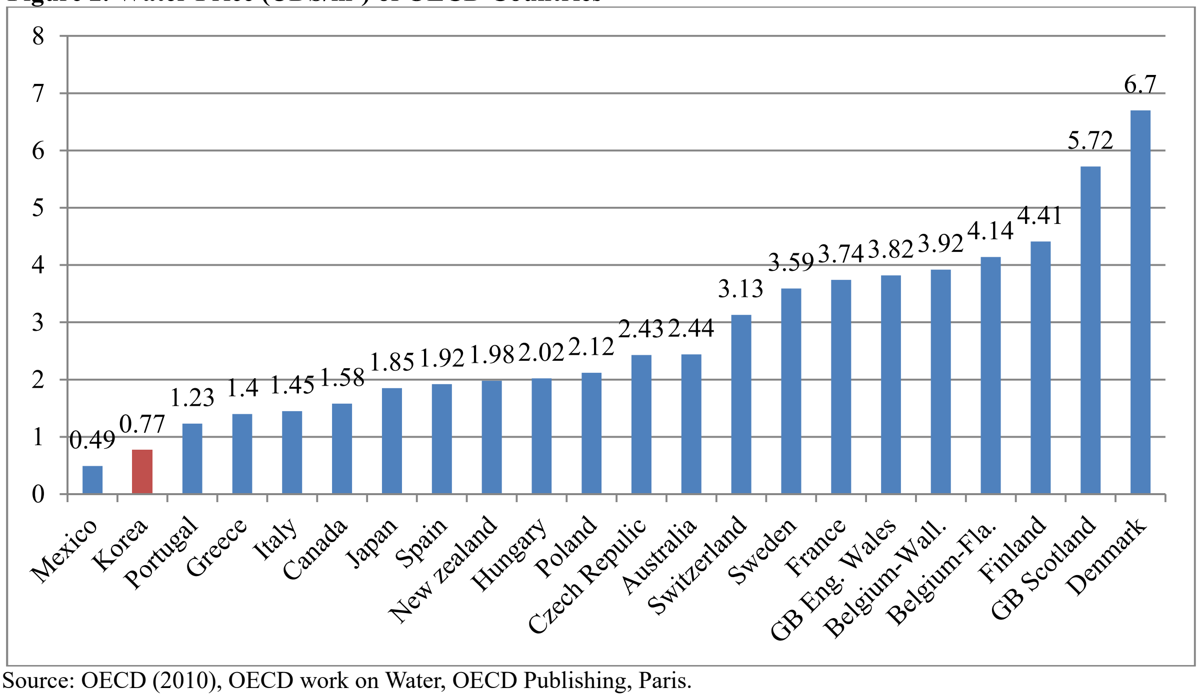
2.2.4 Ground Water Charge

Groundwater charge is charging for using groundwater, but residential groundwater charge is waived according to Groundwater Act 40-3. So, it is not considered in this study.

2.3 Comparison Analysis with Other Countries

OECD (2010) reported the level of water price of OECD member countries. In the report, Korea is the second lowest country among reported countries (Figure 2). Denmark, Great Britain excluding N. Island, Finland, Belgium have higher water price than other OECD countries. Water price of Denmark is 13 times greater than the Mexico's price and 8.7 times greater than Korea's price. With consideration of national GDP per capita level (2007, constant 2010 USD $), Korea is still the second lowest countries (Figure 3). Hungary and Poland are middle rank without national GDP, but become the top, but ranks of Switzerland, Canada, Finland and Denmark become lower. In this regards, similar order was shown in other study. Moon (2010) also said that Korea has lower water rate and sewerage rate than other countries (Figure 4). OECD (1999) explained that water usage of Korea had been increased due to economic growth and law water price, and water usage of other OECD countries are mostly stagnant or trending down.

Figure 2. Water Price (UDS/m^3) of OECD Countries



Source: OECD (2010), OECD work on Water, OECD Publishing, Paris.

Figure 3. Converted Water Price (USD/m^3) of OECD Countries [modified from OECD (2010)]

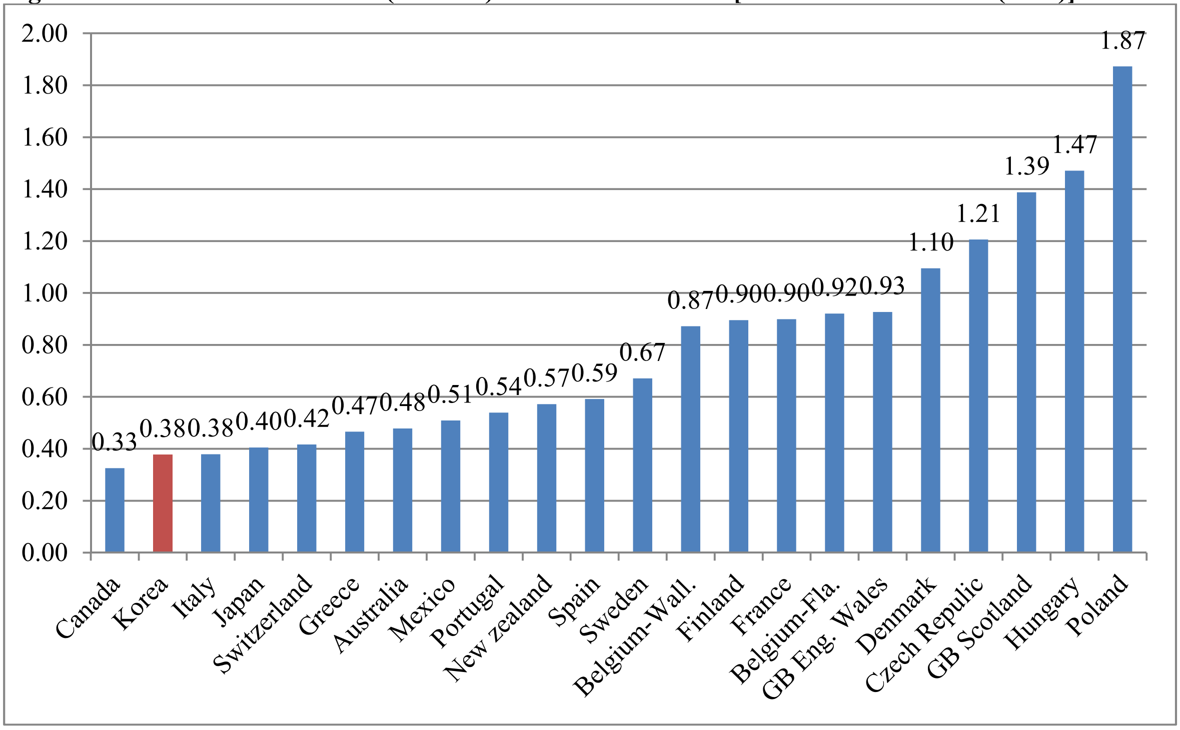
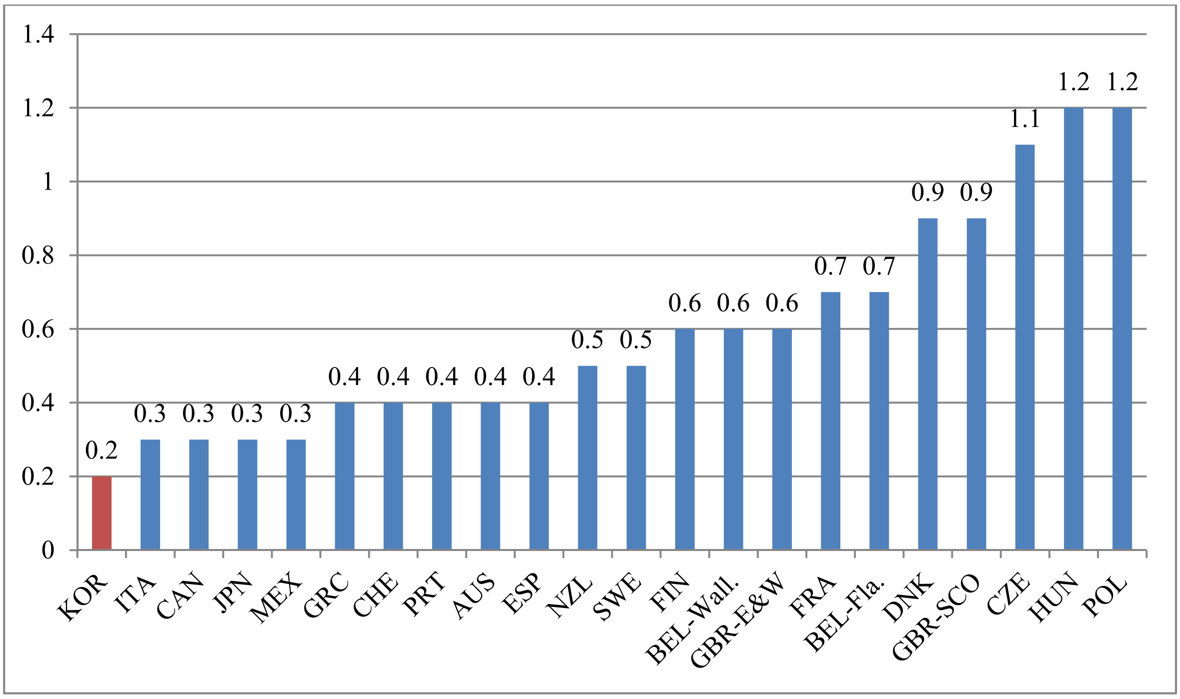


Figure 4. The Ratio of Water Rate and Sewerage Rate to Disposable Income in OECD Member Countries



Source: Moon (2010).

