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# Exploring Effects of Water Price on Residential Water Demand for Water Management*

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## Abstract

**Purpose**: Management of water is a crucial issue globally and is becoming more critical due to climate change. The purpose of this study is to explore water resource management by considering price and water usage based on river basins and to suggest more efficient residential water demand management in South Korea. **Research Design, data, and methodology**: 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 collected by Ministry of Environment in Korea. This study applied regression analyses, ANOVA, and 2-Way ANOVA to verify its claims. **Results**: The results found that effects of price on water usage showed significant in many cities. The results also showed that means of water usages differ based on location (upstream and downstream) and river basins. **Conclusion**: The findings provide important policy and management implications for the improvement of water resource management in terms of demand. The results also indicate that water price should be reconsidered by comparing water price levels with those of OECD countries. Furthermore, the results imply that water management in Korea needs to improve in terms of supply to cope with climate change.

**Keywords**: Water Price, Demand, Water Management

**JEL Classification Code**: Q25, Q28, Q21

## 1. Introduction

The crisis of water management due to climate change has become the threat of human lives. Van Leeuwen and Koop (2015) addressed that climate change and urbanization are among the most significant trends that affect global natural resources such as water and human well-being. As one of sustainability development goals proposed by UN, water management and adequate access to clean water (www.un.org) have paid substantial attention by various researchers and organizations. Choi, Shin, Nguyen, and Tenhunen (2017) addressed the need for sustainable (Zhao, 2016) water governance and management by reforming water policies in South Korea, particularly due to uncertainties of climate change caused seasonal variation.

According to the Paris Agreement, 195 parties recognized the need for 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). In South Korea, the frequency and impact of floods and droughts, exacerbated by climate change, make conditions even more difficult to manage than before (Ministry of Land, Infrastructure and Transportation, 2016). For example, there were increasing cases of flooding in Seoul from 2010 to 2012, a local drought in west coast from 2012 to 2015 (Ministry of Environment, 2017), and most recent flooding

* This paper was modified and developed from the thesis of the first author.

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caused by mainly climate changes in 2020. In addition, the surface water is getting 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, which is the ratio of total abstraction to total water in a country and is one way to reveal the vulnerability of water security (OECD, 2017). Water management conditions in Korea are highly affected by climate change, while water resource management is becoming more unstable and unsustainable.

This research focuses on demand perspectives with respect to approaches to water resources and management. Statistics showed that the case of Seoul has the lowest water price among selected major global cities (OECD, 2015) that might be obstacle for better water management. Korea abstracted 400 liters of water a day, while other countries have lower amounts of water abstraction, such as 345 liters (Japan), 318 liters (Swiss), 282 liters (UK) and 173 liters (Germany) per day (Ministry of Land, Infrastructures and Transportation, and K-water, 2015). In this regard, this paper explores ways to respond to water instability caused by climate change from the demand control aspect. The purpose of this paper is to investigate the price and price elasticity of residential water demand (i.e., $e_{dw}$) in cities in Korea and provides policy and managerial implications. The price elasticity of demand measures how much the quantity demanded responds to a change in price (Mankiw, 2008). This study also employs the river basin approach due to policy movement and political aspects. In South Korea, cities are chosen from four major river basins, Han, Nakdong, Geum and Yeongsan-Seomjin, with both upstream and downstream. Based on these considerations, this paper aims to provide answers to the following research questions: i) Are there significant effects of water price on residential water demand in Korean cities? ii) Are there significant effects of water price on price elasticity of residential water demand in Korea? iii) Are there any different effects of price elasticity of residential water demand based on river basins and upstream and downstream locations? and iv) Are there any different effects of water usage based on river basins and upstream and downstream location?

## 2. 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 ($e_d$) measures how much the quantity demanded responds to a change in price" and the formula for price of elasticity of demand ($e_d$) is given below.

$$e_d = \frac{\Delta Q\%}{\Delta P\%} = \frac{\partial \ln Q}{\partial \ln P} \tag{1}$$

Normally, demand decreases when price increases, so elasticity is almost always a negative value, and four cases possibly occur include as follows: perfect inelastic ($e_d$ = 0), inelastic (-1 < $e_d$ <0), unitary elastic ($e_d$ = -1) and elastic ($e_d$ < -1). Unusually, elasticity is a positive value, while there are cases of Veblen (1899) and Giffen Goods (Masuda & Newman, 1981). Veblen Goods means that demand rises with price increase, and Giffen Goods (Masuda & Newman, 1981) means that demand reduces when prices decrease.

