The Effects of Water Pricing on Domestic Water Demand in Dhaka, Bangladesh

By

RAHMAN, Md. Mujahidur

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF DEVELOPMENT POLICY

2024

The Effects of Water Pricing on Domestic Water Demand in Dhaka, Bangladesh

By

RAHMAN, Md. Mujahidur

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF DEVELOPMENT POLICY

2024

Professor Kim, Yeong Jae

The Effects of Water Pricing on Domestic Water Demand in Dhaka, Bangladesh

By

RAHMAN, Md. Mujahidur

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF DEVELOPMENT POLICY

Committee in charge:

Professor Kim, Yeong Jae, Supervisor ____________________

Professor Park, Sungho ____________________

Professor Pham, Thi Tuyet Trinh ____________________

Approval as of December, 2024

Abstract

Due to climate change, Dhaka city experiences acute water scarcity during annual droughts from March to June. Despite the relatively low uniform volumetric tariff compared to other Asian cities, the city's groundwater supply is substantially subsidized, resulting in excessive usage, water pollution, and depletion of groundwater resources. This study conducts a quasi-experiment using the difference in differences (DID) model to find the effect of water price increases on domestic household water consumption. Using 19 months of water billing panel data from respective municipalities and considering meteorological and COVID-19 factors as controlled variables, this study finds that a 1 BDT rise in water price leads to a 6103-liter increase in average monthly water consumption of domestic households in Dhaka city. Additionally, we find an insignificant impact of temperature and rainfall on water consumption with a minimal effect of COVID-19 shock. As a policy implication, Dhaka WASA should consider increasing water demand when implementing new tariffs. Price adjustments should be made during the winter season instead of April to July each year, as this could help manage demand during drought periods. It is necessary to thoroughly assess the current tariff system to understand how domestic customers behave when prices increase or a new tariff system is being developed in megacities.

Keywords: water price, water demand, difference-in-differences, sustainable water management

Table of Contents

List of Tables

List of Figures

1. Introduction

Water is regarded as a valuable resource and asset of a Nation. The majority of the Earth's water is saline water, and only 2.5% is freshwater, which becomes water resources with the composition of proper technology, efficient processes, and optimal cost. Water is essential for sustaining the ever-changing environment, yet its availability is dwindling despite its profound significance. The diminishing status is mainly attributed to anthropogenic activities, including unconscious use and pollution (Kılıç, 2020). As per the United Nations Development Programme (UNDP), over 40% of the world's population is facing water scarcity, which is expected to increase by 2050 due to climate change. Access to potable water is crucial for sustaining life on Earth, so it is given utmost importance in the sustainable development goals (SDGs) (UNDP, 2015). The importance of sustainable water management cannot be overstated in the face of these challenges.

Dhaka, a megacity with a population of over 22 million, primarily relies on groundwater for its water supply (DWASA Annual Report, 2022-23). The city faces significant water scarcity issues, particularly during seasonal droughts from March to June each year, when demand often surpasses supply due to decreased groundwater levels. Recently, the city has encountered severe groundwater diminution. The declining scenarios are dissimilar in different parts of the city due to the heavy groundwater abstraction that supports the city's increasing population. Consequently, Dhaka Water Supply and Sewerage Authority (DWASA) faces the formidable task of guaranteeing incessant and efficient water delivery to the rapidly expanding population of Dhaka.

Water has concurrent social, physical, and economic characteristics. The market price of water is devoid of these effects of water usage. Consequently, these fees are not factored into the expenses borne by users, leading them to disregard these costs when determining the amount of water to extract. Occasionally, these consequences are referred to as negative externalities such as contamination, depletion of groundwater, harm to the ecosystem, and over-utilization, resulting in a divergence between the private and social marginal costs of water resources. In Dhaka City, water is provided for a subsidized fixed rate per unit of volume, which is relatively lower than in many other Asian cities (Arfanuzzaman & Rahman, 2017). The reduced subsidized water tariff rate promotes thoughtless and wasteful water consumption (Macian-Sorribes et al., 2015). Consequently, groundwater has become a common pool resource that can be accessed freely. This has led to a significant depletion of the precious environmental resources in Dhaka City.