2.4 River Basin Management

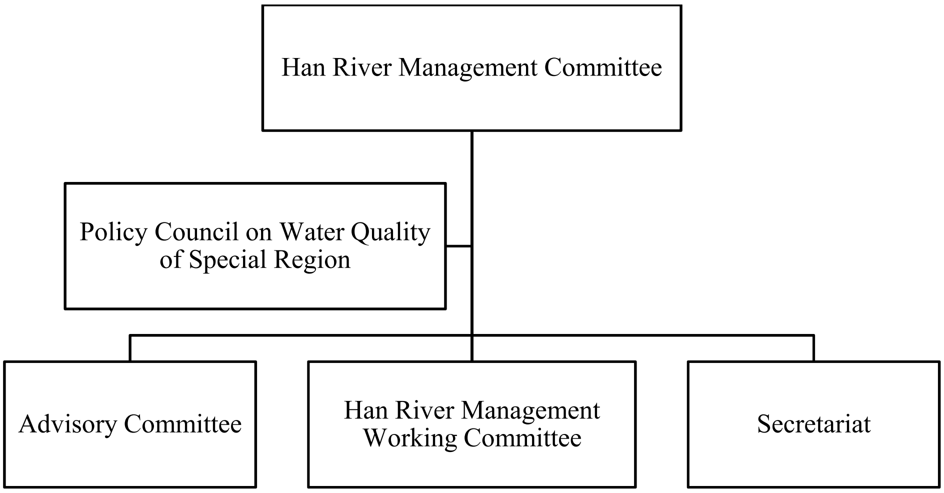
2.4.1 Concept of River Basin Management

River basin means nature boundary by river and hill and conceptually includes watershed and catchment. River basin management started to solve water quality problem in Transboundary Rivers, such as Rhein River and Donau River in EU and then transformed to integrated water resource management (IWRM) (Molle, 2009). Antunes, Kallis, Videira and Santos (2009) also argued that the EU developed the river basin management based on IWRM for environment and human being, finally EU adopted Water Framework Directive (WFD).

The River basin management is adapted not only EU but also U.S. and Korea. Gerlak (2005) insisted that water resource management based on river basin is a representative case of pragmatic federalism and custom-made approach in U.S. Ahn and Jeong (2008) explained that concept of river basin management first applied by adopting Act on water management and resident support in the Han River basin in 1999 in Korea, and the concept developed from water quality management to IWRM with administrative re-organization in 2018.

A unit of river basin management is not a central government, but it is local government and variety of stakeholders in aspects of governance in EU (Antunes et al., 2009). Similar to Europe, river basin management is shifting to local governments and basins. A representative example is the composition of the RMC in Korea (Figure 5 and Table 6).

Figure 5. Structure of Han River Basin Management Committee



Source: Financial Report of Han River Basin Management Committee (2017), www.me.go.kr

Table 6. Composition of Han River Basin Management Committee

Organization	Members
Han River Management Committee	Ministry of Environment (Chairman), Ministry of Land, Instrastructure and Transportation, Seoul, Incheon, Gyeonggi-do Province, Gangwon-do Province, Chungcheongbuk-do Province, K-water (Korea Water Resource Corperation) and KHNP (Korea Hydro & Nuclear Power Co. Ltd.)
Policy Council on water Quality of Special Region	Ministry of Environment, Han River Basin Environment Office, Gyeonggi-do, 7 cities (mayor and chairman of local council) in Special Region, Representatives of local resident
Advisory Committee	Representatives of local resident, NGOs, Representatives of industry and Environmental Experts
Han River Management Working Committee	Han River Basin Environment Office, Wonju Regional Environment Office, Seoul Regional Office of Construction and Management, 5 local government, K-water and KHNP
Secretariat	Han River Basin Environment Office

Source: Financial Report of Han River Basin Management Committee (2017), www.me.go.kr

2.4.2 Characteristics of Korean's Rivers

In Korea, there are 4 administrative river basins: Han, Nakdong, Geum and Yeongsan-Sumjin (Framework Act on Water Management, www.law.go.kr). Each river basin has own characteristics. Han River basin has a special region in upstream for maintain water quality for twenty million people who live in the basin. There are conflicts between several types of stakeholders due to the special region under very tightly regulation (Water Environmental Master Plan of Han River Basins, 2017). In Nakdong River, there are metropolitan and large cities, and water intake sites of each city located along the river like Rhein River (Water Environmental Master Plan of Nakdong River Basins, 2017). Geum River is similar to Han River and additionally has issues of allocation of water resource in order to serious local drought in downstream agriculture cities (Water Environmental Master Plan of Geum River Basins, 2017). Yeongsan-Sumjin River consists with two rivers, and also has issues of allocation of water resource due to almost of cities in Yeongsan River use water of Sumjin River (Water Environmental Master Plan of Yeongsan-Sumjin River Basins, 2017).

III. Hypothesis development

3.1 Relationships between Water Price and Residential Water Demand (H1)

This paper secures a relationship between water price and residential water demand. Additionally, Espey, Espey & Shaw (1997) summarized that season effects residential water demand in U.S.A. Hortová et al. (2014) showed that senior didn’t affect water consumption but price, income and senior effect consumption in Czech Republic. Lim and Han (2016) argued that awareness of water usage effects water demand and Grafton et al. (2011) said that income and environmental concerns are a significant factor on water consumption. In this regards, price is an essential factor on the demand and other factors are needed individual data, not a group. So, this study finds a relationship between water price and residential water consumption in each region.

With this hypothesis, e_{dw} will be found out from the relationship.

H1i: Water price affects residential water demand in i.

i = a, b, c … o, each means Seoul, Incheon, Wonju, Chuncheon, Busan, Daegu, Munkyeong, Jinju, Daejeon, Jeonju, Okcheon, Muju, Gwangju, Mokpo and Namwon in order.

3.2 Relationship between Water Price and e_{dw} (H2)

Different cities in Korea have different water prices so that the study will explore any meaningful relationship between water price and e_{dw}. Other studies explored e_{dw} in Korea (Kim 1991, Yoo 1996, Kim 1996, Kim et al.. 1997, Ministry of Environment 1999, and Ministry of Land, Transportation, Marine Affair 2010). And Moon (2010) summarized water price system in Korea. Lim and Han (2016) focused on a relationship between awareness of water price and water saving. But there is no study about securing water price as dependent variable and e_{dw} as independent variable. So, this is to explore whether the level of water price effects on the price elasticity of residential water demand or not.

H2a: Water price (Latest) affects e_{dw} in Korea.

H2b: Water price (Average) affects e_{dw} in Korea.

3.3 Affecting Factors on e_{dw} (H3)

Similar to relationship between water price and e_{dw}, this study also will an investigate relationship between e_{dw} and location of regions, such as upstream or downstream, and river basins.

H3a: Mean values of e_{dw} are not all equal based on location (upstream or downstream).

H3b: Mean values of e_{dw} are not all equal based on river basins.

H3c: Mean values of e_{dw} are not all equal based on Han River basin.

H3d: Mean values of e_{dw} are not all equal based on Nakdong River basin.

H3e: Mean values of e_{dw} are not all equal based on Geum River basin.

H3f: Mean values of e_{dw} are not all equal based on Yeongsan-Sumjin River basin.

3.4 Affecting Factors on Water Usage (H4)

Additionally, this study will take account of water usage and affecting factors. Other studies explored affecting factors on water consumption, individually or systemically. Wills, Stewart, Giurco, Talebpur and Mousavinejad (2013) focused on individual factors such as income, number of family members, efficiency of house applications in Australia. Also Rathnayaka, Maheepala, Nawarathna, George, Malano, Arora and Roberts (2014) also investigated domestic water use in Melbourne affected by individual factors: typology of dwelling, appliance efficiency, presence of children under 12 years, dwelling age, and presence of swimming pool. But Fan, Liu, Wang, Geissen and Ritsema (2013) studied water supply system affecting water usage in Wei River basin in China. In this vein, this study will explore that external factors, location or river basin, have a relationship with water usage.

H4a: Mean values of water usage are not all equal based on location (upstream or downstream).

H4b: Mean values of water usage are not all equal based on river basin.

H4c: Mean values of water usage are not all equal based on Han River basin.

H4d: Mean values of water usage are not all equal based on Nakdong River basin.

H4e: Mean values of water usage are not all equal based on Geum River basin.

H4f: Mean values of water usage are not all equal based on Yeongsan-Sumjin River basin.

H47g: Mean values of water usage are not all equal based on location.

H47h: Mean values of water usage are not all equal based on river basins.

H47i: There are interaction effects between location and river basin.

IV. Methodology

4.1 Data Collection

This study collects daily water usage per person, water price including water rate, sewerage rate and water use charge from the statistics of waterworks and sewerage during 1998 to 2018 by the Ministry of Environment of Korea, and statistic reports of River Basin Management Fund by 4 river basin committee. Especially, there are omissions on sewerage date during 2004 to 2014 due to changes in the agency in charge from Korea Water and

Wastewater Works Association (KWWA) to Korea Environment Corporation (K-eco). These data are collected by interviews of person who is in charge of the statistics of sewerage but there remains some gap in order that incomplete of date collection at that time.