### 2.1.2. Price Elasticity of Residential Water Demand with Case Studies

Worthington and Hoffman (2008) addressed that water demand management with supply efficiency are increasingly important issues for residential water supply authorities through the world. Previous studies (Espey, Espey, & Shaw, 1997; Hortová & Krištoufek, 2014) showed that price elasticity (Choi, 2015; Zhang, Li, & Kong, 2016) of residential water demand ($e_{dw}$) is different between the short and the long term. Hortová and Krištoufek (2014) also stated that the $e_{dw}$ is affected by consumption, price, and income, instead of temperature, aging, or waterfall. Grafton, Ward, To, and Kompas (2011) argued that water is inelastic goods, residential water demand is more sensitive than others, and environmental concerns affect its elasticity. However, Espey, Espey, and Shaw (1997) observed that $e_{dw}$ is affected mainly by season and the equilibrium state is reached as the absolute value of $e_{dw}$ increases in the long term, although the short term price elasticity of residential water demand is small against the price increase. Espey, Espey and Shaw also stated that family members, income and seasons cannot directly affect demand, but these affect the pattern of water use indirectly.

With respect to the cases in Korea, 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 and these results show that the absolute value of $e_{dw}$ has decreased. Previous studies rarely analyzed whether the $e_{dw}$ of Korea was affected by income, season, or number of family members and also examined with insufficient statistical data. Moon (2010) also mentioned that water use does not decrease even if the water rate increases and summarized case studies on the price elasticity of residential water demand in Korea. The Ministry of Land, Transport, and Maritime Affairs (2010) studied demand elasticity of residential water use in 16 metropolitan cities and provinces of Korea and summarized water usage ($m^3$) and water rate (KRW) from 1985 to 2008 and found that ranges between - 0.09 (in Jeju) and - 0.56 (in Chungnam).

## 2.2. Water Price in South Korea

A water bill for a common Korean household consists of water rate, sewerage rate, water use charge, and charges for using groundwater (groundwater charge). According to The Ordinance (www.law.go.kr), water rate is estimated with diameter rate and water use rate and Table 1 summarized residential water rates of four major cities in Korea. The Ordinance defines that the diameter rate is charged a constant rate according to the diameter of supply pipe, while water use rate charge is assessed in proportion to water usage (www.law.go.kr). Lim and Han (2016) asserted 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. Kwak, Lee and Kim (2004) pointed out problems in the rate system below production costs with a 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 change consumer behavior.

**Table 1:** Summary of Detailed Water Rates of Four Major Cities in Korea

| 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 |
| Dae-jeon 2017 ~ | 15 | 860 | Below 20 | 430 |
| | 20 | 2,420 | More than 20 to below 40 | 720 |
| | 25 | 3,890 | More than 40 | 950 |
| Gwang- Ju 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

### 2.2.1. Sewerage Rate

According to The Ordinance (www.law.go.kr), sewerage rate is charged on water usage and the quantity measured by house water meter, not the disposal amount of sewage. Oh, Kim, Park, Park and Park (2014) argued that the sewerage utility authority of Seoul needs to raise its sewerage rate due to facing financial independence from central government to local government and suggesting realization of the sewerage rate. Yun, Choi, and Hong (2009) also stated that a low sewerage rate could help to press inflation, but there are heavy water usage and old infrastructure issues. Saal and Parker (2001) introduced results of privatization of water and sewerage in England and Wales insisting that more regulation causes fewer marginal returns. The residential public sewerage rate of four major cities is summarized in Table 2.