Finally, the water of yesterday is not the water of today. The bulkiness and mobility of water connect variables related to nature, population, land size, precipitation, water quality, living standards, and how people use water. The essence of comprehending water as an economic resource lies in grasping the nature of water dynamics. Thus, it is necessary to investigate the factors contributing to differences in water usage among individual residential water consumers by analyzing micro-level data (Schleich & Hillenbrand, 2009). The study aims to investigate how water price dynamics, current tariff structures, meteorological factors (such as rainfall and temperature), and unanticipated events like the COVID-19 pandemic influence domestic water consumption patterns in Dhaka using the difference-in-differences (DID) method and suggests comprehensive policy strategies to promote sustainable water resource management in megacities.

1.1 Objective of the Study

This study aims to offer essential responses to the subsequent research inquiries:

1. How do water pricing, tariff structures, meteorological factors, and events like the COVID-19 pandemic impact domestic water demand in Dhaka City?

2. What policy strategies can promote sustainable water management in megacities?

The subsequent sections of this paper are organized in the following manner. Section 2 provides a concise overview and analysis of the relevant water pricing and demand management literature. Section 3 briefly describes the water supply system and socio-economic factors of our study area. In Section 4, a conceptual sample design and empirical model are developed to identify the causal relationship. Section 5 provides the main findings of this study. In Section 6, discussion about our results, policy implications, and limitations are discussed. Finally, Section 7 addresses this study's conclusion, and Section 8 addresses future research opportunities.

2. Literature Review

The existing scientific literature extensively examines various water conservation policies, particularly pricing and prescriptive mechanisms. To mitigate water consumption in response to escalating drought conditions, local governments, municipalities, water utilities, and water conservation organizations have implemented various measures (Cook et al., 2015; Diffenbaugh et al., 2015). Policy measures aimed at diminishing water demand encompass pricing (Olmstead & Stavins, 2009; Olmstead, 2010), providing subsidies during droughts (Chang et al., 2023), rebate programs (Tsai et al., 2011; Brelsford & Abbott, 2021), behavioral interventions (Russell & Fielding, 2010; Chesnutt et al., 2019; Wichman et al., 2016), and usage restrictions (Inman & Jeffrey, 2006). These policies are implemented mainly in developed economies.

Raising water prices has been suggested to efficiently allocate the burden of water rationing across users (Olmstead, 2010). Using the difference in differences and regression discontinuity in North Carolina, USA, Wichman (2014) shows that residential consumers respond to the average price rather than the marginal price and change water consumption behavior` accordingly. Furthermore, this study provides evidence of various price elasticity estimates obtained via regression analysis, which support the well-established notion that residential water demand is frequently price inelastic, albeit not completely unresponsive to changes in price. This study concludes that the implementation of increasing block rates can lead to a counterproductive outcome of higher overall demand in a block tariff scenario. However, this finding only applies to our case, as DWASA supplies water under a uniform volumetric subsidized tariff system. However, a sudden substantial increase in water pricing is politically unfavorable, as low-income households exhibit heightened sensitivity to price changes (Wichman et al., 2016), whereas such price adjustments may have a minimal effect on higher-income consumers (De Oliver, 1999). Wichman et al. (2016) further asserted that substantial increases in water tariffs may lead to revenue instability and budget deficits.

Introducing subsidies for water conservation during severe droughts is a vital approach to addressing these difficulties and ensuring fair access to water resources. According to Chang et al. (2023), a detailed difference in differences analysis of K-water's "Subsidy for Water Savings During the 2015 Drought in Korea" program found that families receiving the subsidy used roughly 4% less water than the same month in the previous year, which is noteworthy, especially during the drought. During the dry season, water shortages disproportionately affect low-income neighborhoods in Dhaka City, where access to clean water is already limited. Subsidies for water conservation can bridge this gap by providing financial assistance to households and communities to invest in water-saving technologies. One central question with the subsidy for water savings is the sustainability of the policy. Water authorities' provision of subsidies to households, constrained by their limited budget, may impede investment in supplementary water infrastructure. However, studies suggest that water conservation's long-term benefits may outweigh the subsidies' initial costs. Moreover, innovative financing mechanisms, such as public-private partnerships, international aid, and efficient water pricing, may help alleviate the financial strain on the government while still promoting water conservation efforts.