The statistics of waterworks and sewerage take one year to collect, verify and publish date. For instance, real data for 2004 were produced all year round and by December 31, 2004, data production and collection for the year end, and then these had verified and published until December 2005.

And this study uses National income date during 1997 to 2017 with nominal and real income by Statistics Korea to convert past water price to present value, 2017

4.2 Selection of Regions

There are 161 local government consist of 9 metropolitan cities including special metropolitan city, metropolitan autonomous city and special self-governing province, and 152 Si and Gun in Korea. This study choice 4 local governments in each river basin and a local government should be belonging a river basin. There is some local government which is partially located in an administratively defined river basin. The partially local government can't be calculated water price due to partially applied water use charge. The chosen local governments are classified as upstream (receiving area) or downstream (payment area). And additional reason for this choice is population.

First Han River Basin, there are Seoul metropolitan city (Capital city of Korea) and Incheon metropolitan city located in downstream, and Chuncheon Si and Wonju Si located in upstream. Chuncheon and Wonju have more population than other Si and Gun in upstream.

Nakdong River Basin, Busan metropolitan city and Daegu metropolitan city are in class of downstream. Daegu located in midstream but considered as payment area so Daegu is put in downstream. And Munkyeong Si and Jinju Si are located in upstream. Geum River Basin, Daejeon metropolitan city and Jeonju Si located in downstream, and Okcheon Gun and Muju Gun are in upstream. Yeonsan-Sumjin River Basin, Gwangju metropolitan city and Mokpo Si are located in downstream of Yeongsan River. Namwon Si is in upstream of Seomjin River.

The Yeonsan-Sumjin River Basin has different structure than other river basins. Other river basin has a river each river basin but the Yeongsan-Seomjin river basin has two rivers, Yeongsan River and Seomjin River. Because cities in Yeonsan River uses water from Seonjin River, so that the cities pay water use charge to cities in upstream of Seomjin River. In this regard, there is only one Si in upstream of Seonjin River which also wholly belonging the river basin. Therefore, three local governments represent of water use in Yeonsan-Sumjin River Basin.

4.3 Data Collection Period

This study uses data during 1997 to 2017 due to limitation of statistics. After amendment of Act of sewerage on 1995, the date of sewerage has been subdivided into residential. The statistics of waterworks has not offered residential water usage since 1996. Therefore, this study collects from the oldest to the newest data.

4.4 Description of Water Usage

Daily water usage (metered) is that metered annual water amount is divided total water supplied population and 365 or 366. Other studies (Ministry of Land, Transportation and Marine Affair, 2010 and Moon 2010) didn't specify what values were used; daily amount of water abstraction, daily amount of water supply or daily amount of water use (daily water usage).

Daily amount of water abstraction is from how much water comes from river or dam and this value is usually applied in terms of water resource. Daily amount of water supply means that how much water is sent out from water suppliers such as local government waterworks corporations or K-water. And daily amount of water use can represent water usage of consumer aspect.

4.5 Water Price

Water rate (KRW/m^3) is an average water rate per m^3 of a city calculated by total water rate per the city and total metered water amount of the city. Sewerage rate (KRW/m^3) is an average sewerage rate per m^3 of a city that equals total sewerage rate of the city divided by total water usage of the city. And water use charge (KRW/m^3) is simply published its value.

$$\text{Water rate } \left(\frac{\text{KRW}}{m^3}\right) = \frac{total\ water\ rate\ \ in\ a\ city\ (KRW)}{total\ metered\ water\ volume\ in\ a\ city\ (m^3)}$$

$$\text{Sewerage rate} \left(\frac{\text{KRW}}{m^3}\right) = \frac{total\ sewerage\ rate\ in\ a\ city\ (KRW)}{total\ metered\ water\ volume\ in\ a\ city\ (m^3)}$$

$$\text{Water price } \left(\frac{\text{KRW}}{m^3}\right) = Water\ rate + Sewerage\ rate + Water\ use\ charge$$

V. Data Analysis

5.1 Tendency of Water Price and Water Usage in 15 Regions

Water prices of all 15 regions are on the rise during the period, but responses of water usage are defined two types: increasing or decreasing. Cities where water usage increased are Wonju, Busan, Daegu, Munkyung, Jinju, Daejeon, Jeonju, Okcheon, Muju, Gwangju and Mokpo. And cities where water usage decreased are Seoul, Incheon, Chuncheon and Namwon. (Appendix A)

5.2 Hypothesis Testing

5.2.1 Water Price and Residential Water Usage (H1)

The table 7 is summary of the result of regression of 15 cities in Korea.

Table 7. Summary of e_{dw} in 15 Regions

Variable (Independent → Dependent)	Standardized Coefficient (t-value-Sig)	R^2
Water Price → Water Usage, Seoul (H1a)	-.839 (-5.976***)	0.704
Water Price → Water Usage, Incheon (H1b)	-0.235 (-0.966)	0.055
Water Price → Water Usage, Wonju (H1c)	0.799 (4.971***)	0.638
Water Price → Water Usage, Chuncheon (H1d)	-0.070 (-0.264)	0.005
Water Price → Water Usage, Busan (H1e)	0.596 (2.965***)	0.355
Water Price → Water Usage, Daegu (H1f)	0.893 (7.439***)	0.798
Water Price → Water Usage, Munkyeong (H1g)	0.407 (1.723)	0.110
Water Price → Water Usage, Jinju (H1h)	0.921 (8.821***)	0.848
Water Price → Water Usage, Daejeon (H1i)	0.511 (2.375**)	0.261
Water Price → Water Usage, Jeonju (H1j)	0.706 (3.857***)	0.498
Water Price → Water Usage, Okcheon (H1k)	0.079 (0.307)	0.006
Water Price → Water Usage, Muju (H1l)	0.180 (0.485)	0.032
Water Price → Water Usage, Gwangju (H1m)	0.698 (3.777***)	0.487
Water Price → Water Usage, Mokpo (H1n)	0.239 (0.920)	0.057

Water Price → Water Usage, Namwon (H1o)	-0.086 (-0.321)	0.007

**** Significant at 0.05 level (2-tailed); *** Significant at 0.01 level (2-tailed)**

In Han River basin, Seoul shows to decrease residential water demand with increasing water price (Appendix A. a). A result of regression between water price and water usage in Seoul is standardized coefficient, e_{dwa} = -0.839 and significant at the level of 0.01 (R^2 = 0.704). So H1a is accepted. And Wonju, however, shows both water price and water usage increased (Appendix A. c). A result of regression between water price and water usage in Wonju is e_{dwc} = 0.799 and significant at the level of 0.01 (R^2 = 0.638), so H1c is accepted. Incheon has not meaningful relationship between water price and residential water demand (Appendix A. b). Chuncheon has similar tendency with Wonju on water price and water usage (Appendix A. d) but H1b and H1d are rejected.

About Nakdong River basin, Busan has a tendency, increasing both water price and water usage (Appendix A. e). A result of regression between water price and water usage in Busan, e_{dwe} is 0.596 and significant at the level of 0.01 (R^2 = 0.355). So H1e is accepted. And Daegu also shows to increasing both water price and water usage (Appendix A. f). A result of regression between water price and water usage in Daegu, e_{dwf} is 0.893 and significant at the level of 0.01 (R^2 = 0.798). So H1f is accepted. Munkyeong shows to increasing both water price and water usage (Appendix A. g). A result of regression between water price and water usage in Munkyeong, e_{dwg} is 0.but H1g is rejected. And Jinju also has a tendency, increasing both water price and water usage (Appendix A. h). A result of regression between water price and water usage in Jinju, e_{dwh} is 0.921 and significant at the level of 0.01 (R^2 = 0.848). So H1h is accepted.

In Geum River basin, Daejeon shows to increasing both water price and water usage (Appendix A. i). A result of regression between water price and water usage in Daejeon, e_{dwi} is 0.511 and significant at the level of 0.05 (R^2 = 0.261). So H1i is accepted. Jeonju has same tendency with Daejeon (Appendix A. j). A result of regression between water price and water usage in Jeonju, e_{dwj} is 0.706 and significant at the level of 0.01 (R^2 = 0.498). So H1j is accepted. Okcheon and Muju also have the same trend with Jeonju (Appendix A. k & l), but H1k and H1l are both rejected.

Fourth, in Yeonsan-Sumjin River basin, Gwangju shows to increasing both water price and water usage (Appendix A. m). A result of regression between water price and water usage in Gwangju, e_{dwm} is 0.698 and significant at the level of 0.01 (R^2 = 0.487). So H1m is accepted. Mokpo also has the same trend with Gwangju on water usage and water price (Appendix A. n). Namwon shows to decrease residential water demand with increasing water price (Appendix A. o). But H1n and H1o are rejected.

5.2.2 Water Price and Price Elasticity of Residential Water Demand (H2)

Table 8 indicates the outcomes of regression analysis for effects of water price, latest and average value used, on price elasticity of residential water demand. According to regression, the result of latest water price and e_{dw} isn't significant at the level of 0.05 (R^2 = 0.085) and the result of average water price and edw also isn't significant at the level of 0.05 (R^2 = 0.002). So, H2a and H2b are rejected.