**Table 2:** Summary of Residential Public Sewerage Rate 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 |

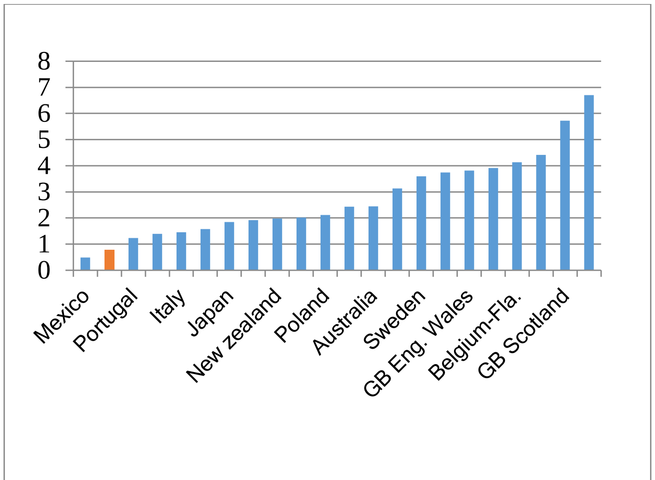
Source: www.law.go.kr

### 2.2.2. Ground Water Charge

Groundwater charge is for using groundwater, but residential groundwater charge is waived according to Groundwater Act 40-3. Therefore, 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 and stated that Korea is the second lowest country among the reported countries (Figure 1).




Note: Orange-colored line is the case of Korea
Source: OECD (2010), OECD work on Water, OECD Publishing, Paris.

**Figure 1:** Water Price (UDS/m$^3$) of OECD Countries

Denmark, Great Britain (excluding Northern Ireland), Finland, and Belgium have higher water prices than other OECD countries (OECD, 2010). In particular, the water price of Denmark is 13 times greater than Korea's price (OECD, 2010). By considering national GDP per capita level, Korea also showed the second lowest country (OECD, 2010). Hungary and Poland are middle-rank without national GDP, but become the top with GDP, while the ranks of Switzerland, Canada, Finland and Denmark drop. In this regard, similar order was shown in other studies. Moon (2010) also stated that Korea has a lower water rate and sewerage rate than other countries. OECD (1999) explained that water usage in Korea had increased due to economic growth and low water price, while water usage of other OECD countries have mostly been stagnant or trending downward. Lim (2018) addressed that policies of water management should be prepared by increasing water to save water for sustainability in Korea.

## 2.4. River Basin Management

### 2.4.1. Concept of River Basin Management

River basin means a natural boundary formed by rivers and hills and conceptually includes watersheds and catchments. River basin management started to solve water quality problems 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 beings, finally adopting a Water Framework Directive (WFD). River basin management has been adapted not only in the EU, but also the US and Korea. Gerlak (2005) insisted that water resource management based on river basins is a representative case of pragmatic federalism and a custom-made approach in the US. Ahn and Jeong (2008) explained that the concept of river basin management was first applied by adopting acts on water management and resident support in the Han River basin in 1999 in Korea, and the concept developed from water quality management into IWRM with administrative re-organization in 2018. A unit of river basin management is not the central government, but it is local government and a variety of stakeholders in different aspects of governance in the EU (Antunes et al., 2009). Similar to Europe, river basin management is shifting to local governments and basins.

### 2.4.2. Characteristics of Korean Rivers

The country of South Korea develop the concept of the comprehensive river basin development concept was first adopted and is heavily dependent on river basins as the primary water source for human activities (Choi, Shin, Nguyen, & Tenhunen, 2017). There are four administrative river basins in Korea including Han, Nakdong, Geum and Yeongsan-Sumjin (Framework Act on Water Management, www.law.go.kr) with own characteristics. Characteristics of river basins include the direction to the source of the river. The Han River Basin has a special region upstream for maintaining water quality for the twenty million people who live in the basin, while there are conflicts between several types of stakeholders due to the special region under very tight regulation (Water Environmental Master Plan of Han River Basins, 2017). In the Nakdong River, there are large metropolitan cities, and water intake sites for each city located along the river like Rhein River (Water Environmental Master Plan of Nakdong River Basins, 2017). The Geum River is similar to the Han River and additionally has issues of allocation of water resources in order to serious local drought in downstream agriculture cities (Water Environmental Master Plan of Geum River Basins, 2017). The Yeongsan-Sumjin River consists of two rivers, and also has issues of allocation of water resources due to almost all cities along the Yeongsan River use water from the Sumjin River (Water Environmental Master Plan of Yeongsan-Sumjin River Basins, 2017).

## 3. Hypothesis Development

## 3.1 Effects of Water Price on Residential Water Demand

This study investigates a relationship between water price and residential water demand. Espey, Espey, and Shaw

(1997) examined season effects of US residential water demand. Worthington and Hoffman (2008) addressed that the demand for water has been also shown to vary with seasonal factors, household composition, and the imposition of water restrictions. Hortová and Krištoufek (2014) showed that age didn't affect water consumption, but that price, income, while it affected consumption in the Czech Republic. Lim and Han (2016) argued that awareness of water usage effects water demand, and Grafton et al. (2011) argued that income and environmental concerns are significant factors in water consumption. In this regard, price is an essential factor in terms of demand, and other factors need individual data, not a group. Therefore, this study hypothesized effects of water price on residential water consumption. This study also hypothesized effects based on regions that include Seoul, Incheon, Wonju, Chuncheon, Busan, Daegu, Munkyeong, Jinju, Daejeon, Jeonju, Okcheon, Muju, Gwangju, Mokpo and Namwon.