A rebate is another form of policy program that aims to reduce water demand by offering consumers a subsidy for adopting high-efficiency toilets (Tsai et al., 2011; Bennear et al., 2013), high-efficiency clothes washers (Tsai et al., 2011), smart irrigation controller (Morera et al., 2019), or replacing lawns with desert landscape (Brelsford & Abbott, 2021).

Water pricing is a recognized strategy for demand management in the literature. A case-by-case analysis is necessary to ascertain the correlation between water pricing and domestic demand. Consistent with the available information, Seo and Cho (2020) found that Seoul experienced a decrease in water usage when water prices increased among the eight regions in South Korea. This finding indicates that water costs have a substantial impact on water usage. Nevertheless, the other seven cities continued to grow despite the price increase. This study uses simple regression analysis with repeated cross-sectional data from 1998 to 2017 without considering the effect of critical meteorological parameters like temperature and rainfall. In contrast, our study develops a fixed effects model and controls for meteorological, urban factors, and exogenous COVID-19 shock.

As identified in existing literature, the primary determinants of water use among domestic consumers include water pricing, precipitation levels, temperature, household income, and age demographics. In Portugal, Martins and Fortunato (2007) conducted a study that used marginal price as an instrumental variable to examine the factors influencing residential water use. They found that temperature and age demographics, in addition to price, substantially impact water consumption. However, rainfall and family income do not significantly influence water consumption. Additionally, they emphasized the equity concerns of vulnerable groups while increasing the block tariff. They proposed that the amount of water allocated in the initial block should be sufficient to meet a household's necessary water requirements.

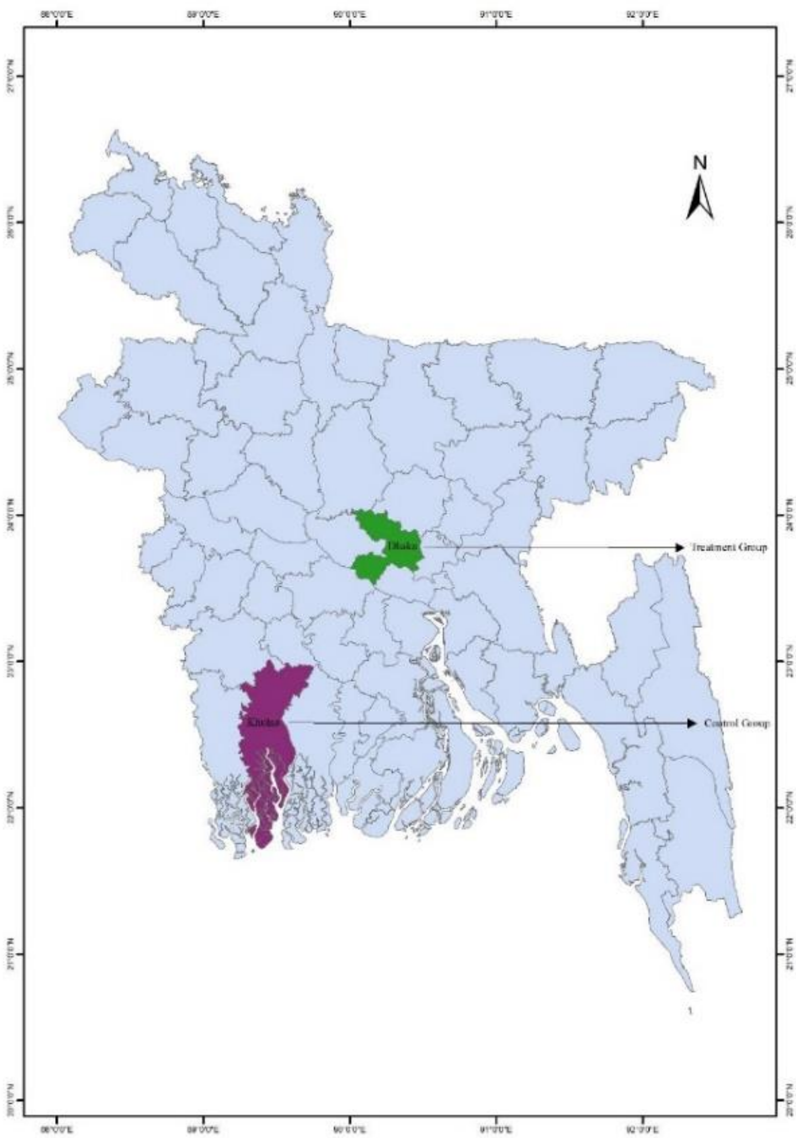
In this context, Wichman et al. (2016) suggested that non-price policies like demand-side management programs may have more consistent effects across different sociodemographic groups. The implementation of command-and-control restrictions can be effective (Kenney et al., 2004; Renwick & Archibald, 2018; Haque et al., 2014; Palazzo et al., 2017); however, their efficacy is limited by political will (Cooper et al., 2011; Stoutenborough & Vedlitz, 2014), enforcement and monitoring difficulties (Sisser et al., 2016). Behavioral interventions, such as conservation programs that promote voluntary water savings through education, information dissemination, and persuasion, are prevalent policy tools (Russell & Fielding, 2010) and may be adaptable and cost-effective (Chesnutt et al., 2019). Evidence supports the efficacy of behavioral interventions, especially social comparison messages, in water consumption (Ferraro et al., 2011; Ferraro & Price, 2013; Visser et al., 2021).