Table 8. Summary of Relationship between Water Price and e_{dw} in Korea

Variable (Independent → Dependent)	Standardized Coefficient (t-value-Sig)	R^2
Water Price (Latest) → e_{dw} (H2a)	0.291 (0.745)	0.085
Water Price (Average) → e_{dw} (H2b)	-0.041 (-0.100)	0.002

**** Significant at 0.05 level (2-tailed); *** Significant at 0.01 level (2-tailed)**

5.2.3 Location, River Basins and e_{dw} (H3)

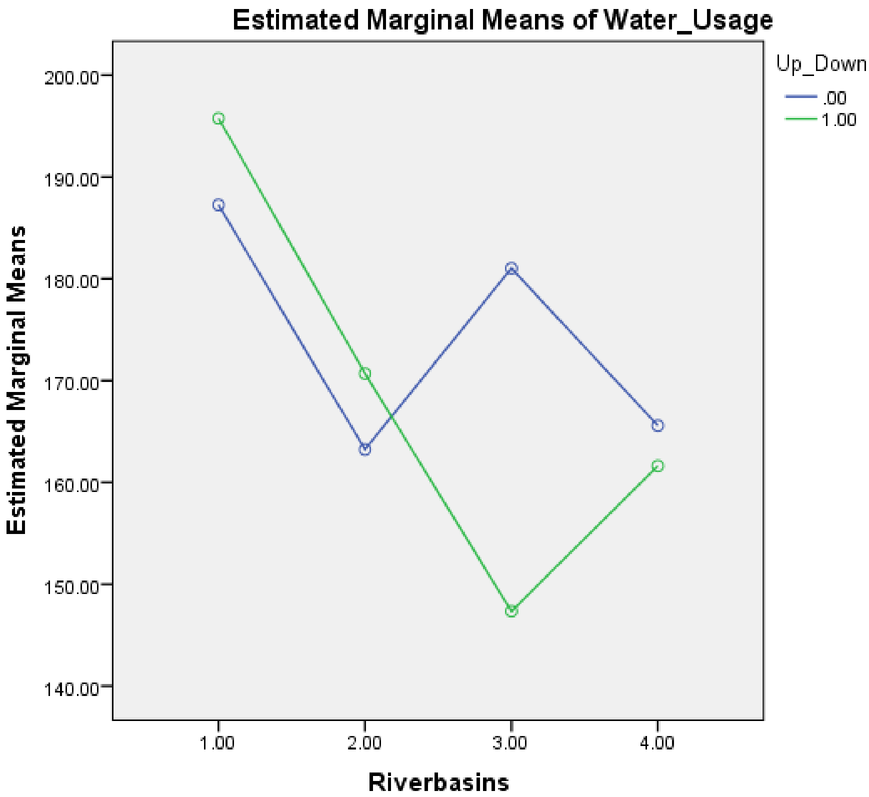
According to results of ANOVA testing on location, river basins and e_{dw}, all F value are not significant at level of 5%. About location and e_{dw} (H3a), F-value is 0.836. F-value of river basins and e_{dw} (H3b) is 0.813, Han River basin is 3.357, Nakdong River basin is 1.058, Geum River basin is 0.037, and Yeongsan-Sumjin River basin is 0.080. So, H3a, H3b, H3c, H3d, H3e and H3f are rejected. Therefore, mean values of e_{dw} are indifference based on location, river basins.

5.2.4 Location, River Basins and Water Usage (H4)

According to the results of ANOVA testing on location and water usage, F-value (1.934) is larger than alpha (1%). And the results of the analysis (ANOVA) of water usage and four river basins is that F-value (47.372) is smaller than alpha (1%). According to results of analysis of each river basin and water usage, F-value of Han River (141.657), Nakdong River (10.416), Geum River (9.880) and Yeongsan-Sumjin River (14.346) are smaller than alpha (1%). So, H4a is rejected, and H4b, H4c, H4d, H4e and H4f are accepted and mean values of water usage are different based on all river basins: Han River basin, Nakdong River basin, Geum River basin and Yeongsan-Sumjin River basin.

According to the result of MANOVA testing, F-values of location (11.915), river basins (79.644) and both (42.315) are significant at the level of 1%. So, H4g, H4h and H4i are accepted and mean values of water usage are different based on location. Figure 6 shows the result of MANOVA testing. Differences in mean value of water usage between upstream (1) and downstream (0) are observed for each river basin, upstream spent more water than downstream in Han River basin (1) and Nakdong River basin (2), and downstream spent more water than upstream in Geum River basin (3) and Yeongsan-Sumjin River basin (4). And an interaction are shown between Nakdong River basin (2) and Geum River basin (3).

Figure 6. Result of MANOVA for Location and River Basins on Water Usage



VI. Conclusions

6.1 Findings

This study found that among 8 regions which are significant on water usage and water price, only Seoul is shown decreased water usage with increased water price. Water usages of other 7 cities are increased even though water price increased. Previous studies on water usage or price elasticity of residential water demand (Ministry of Environment 1999, Kim and Park 2001, and Ministry of Land, Transportation and Marine Affair 2010) addressed that price elasticity of water demand on Korea is negative and inelastic. In this study, the results of regression on water price and water usage in 15 cities in Korea, however, showed that the price elasticities of residential water demand are positive, excluding Seoul.

First of all, this difference may be due to differences in how water usage is metered. In this study, water usage shows measurement of accurate volume of water use in each household by measurement, but volume of water abstraction and water supply include water loss during transport water from river or purification plant. According to Annual Statistics Reports of Waterworks (Ministry of Environment, 1997 and 2018), water loss rate is decreased from 19.6% in 1996 to10.5% in 2017. In other words, people used more water than previous year but the water loss was reduced, so the amount of abstraction or supply could be reduced.

Second, economic growth may be still affecting to water usage. OECD (1999) analyzed reasons of rising water usage in Korea are economic growth and law water price than other OECD countries and other countries that have grown more economically than Korea have seen water use in steady state or decreasing state. The level of water price in Korea was much lower than other OECD countries, so it seems that both causalities still affects water usage in Korea. Only Seoul has significant negative elasticity and it is observed that changes in water usage in Seoul are relatively smaller than other cities. In other words, it can be explained that the improvement of water supply and living standard in Seoul proceeded earlier than other cities, so it tends to be similar the OECD countries.

Lastly, Normal goods show negative elasticity, but Veblen Goods and Giffen Goods have positive elasticity. Veblen Goods is kind of luxury things for which the demand rises as the price increases, an apparent contradiction of the law of demand. (Veblen, 1899). Giffen Goods is about an essential good with rear substitutes at the same price level, such as rice in Hunan, China (Jensen and Miller, 2007). The water is regarded as an essential good with no substitute, like Giffen Goods case, but price-demand behavior is like Veblen Goods in Korea. Bagwell and Bernheim (1996) said that the Veblen effect is shown in consumption to show off wealth as the high class consumes luxury goods. Therefore, water in Korea excluding Seoul could be regarded as a special case of Giffen Goods with both price and demand increasing.

Additionally, according to regression analysis in this study, water price of Seoul, Wonju, Daegu and Jinju have significant affect on water demand. Values of R-square are 0.704 (Seoul), 0.638 (Wonju), 0.798 (Daegu) and 0.848 (Jinju), and an absolute value of e_{dw} is larger than other studies. Besides, correcting the raw data, which appears to be a typo, calculates a significant e_{dw} in Mokpo. And water price has no significant effects on level of e_{dw} and also water usage growth. In other words, the water price is hard to effect on behavior of customer. And location and river basins have no impact on level of e_{dw}.

However, location and river basins have effect on mean value of water usage. Where the upstream used more water is Han River basin and Nakdong River basin, and where the downstream used more water is Geum River basin and Yeongsan-Sumjin River basin. More details, the gap of mean value of water usage between upstream and downstream in Geum River basin is the largest among river basins due to the characteristic of the upstream regions, Okcheon and Muju. Only Okcheon and Muju are Gun, which have smaller population than Si, population of at least 50,000, as well as lower water supply rate. Water supply rate of overall was 96.8% in 2018, metropolitan cities were 99.7%, but Okcheon was 85.7% and Muju was

79.3% (Ministry of Environment 1998-2018). The inadequate water supply is being filled by groundwater, resulting in the low water usage.

6.2 Policy Implications

The results of this study show that the 14 cities excluding Seoul are hard to manage water demand by water price. Common households spend more water even water price increased. Due to the price can't work as adjustment factor on water consumption, it may be burden to rise of water price for people who have to use water at least.

To make a significant change in residential water demand in Seoul, the government could raise the water price, while other regions are better to be approached non-economical ways. The cases of OECD countries show how much the water price should be raised to affect the residential water demand. Spain and Czech not only used data from a time period similar to this study but also had negative values (Table 1). Indeed, Spain has a water price 1.5 times higher than that of Korea, and the Czech has a water price 3.2 times higher (Figure 3). In other words, if Korea raises the water price by 1.5 to 3.2 times, it can be interpreted that the e_{dw} become negative and the water demand can be controlled by the water price as normal goods. Of course, an important consideration here is the need to approach differently for different locations and river basins. For example, this study suggests application of the water demand management policy to the Han River basin, which has the highest water usage, and to the Geum River basin, which has a larger difference in water usage between upstream and downstream.

In addition, it would be working to raise awareness about water conservation or distributing water saving devices, such as special designed faucet and water saving toilet (Lim and Han, 2016).

As demand management of residential water is critical issue in Korea, efficient use of water resources should be adopted for improved supply chain management. According to press release from the Ministry of Environment of Korea (2018, www.me.go.kr), water loss rate will be decreased and efficiency of using water resource will be increased. Like this, it is important to make the proper use of the abstract water through efficient water resource allocation and to deliver the purified water to the home as much as possible by reducing the water loss rate.