**H1*i***: Water price affects residential water demand in *i* (*i* = a ~ o based on each region).

## 3.2. Effects of Water Price on Price Elasticity of Residential Water Demand

Different cities in Korea have different water prices, so this study explored any meaningful relationship between water price and price elasticity of residential water demand. Other studies explored price elasticity of residential water demand in Korea (Ministry of Environment, 1998-2018; Ministry of Land, Transportation, and Marine Affairs, 2010). Moon (2010) summarized the water price system in Korea. Lim and Han (2016) focused on the relationship between awareness of water price and water saving. However, previous studies rarely examined effects of water price on $e_{dw}$. Therefore, this study hypothesized that the level of water price affects the price elasticity of residential water demand.

**H2**: Water price affects price elasticity of residential water demand in Korea.

## 3.3. Price Elasticity of Residential Water Demand based on Location (Upstream vs. Downstream) and River Basins

This study also investigate effects of mean values of price elasticity of residential water demand differ based on location of regions, such as upstream or downstream and river basins.

**H3a**: Mean values of price elasticity of residential water demand are not all equal based on location (upstream or downstream).

**H3b**: Mean values of price elasticity of residential water demand are not all equal based on river basins.

**H3c~f**: Mean values of price elasticity of residential water demand are not all equal based on the Han, Nakdong, Geum, and Yeongsan-Sumjin River Basin.

## 3.4. Water Usage based on Location (Upstream vs. Downstream) and River Basins

Additionally, this study will take water usage and other affecting factors into account. Other studies explored affecting factors on water consumption, individually or systematically. Wills, Stewart, Giurco, Talebpur, and Mousavinejad (2013) focused on individual factors such as income, number of family members, and efficiency of house applications in Australia. Rathnayaka, Maheepala, Nawarathna, George, Malano, and Arora (2014) also investigated domestic water use in Melbourne affected by individual factors such as typology of dwelling, appliance efficiency, presence of children under 12 years, dwelling age, and presence of swimming pool. Fan, Liu, Wang, Geissen, and Ritsema (2013) studied water supply system affecting water usage in the Wei River Basin in China. Yoon, Rhodes, and Shah (2015) examined effects of upstream water resource management with downstream pollution concerns. This study explores the possibility that external factors, such as location (upstream vs. downstream) or river basin have a relationship with water usage. Further, this study also hypothesized mean values of water usage based on location and river basins with interaction effects.

**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~f**: Mean values of water usage are not all equal based on Han, Nakdong, Geum, and Yeongsan-Sumjin River basin.

**H4g-h**: Mean values of water usage are not all equal based on location and river basins.

**H4i**: There are interaction effects of water usage based on location and river basins.

# 4. Methodology

## 4.1. Description of Data

This study applied data collected by Ministry of Environment of Korea from 1998 and 2018. Data include daily water usage per person, water price including water rate, sewerage rate and water use charge from the statistics of waterworks and sewerage. Statistical reports of River Basin Management for the data are conducted by 4 river basin committees. There are omissions of sewerage dates from 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), while these data are collected through interviews with persons who are in charge of sewerage statistics.

## 4.2. Selection of Regions

There are 161 local governments consisting of 9 metropolitan cities, including special metropolitan cities, metropolitan autonomous cities, and special self-governing provinces, and 152 other cities and districts in Korea. This study selected 4 local governments in each river basin, and a local government belonging to that river basin. There is some local government that is partially located in an administratively defined river basin. The partially local government cannot 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). An additional reason for this choice is population.