While there has been extensive research on the effects of pricing and prescriptive mechanisms on water demand, researchers have yet to identify the specific price signal that residential water users in developing countries rely on to make consumption decisions, particularly in areas with low water costs and uniform volumetric tariff systems. Moreover, meteorological factors should be considered in the econometric model to properly evaluate the impact of water prices on domestic water consumption. This research investigates water consumption in Dhaka, a densely populated megacity with high-income disparity, by controlling demographic, meteorological, and exogenous factors. The study addresses the lack of literature on water consumption behavior in Asian cities like Dhaka.

3. Description of the Study Area

This study seeks to identify changes in consumer behavior regarding water consumption in response to alterations in water tariffs in Dhaka City, the capital of Bangladesh. In our difference-in-difference model, we designate a portion of Dhaka City as the treatment region and a segment of Khulna City as the control area. DWASA is responsible for water supply and sewerage management in Dhaka, whereas KWASA oversees analogous functions in Khulna. This study focuses on the domestic households of two contiguous areas, Khilkhet and Nikunjo, located in the northern central region of Dhaka city, which are designated treatment groups. DWASA is partitioned into 156 District Metered Areas (DMAs) for operational efficiency. The Khilkhet area is classified as DMA-909, while Nikunjo is classified as DMA-910. The treatment group had alterations in water tariffs in July 2021. Subsequently, we designated the KWASA households as the control group to establish the difference-in-difference model. KWASA households had not faced tariff increases. The lower section briefly describes our treatment and control group's water supply system and socio-economic condition.

Figure 1: *Map Showing the Geographical Position of the Treatment and Control Area*



3.1 Water Supply at Dhaka City

DWASA was founded in 1963 as an autonomous entity tasked with the provision of water supply and sewage disposal for the residents of Dhaka. The 'WASA Act of 1996' has restructured its operations, and under this legislation, DWASA functions as an autonomous entity characterized by a corporate management culture, aspiring to be the premier public sector water utility in Asia, emphasizing environmental sustainability and a people-centric water management system.

The city's water supply originates from groundwater and surface water sources. Approximately 67% of water is derived from subterranean sources, while the remaining 33% originates from surface water. The current number of Deep Tube Wells is 997, from which groundwater is extracted and distributed. Five water treatment facilities are located in various areas throughout the city. The entities are designated as Chandni Ghat Water Works, Saydabad Phase 1, Saydabad Phase 2, Padma Water Treatment Plant, and the Savar Vakurta well field plant. The water of the Shitalakhiya, Buriganga, and Padma rivers are being processed and distributed inside the city. The current water demand in the city is 265-270 million liters per day (MLD), whereas DWASA has a production capability of 275 MLD from the existing infrastructure and facilities.

DWASA jurisdiction is around 314 square kilometers which is divided into ten zones for its maintenance, operation, and distribution services. In short, these are known as MODS zones. These MODS zones are responsible for providing water supply and maintenance of its area of jurisdictions as well as the sewerage facilities. In the whole city, there was a single network. There were no as-built drawings of the network, creating a big problem for the operational and maintenance personnel. In the year 2007, DWASA took the initiative to separate the single network into an area-based network, which is called DMA (District Metered Area). The whole city was divided into 156 DMAs in the 10 MODS Zone of DWASA.