6.3 Limitations and Future Research

This study examines the price elasticity of residential water demand by location of cities in Korea; it has limitations due to the sample size. Data based on each region are representative of the group, while it was not sufficient. According to H3, relationships between location, river basin and e_{dw}, are able to explain more consumer behavior. However, there are only 8 significant e_{dw} values so that the results are hard to show any affecting factors of e_{dw}.

Previous studies focused on external or internal factors on water usage. External factors were seasons (Espey, Espey & Shaw, 1997). Internal factors were awareness of water usage effects water demand (Lim and Han ,2016), and income and environmental concerns

Grafton et al, 2011). It might be better to explore effects on water usage by external factors such as water loss rate, water supply rate and sewerage rate as well.

Following by analysis by OECD (1999), economic growth could be affecting water usage. And the change in price elasticity by price is small when rear substitutes or lower price level than income or GDP per capita (Mankiw, 2008). So instead of only time series analysis of Korea regions, it also would be further meaningful step to compare GDP and e_{dw} of cities around the world.

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Online Resources

http://law.go.kr/ordinSc.do?tabMenuId=tab138&query=#AJAX (Seoul waterworks ordinance)

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http://law.go.kr/ordinSc.do?tabMenuId=tab138&query=#AJAX (Daejeon waterworks supply ordinance)

http://law.go.kr/ordinSc.do?tabMenuId=tab138&query=#AJAX(Gwangju waterworks supply ordinance) http://law.go.kr/ordinSc.do?tabMenuId=tab138&query=#AJAX (Seoul sewerage usage ordinance)

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http://law.go.kr/ordinSc.do?tabMenuId=tab138&query=#AJAX (Gwangju sewerage use ordinance)

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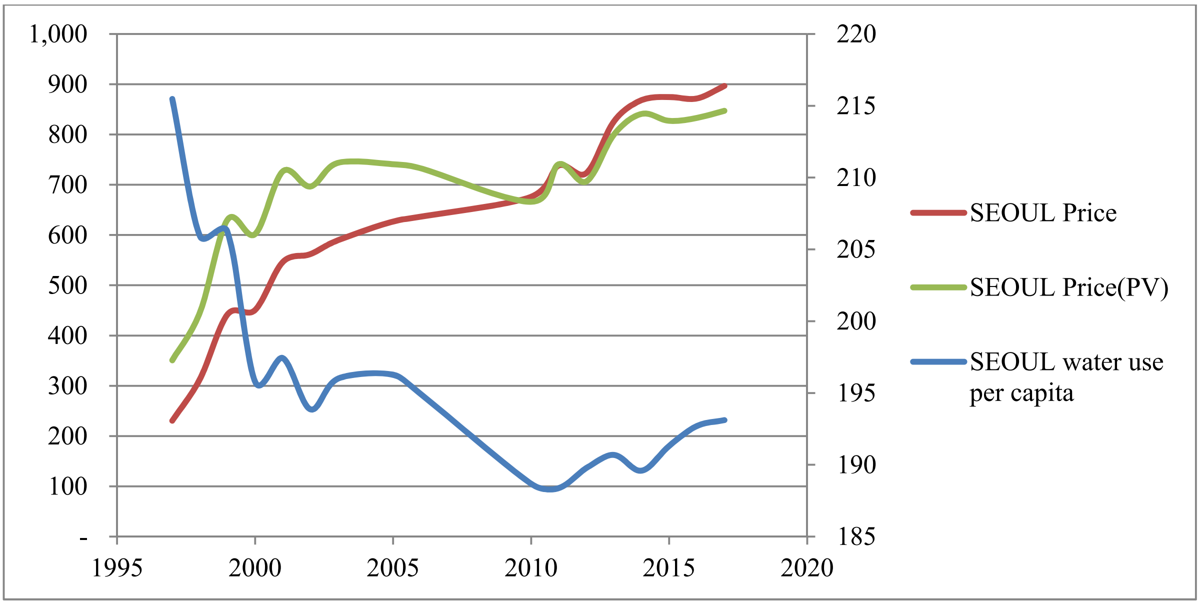
World Bank database, https://databank.worldbank.org/source/world-development-indicators#

Appendix A. Water Price and Water Usage by Regions

a. Seoul



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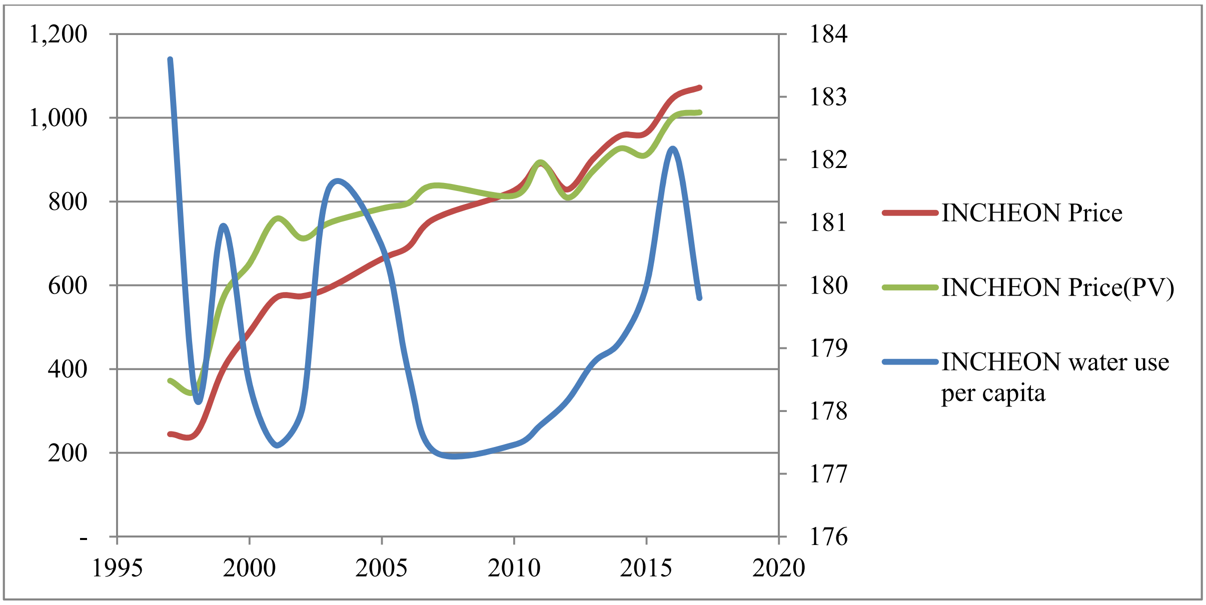

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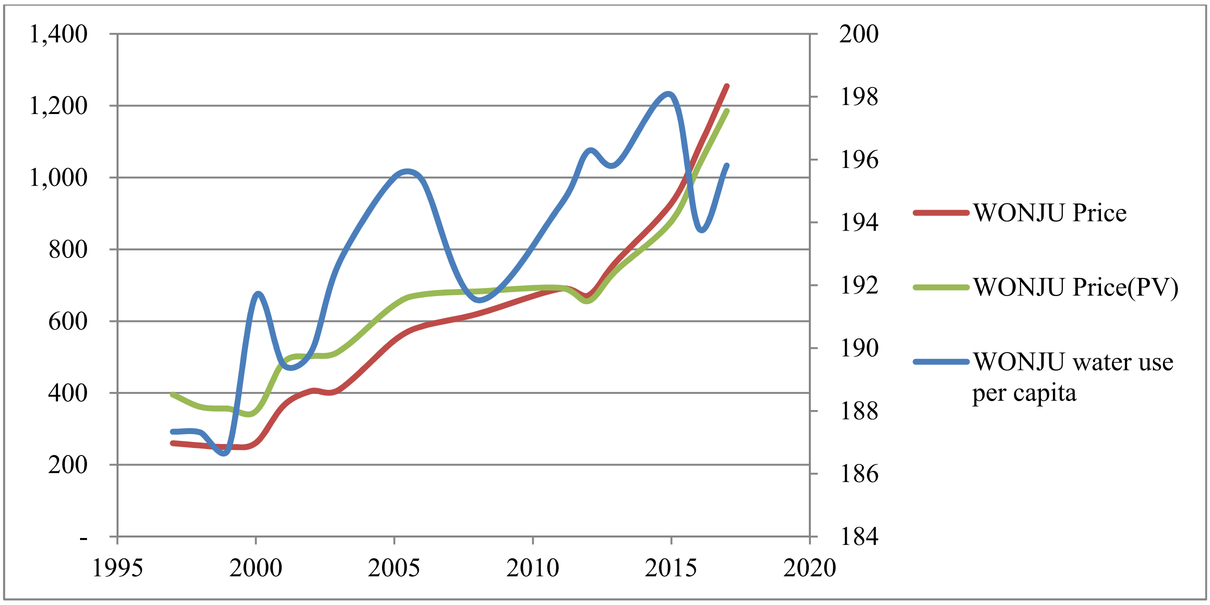