The Han River Basin is located in Seoul metropolitan city (Capital city of Korea), Incheon metropolitan city is located downstream, and Chuncheon city and Wonju city is located upstream. Nakdong River Basin, Busan metropolitan city and Daegu metropolitan city are located downstream, while Munkyeong Si and Jinju Si are located upstream. In the case of Geum River Basin, Daejeon metropolitan city and Jeonju city are downstream, while Okcheon Gun and Muju Gun are upstream. In the case of Yeonsan-Sumjin River Basin, Gwangju metropolitan city, and Mokpo city are downstream of Yeongsan River, while Namwon city is upstream. The Yeonsan-Sumjin River Basin has a different structure than other river basins. Other river basin has one river each, while the Yeongsan-Seomjin river basin has two rivers, Yeongsan River and Seomjin River. Because cities in Yeonsan River use water from Seonjin River, the cities pay water use charges to cities upstream of Seomjin River.

## 4.3. Description of Water Usage

Daily water usage (metered) is metered annual water amount divided by total water supplied population and 365 or 366. Other studies (Ministry of Land, Transportation, and Marine Affairs, 2010; 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 how much water comes from rivers or dams and this value is usually applied in terms of water resources. Daily amount of water supply refers to how much water is sent out from water suppliers such as local government waterworks corporations or Korea Water Resources Corporation (K-water). Daily amount of water use can represent water usage of consumers.

## 4.4. Description of Water Price

Water rate (KRW/$m^3$) is the 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 the city's total water usage; water use charge (KRW/$m^3$) is simply the published value.

Water rate (KRW/$m^3$) =
Total Water Rate in a City (KRW) / Total Metered Water Volume in a City ($m^3$)

Sewerage rate (KRW/$m^3$) =
Total Sewerage Rate in a City (KRW) / Total Metered Water Volume in a City ($m^3$)

Water price (KRW/$m^3$) =
Water rate + Sewerage rate + Water use charge

# 5. Data Analysis

## 5.1. Water Price and Water Usage in 15 Regions

Water prices in all 15 regions were on the rise during this period, but responses of water usage were either increasing or decreasing. Cities where water usage increased include Wonju, Busan, Daegu, Munkyung, Jinju, Daejeon, Jeonju, Okcheon, Muju, Gwangju, and Mokpo. Cities where water usage decreased are Seoul, Incheon, Chuncheon and Namwon.

## 5.2. Hypothesis Testing

### 5.2.1. Effects of Water Price on Residential Water Usage

Table 3 summaries the results of regression analyses for 15 cities in Korea.

**Table 3:** Summary of Effects of Water Price on Residential Water Usage $e_{dw}$ in 15 Regions

| Variable (Independent → Dependent) | Standardized Coefficient (Sig) | $R^2$ |
|---|---|---|
| Water Price → Water Usage, Seoul (H1a) | -.839 (***) | 0.704 |
| Water Price → Water Usage, Incheon (H1b) | -0.235 | 0.055 |
| Water Price → Water Usage, Wonju (H1c) | 0.799 (***) | 0.638 |
| Water Price → Water Usage, Chuncheon (H1d) | -0.070 | 0.005 |
| Water Price → Water Usage, Busan (H1e) | 0.596 (***) | 0.355 |
| Water Price → Water Usage, Daegu (H1f) | 0.893 (***) | 0.798 |
| Water Price → Water Usage, Munkyeong (H1g) | 0.407 | 0.110 |
| Water Price → Water Usage, Jinju (H1h) | 0.921 (***) | 0.848 |
| Water Price → Water Usage, Daejeon (H1i) | 0.511 (**) | 0.261 |
| Water Price → Water Usage, Jeonju (H1j) | 0.706 (***) | 0.498 |
| Water Price → Water Usage, Okcheon (H1k) | 0.079 | 0.006 |
| Water Price → Water Usage, Muju (H1l) | 0.180 | 0.032 |
| Water Price → Water Usage, Gwangju (H1m) | 0.698 (***) | 0.487 |
| Water Price → Water Usage, Mokpo (H1n) | 0.239 | 0.057 |
| Water Price → Water Usage, Namwon (H1o) | -0.086 | 0.007 |