Moreover, integrating SCADA into the operation of Water and Sewerage Treatment Plants, along with Deep Tube Wells (DTW), has revolutionized service delivery, drastically reducing non-revenue water (NRW) from a staggering 40% to a mere 10% in targeted DMA areas but still problematic in non-DMA areas. This achievement is further underscored by an impressive operating ratio of 0.66. Leveraging software-based digital accounting systems has streamlined operations, enhancing efficiency and transparency across critical areas like billing, customer service, and asset management. DWASA is also responsible for providing permission and licensing for personal deep tube wells in households with higher consumption for groundwater extraction.

Though Dhaka WASA is capable of providing water supply as per the growing demand of Dhaka City, seasonal droughts have become more challenging. Due to the heavy abstraction of groundwater, the groundwater level is declining day by day. Climate change has worsened the scenario. According to Moshfika (2021), the maximum groundwater declination rate was found for the South Khilgaon area (around -2.4 m/yr). Groundwater levels in Dhaka City have dropped significantly since 1980. The primary causes of groundwater decrease include overexploitation, population growth, urbanization, rainfall fluctuations, etc. Groundwater depletion affects Dhaka greatly. It caused water scarcity, well construction delays, food production issues, ecological imbalance in the city, earthquake danger, and other issues.

The deterioration of the surface water quality of the rivers located on the outskirts of Dhaka City is another key cause for concern. Buriganga, Turag, Dhaleswari, Shitalakhya, and Balu are those of the five peripheral rivers that surround the city of Dhaka. Padma and Meghna are the two important rivers located in the city's immediate vicinity. It has been reported by the Department of Environment (DoE) that the water quality of the Burignaga, Turag, Balu, Shitalakhya, and Dhaleswari rivers has significantly worsened over the course of the past several years. A continual decline in water quality has been brought about as a consequence of the accumulation of toxins that originate from a variety of industrial and domestic sources. With the exception of a few months of the year (July to October), none of the rivers on the city's periphery have been deemed acceptable for use as raw water sources. A considerable decline in water quality can be observed in the rivers that are located on the outskirts of Dhaka during the dry season. Consequently, there is an increase in the amount of chemicals that are utilized in Surface Water Treatment Plants (SWTPs).

3.2 Water Supply at Khulna City

Khulna, which is the third-largest city, is located in the southwest part of Bangladesh. Being a port city, Khulna is also home to a large number of manufacturing enterprises and is facing rapid urbanization. Khulna is a city that can be found in the delta of the Ganges River. Although the city is located around 2.5 meters above the mean sea level (MSL), the land is impacted by the fast increase in the population as well as the operations of the economy.

KWASA is the sole authority responsible for providing water supply and sewerage facilities in Khulna City. Prior to the establishment of KWASA, the Khulna City Corporation (KCC) was in charge of the responsibilities associated with the city's water supply. In 2008, KWASA was established as an autonomous body with a mission to become one of the leading organizations in Bangladesh in the field of water and sanitation by achieving customer service satisfaction through a safe water supply and environmentally friendly sewerage system. After the DWASA and the Chittagong WASA, the KWASA is the third Water Supply and Sewerage Authority (WASA) in the country.

KWASA's current water supply is primarily derived from groundwater sources, and this is accomplished through the use of both deep and shallow tube wells. Currently, there are around 9,000 hand tube wells, 41 production tube wells, and 52 mini tube wells in use. KWASA aims to provide optimal services through modern planning, efficient management, human resource development, and increased organizational capacity, ensuring transparency and accountability through safe water supply and environmentally friendly sewerage systems. Within their service area, KWASA now encompasses 45.60 square kilometers. A total of 40368 homes are supplied with water by KWASA from the organization. Only about seventy percent of the people living in KCC are served by KWASA, despite the fact that the total population of KCC is close to 1.5 million. KWASA is responsible for pumping up approximately 75 million liters of groundwater per day and supplying it through its pipes. This is in response to an aggregated daily demand of 250 million liters of groundwater (Roy et al., 2019).

Khulna residents face water issues due to dry season salinity and lack of rainfall. The roadside tap system was introduced to meet demand, but groundwater salinity and arsenic poisoning contribute to water quality concerns. Studies have been conducted to determine reliable water sources and evaluate groundwater resources for the Khulna water supply system.