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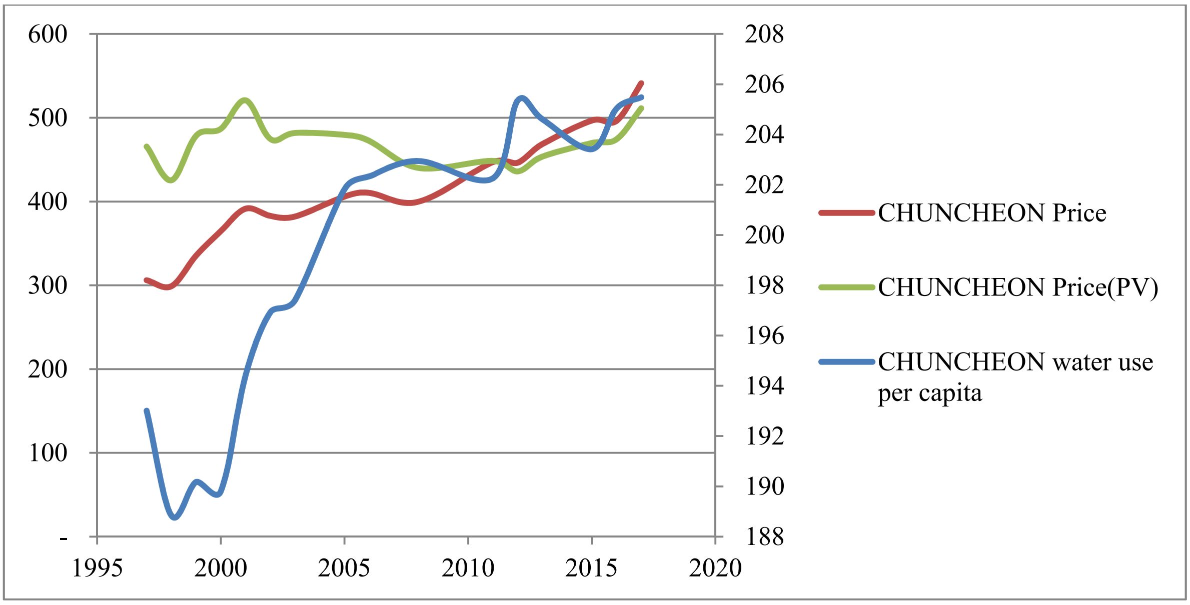

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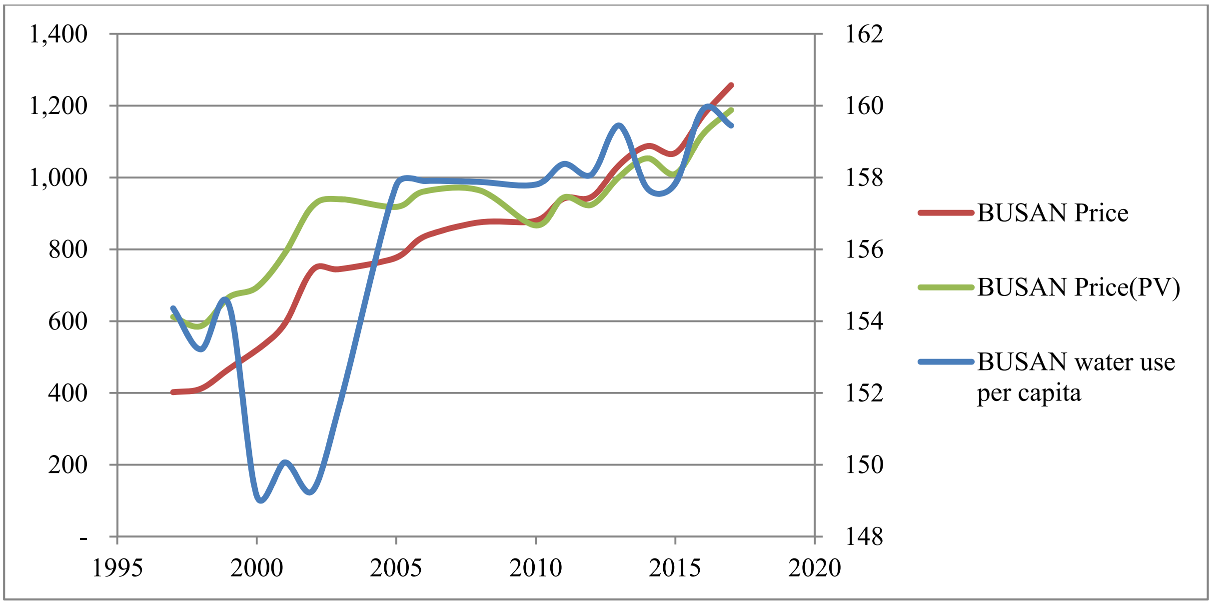

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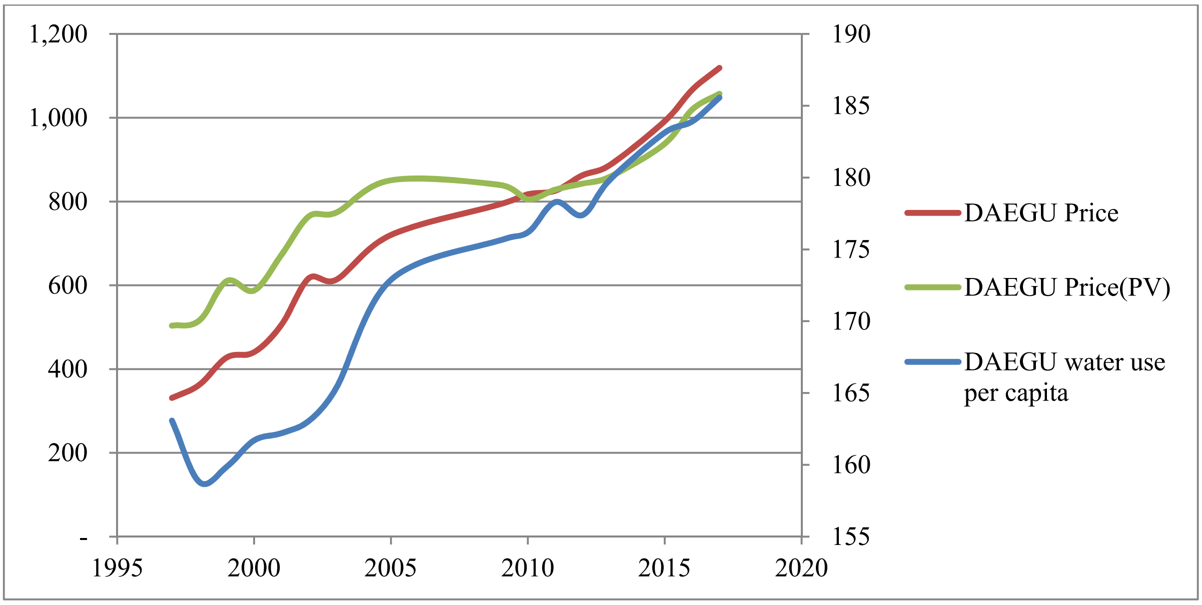
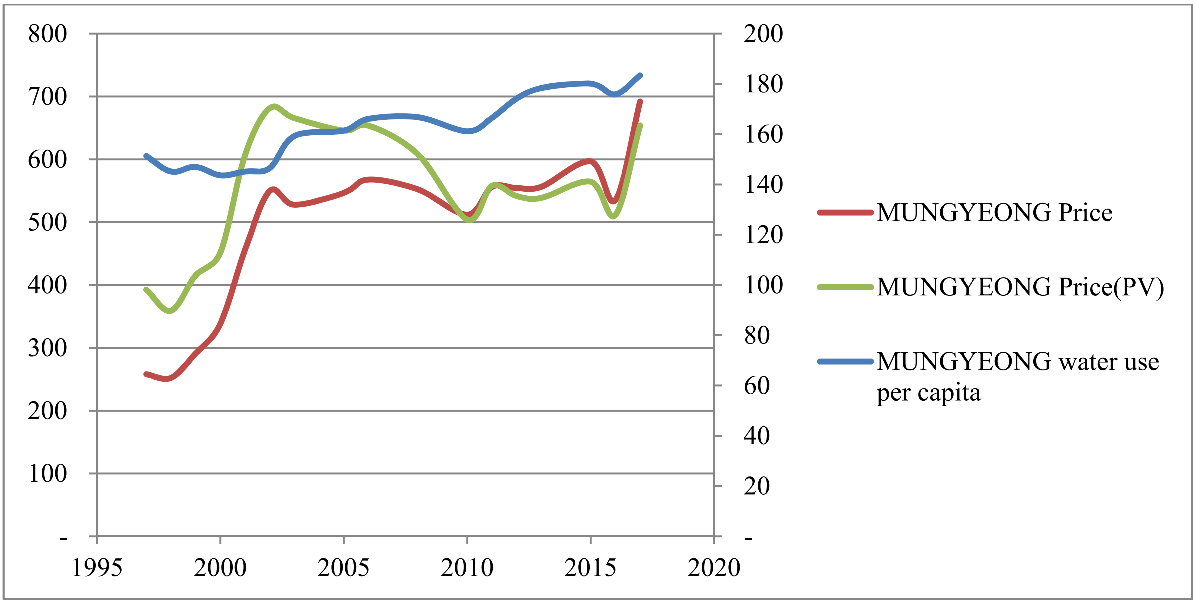