** Significant at 0.05 level; *** Significant at 0.01 level

In the Han River Basin, Seoul showed decreased residential water demand with increasing water price and was significant at the level of 0.01 ($R^2$ = 0.704). Therefore, H1a was accepted. Wonju, however, showed increase in both water price and water usage and was significant at the level of 0.01 ($R^2$ = 0.638), so H1c is accepted. Incheon and Chuncheon cases were not significant. Therefore, H1b and H1d were rejected. Regarding the Nakdong River Basin, the results show that Busan was significant at the level of 0.01 ($R^2$ = 0.355). Therefore, H1e was accepted. Effects in Daegu also showed significant at the level of 0.01 ($R^2$ = 0.798). Therefore, H1f was accepted. Effects in Munkyeong did not show significant. Therefore, H1g is rejected. Jinju showed significant at the level of 0.01 ($R^2$ = 0.848). Therefore, H1h is accepted. In the Geum River Basin, Effects in Daejeon showed significant at the level of 0.05 ($R^2$ = 0.261). Therefore, H1i was accepted. Effects in Jeonju showed significant at the level of 0.01 ($R^2$ = 0.498). Therefore, H1j is accepted. Effects in Okcheon and Muju were not significant. Therefore, H1k and H1l are both rejected. In the Yeonsan-Sumjin River Basin, Effects in Gwangju showed significant at the level of 0.01 ($R^2$ = 0.487). Therefore, H1m is accepted. Effects in Mokpo and Namwon was not significant. Both H1n and H1o were rejected.

### 5.2.2. Effects of Water Price on Price Elasticity of Residential Water Demand

Table 4 indicates the outcomes of regression analysis for effects of water price on price elasticity of residential water demand. According to regression, the result of latest water price and $e_{dw}$ was not significant at the level of 0.05. Therefore, H2 was rejected.

**Table 4:** Effects of Water Price on $e_{dw}$

| Variable (Independent → Dependent) | Standardized Coefficient (Sig) | $R^2$ |
|---|---|---|
| Water Price → $e_{dw}$ (H2) | 0.291 | 0.085 |

** Significant at 0.05 level; *** Significant at 0.01 level

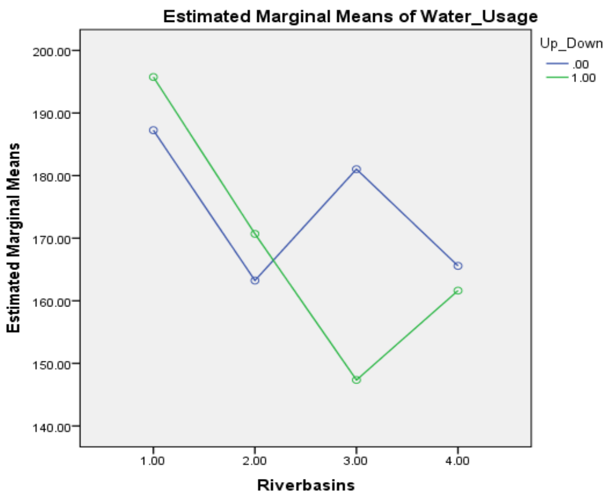
### 5.2.3. Effects of Price Elasticity of Residential Water Demand based on Location and River Basins

According to results of ANOVA, this study found that mean values of price elasticity of residential water demand did not differ based on location and river basins. Therefore, H3a, H3b, H3c, H3d, H3e and H3f were rejected.

### 5.2.4. Effects of Water Usage based on Location and River Basins

According to the results of ANOVA, this study found that mean values of water usage did not differ based on location. Therefore, H4a was rejected. However, mean values of water usage showed different based on all proposed river basins including Han, Nakdong, Geum, and Yeongsan-Sumjin River basin. Therefore, H4b, H4c, H4d, H4e and H4f were accepted.

Additionally, this study conducted 2-Way ANOVA to examine the effects of water usage based on location and river basins. The results showed significant at the level of 0.01 with *F*-values of 11.915 in the case of location. The results also showed that there are interaction effects (Figure 2). Therefore, H4g, H4h and H4i were accepted. 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 the Han River Basin (1) and Nakdong River Basin (2), and downstream spent more water than upstream in the Geum River Basin (3) and Yeongsan-Sumjin River Basin (4). There are interactions between the Nakdong River Basin (2) and Geum River Basin (3).