g. Munkyeong



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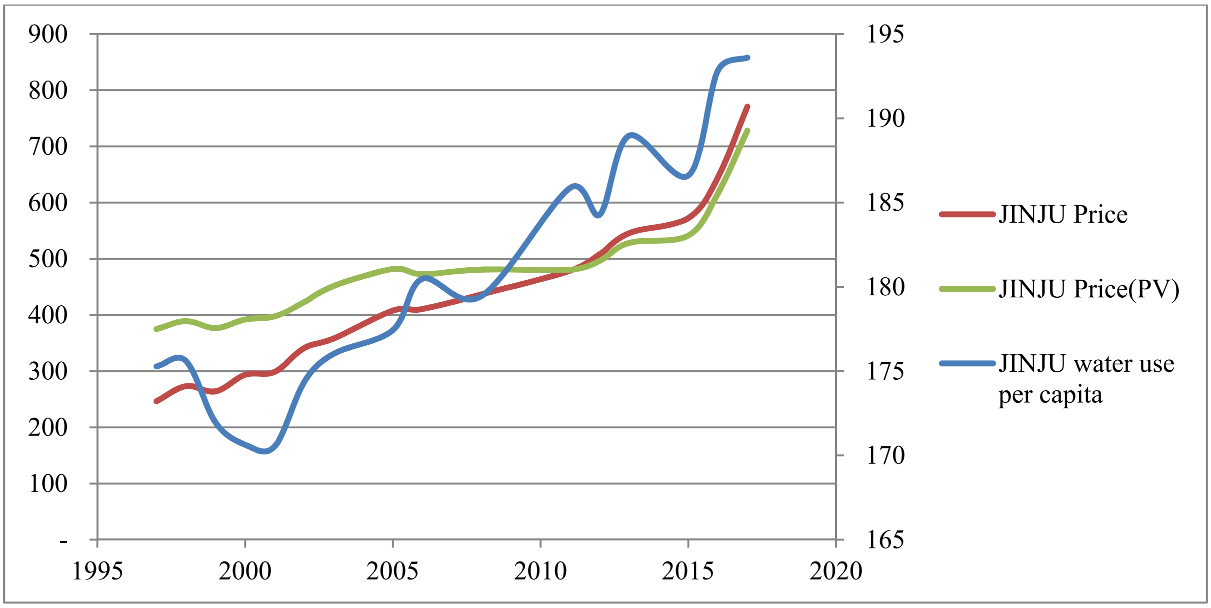

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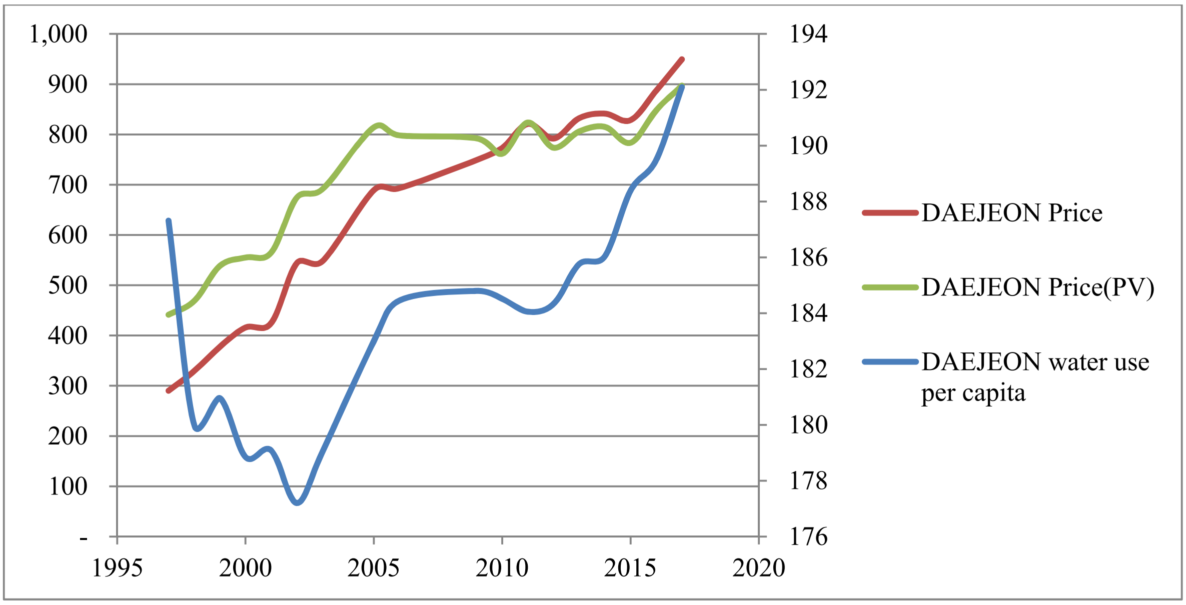

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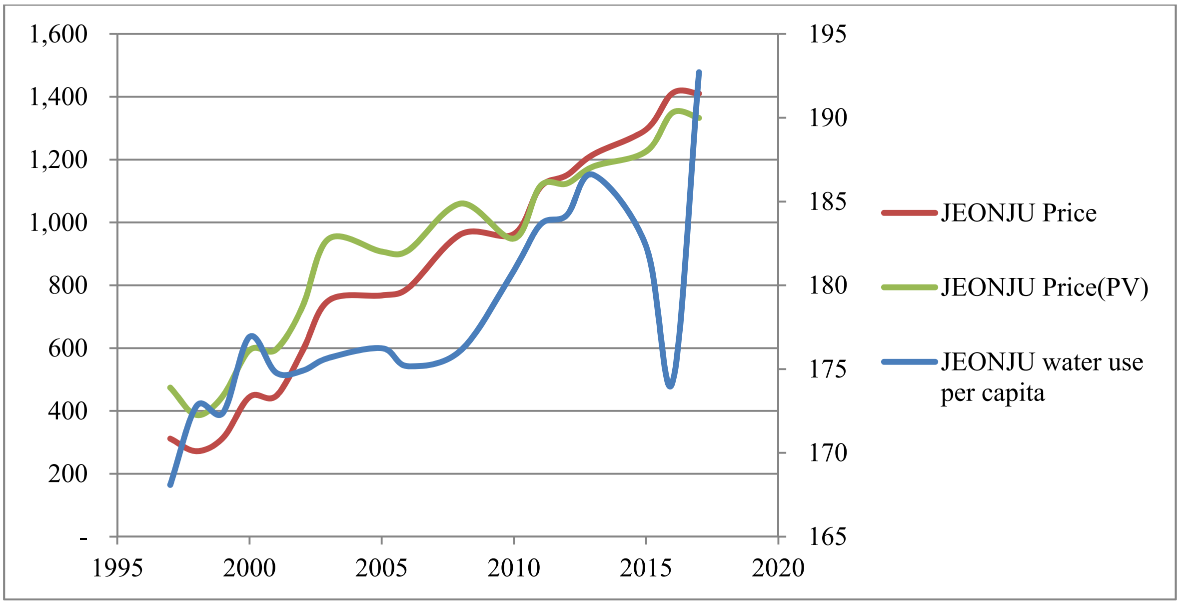

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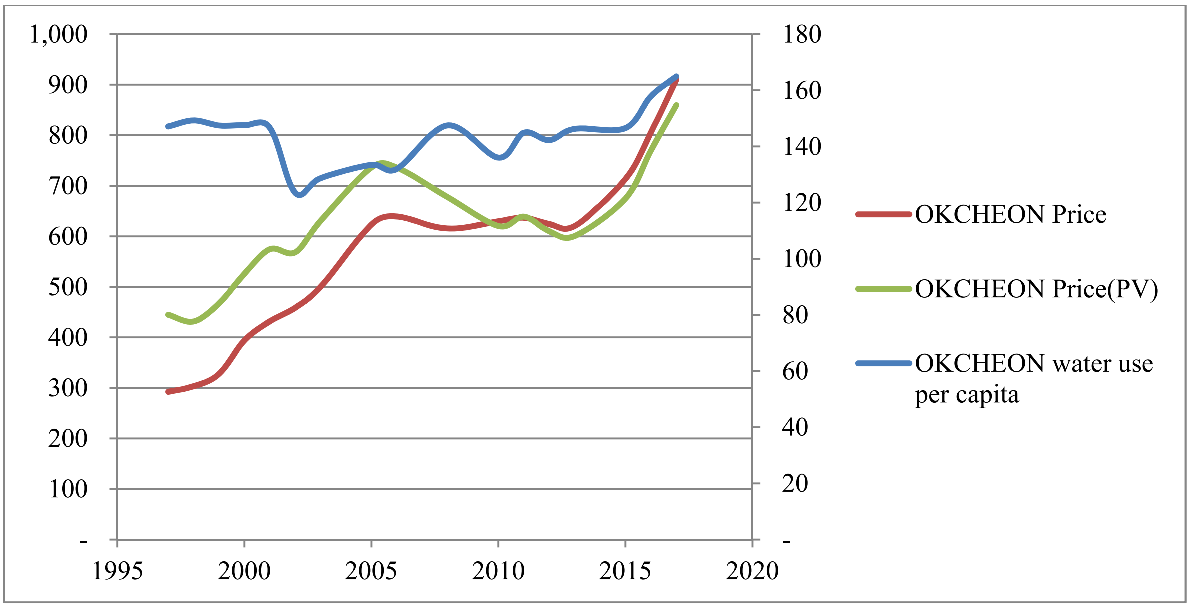

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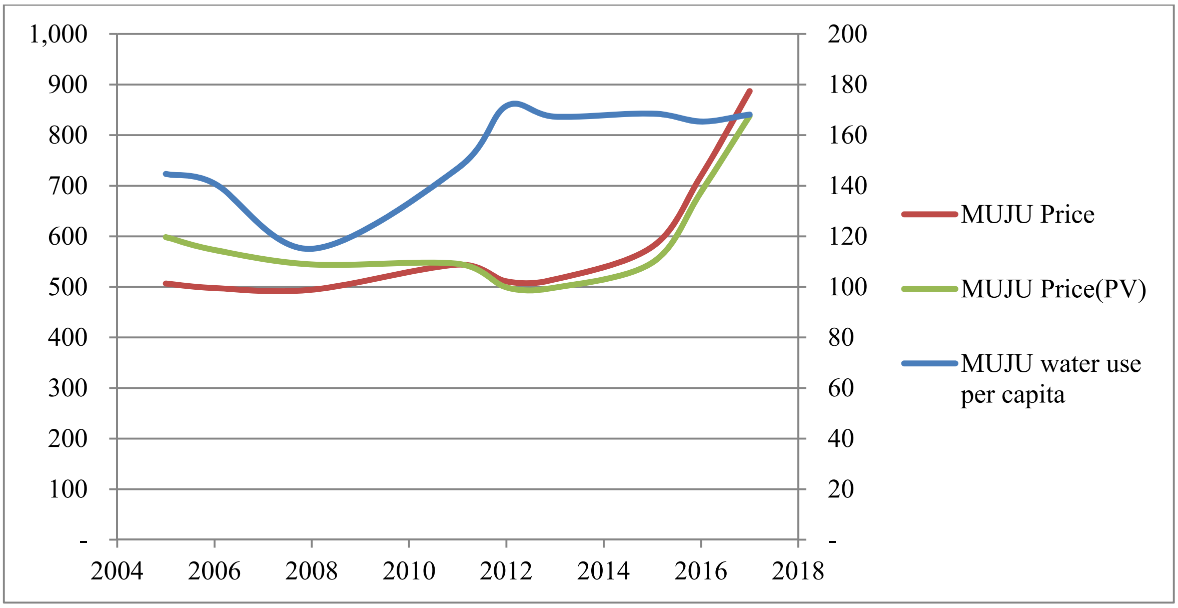

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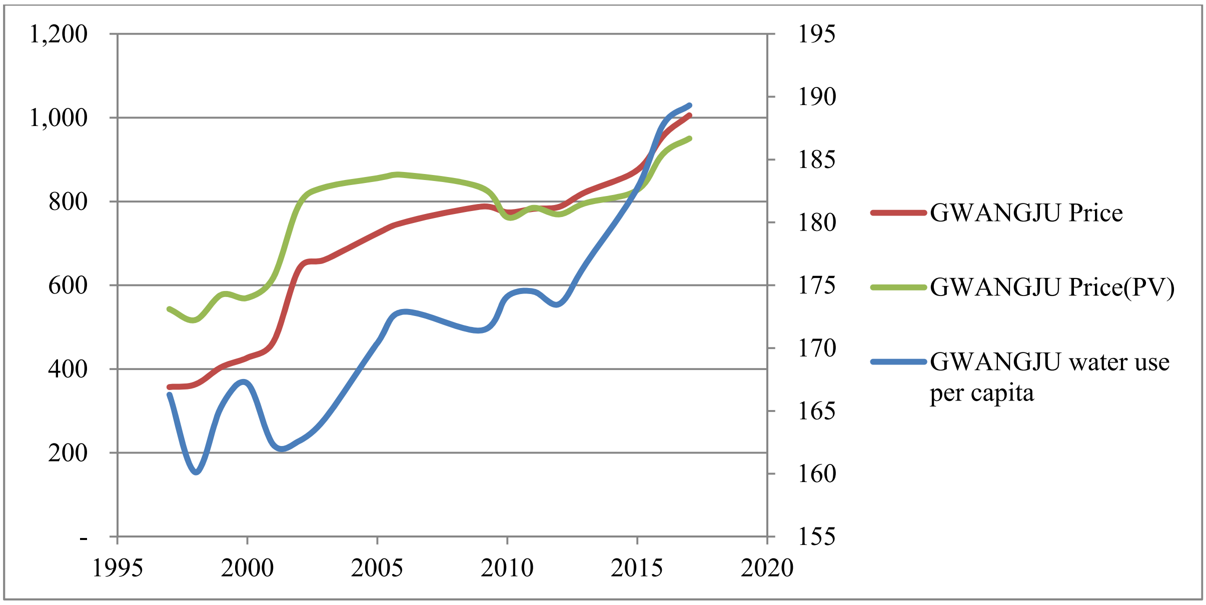

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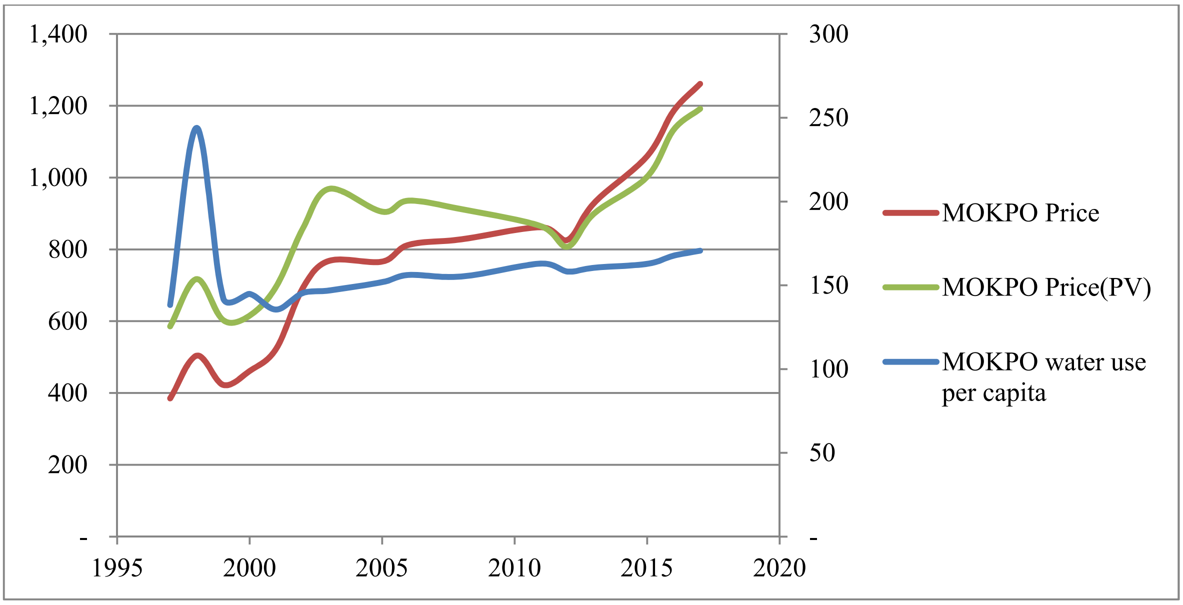

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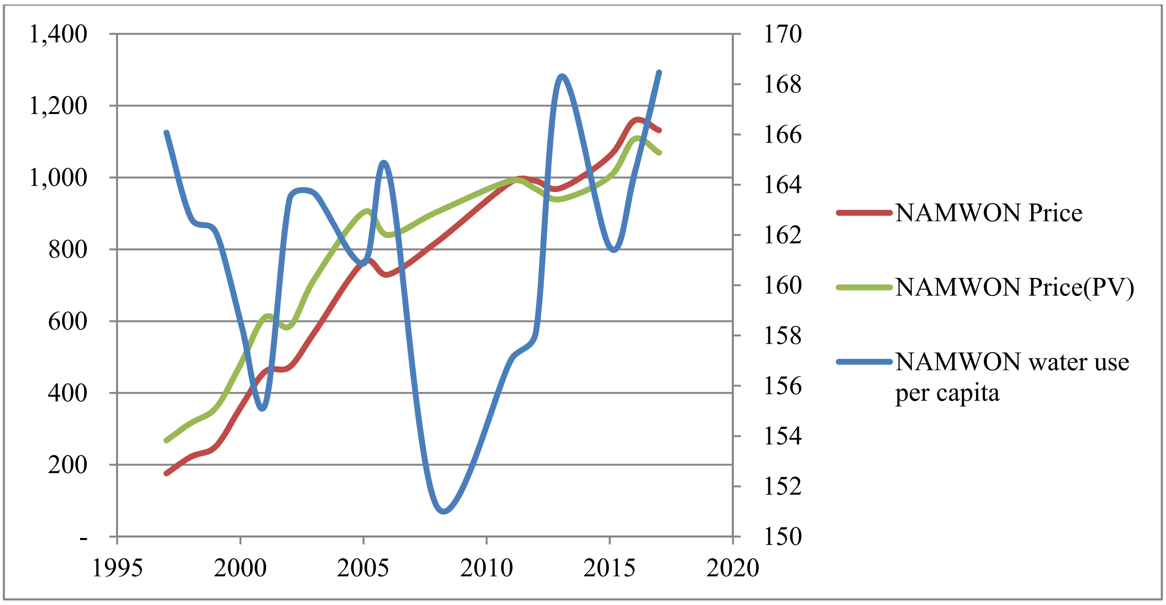

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152
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2005
2010
2015
2020
NAMWON Price
NAMWON Price(PV)
NAMWON water use per capita