* Y-axis: 0 = Downstream, 1 = Upstream;
Y-axis: 1 = Han River Basin, 2 = Nakdong River Basin, 3 = Geum River Basin (3), 4 = Yeongsan-Sumjin River Basin

**Figure 2:** Result of 2-Way ANOVA for Location and River Basins on Water Usage

# 6. Conclusions

## 6.1. Findings and Implications

This study found that among 8 regions with significant water price on water usage, only Seoul was shown to decrease water usage with increased water price. Water usages of the other 7 cities showed increased, even though water price increased. Previous studies on water usage, price, and price elasticity of residential water demand (Ministry of Environment 1998-2018; Kim & Park, 2001; Ministry of Land, Transportation, and Marine Affairs, 2010) addressed that price and price elasticity of water demand on Korea is negative and inelastic. However, in this study, the results of regression on water price and water usage in 15 cities in Korea showed that the price on residential water demand are positive, excluding Seoul. This difference may be due to differences in how water usage is measured. First, in this study, water usage showed measurement of accurate volume of water use in each household by measurement, but volume of water abstraction and water supply include water loss, while transporting water from a river or purification plant. According to Annual Statistics Reports of Waterworks (Ministry of Environment, 1998-2018), water loss rate decreased from 19.6% in 1996 to10.5% in 2017. In other words, people used more water than in the previous year, but water loss was reduced, so the amount of abstraction or supply could be reduced. Second, economic growth may still be affecting water usage. OECD (1999) analyzed the causes of rising water usage in Korea as economic growth, while water price is lower than other OECD countries. Other countries more economically advanced than Korea have seen water use in steady state or decreasing state. The negative impact in the case of Seoul showed similar effects compared to OECD countries. Third, the results could be explained by Veblen Goods and Giffen Goods. Water is regarded as an essential good with no substitute, like Giffen Goods, while price and demand relationships in this study could be explained like Veblen Goods in Korea.

The level of water price in Korea was much lower than other OECD countries, while proper management of water price associated with better water quality should be adopted by considering water demand. Advanced pricing model should be adopted with better estimation of water demand. 2-Way ANOVA results also showed that mean values of water usage differ based on river basins. As Ratnasiri, Wilson, Athukorala, Garcia-Valinas, Torgler, and Gifford (2018) addressed, behavioral responses to price structure associated with water demand should be observed. Further, 2-Way ANOVA results also showed that mean values of water usage differ based on location and river basins. Upstream the Han and Nakdong River Basins used more water, and downstream the Geum and Yeongsan-Sumjin River Basins used more water. The gap in mean values of water usage between upstream and downstream in the Geum River Basin is the largest among river basins due to the characteristics of the upstream regions.

This study provides managerial and policy implications. First, as shown from results, the Han River Basin has the highest water usage, while the Geum River Basin showed big differences in water usage between upstream and downstream. This study suggests that different water demand management policies should be prepared based on river basins. Application of the most appropriate policy by river basin will foster better water management. Adaption of climate change by basin will also help manage water demand and also secure water-related accident. Wang, Zhang, Shahid, Xie, Du, Shang et al. (2017) also examined different temperature change based on the basin area in the case of China. As a previous study (Nguyen & Tu, 2020) examined, proper policies should be also considered river management with social responsibility. Second, as demand management of residential water is a critical issue in Korea, the results implied that efficient use of water resources should be adopted for improved supply chain management. By considering the issues of climate change, Korea should develop policies on water management for sustainability. Hughes, Hafi, and Goesch (2009) stated that policy makers should be considering ways to improve the efficiency of demand management with supply augmentation policies by considering the reality of climate change. As addressed by Lim and Han (2016), it would be desirable to raise awareness of water conservation or distributing water-saving devices by adopting advanced technologies. Lim (2018) suggested the application of digitalized information such as smart metering and regional relationship analysis for water management policy.

Further, According to a press release from the Ministry of Environment of Korea (2018, www.me.go.kr), water loss rate will decrease and efficient use of water resources will increase. It is also important to make proper use of the abstract water through efficient water resource allocation and to deliver the purified water to homes by reducing the water loss rate as much as possible. As stated Nyamwanza and Kujinga (2017), resilience and adaptive management principles should be applied with the direction of essential political project.

## 6.2. Limitations and Future Research

Previous studies focused on external or internal factors on water usage. External factors include seasons (Espey, Espey & Shaw, 1997), while internal factors include awareness of water usage effects on water demand (Lim & Han, 2016), and income and environmental concerns (Grafton et al., 2011; Nguyen, 2020). It might be better to explore effects on water usage through external factors such as water loss rate, water supply rate, and sewerage rate as well. Following the analysis conducted by OECD (1999), economic growth could affect water usage. Change in price elasticity by price is small when rare substitutes or lower price level than income or GDP per capita are considered (Mankiw, 2008). So rather than only time-series analysis of Korean regions, it also would be meaningful to compare GDP and EDW of cities around the world. Future research might also consider water supply ratio.

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