3.3 Demography

According to the Population and Housing Census-2022, the Khilkhet residential area in Dhaka North City Corporation (DNCC) has a population of 0.18 million, with 56.4% male and 43.6% female (BBS, 2023). The sex ratio is 115.6:100, and the area has a population density of 30531 people per square kilometer with 49848 households. The majority of the population is Muslim (93.4%), with a small Buddhist population (0.05%). Hindu and Christian inhabitants also exist. The average annual population growth rate of Dhaka City is 1.79, whereas national level population growth is 1.22.

The Khulna Sadar area has a total population of 0.25 million, with a male-to-female ratio of 100.86:100 (BBS, 2023). The area has a general household size of 3.74 and a population density of 15762 people per square kilometer. The majority of the population is Muslim (88.21%), with a small Buddhist population (0.01%). Hindu and Christian populations also exist. The area has an average annual population growth rate of 1.06. The total no. of households is 65619.

3.4 Educational Status

According to BBS (2023), Dhaka City has a literacy rate of 84.20%, higher than the national rate of 74.08%. Particularly, the Khilkhet residential area has a literacy rate of 87.24%, with males and females at 85.71% and 82.44%, respectively. Khulna City has a literacy rate of 80.20%, also higher than the national rate of 74.08%. The Khulna Sadar residential area has a literacy rate of 88.4%, which is 1.16% higher than the Khilkhet area, with males at 83.01% and females at 77.37%.

3.5 Occupation and Livelihood

The Socio-Economic and Demographic Survey (SEDS)-2023 reveals that in Dhaka City, the labor force participation rate is 58.62% of the population, with males holding the majority (74.94%) and females holding 42.64% (BBS, 2024). The employment rate is 96.24%, and unemployment is 3.76%. The agriculture sector is the most employed, with 43.89% of the population. The service sector is the second highest, with 37.04% working in it. The industry sector is the third largest, with 19.07% working in it. In Dhaka City, 59.69% of the population is employed full-time, 10.45% part-time, 2.51% contractual, 8.10% seasonal, and 19.25% daily labor activity. In Khulna City, 58.98% of the population participates in the active labor force, with 76.38% males and 41.53% females. The work categories in both cities are similar, with 35.83% working full-time, 16.82% part-time, 2.07% contractual, 11.22% seasonal, and 34.06% daily labor activity (BBS, 2024).

3.6 SDG Indicators

The Socio-Economic and Demographic Survey (SEDS)-2023 reveals that Dhaka and Khulna cities have achieved significant progress in achieving SDG 6.1.1 and SDG 6.2.1(a), indicating safe drinking water and sanitation services, respectively. In terms of improved sources of drinking water, Dhaka achieved 99.98 percent, and Khulna city also showed almost similar achievement, which is 98.01 percent (BBS, 2024). Dhaka achieved 72.03 percent of basic sanitation services, while Khulna achieved 83.89 percent. Both cities also achieved 96.80 percent improved sanitation services, surpassing the national level achievement of 95.97%. Access to electricity is another key indicator of growth (SDG 7.1.1), with Dhaka achieving 99.93% and Khulna achieving 99.82%. Both cities scored higher than the national level achievement of 99.64% in terms of access to electricity. Women's engagement in achieving these SDGs is remarkable in both cities.

3.7 Water Pricing in Relation to Water Supply

3.7.1 Nature of Water

Water at the household level is a unique and exclusive private good, unlike other private goods like clothes, food, cosmetics, housing, and cars. Access to safe drinking water is a basic human right, and water cannot be treated like other marketable goods. If water is considered a completely private good, it could violate basic human rights, demonstrating consumer equality. However, after basic water needs are met, additional uses like swimming pools, lawn watering, or long showers are no longer considered a basic human right. In these cases, water becomes a private good and is best allocated through markets, similar to other private goods. This public nature of water as a good highlights the importance of consumer equality in water use.

Water can be a public or private good, and its characteristics make it non-traditionally marketable. Effective water resource management requires a participatory approach involving users, planners, and policymakers. However, certain aspects of water resources, such as desalination plant construction and industrial effluent management, can be efficiently allocated through market processes if the dynamics of water uses are considered, allowing for a sustainable integrated water resource management system.

Water pricing is a crucial aspect of managing water resources and determining the best price for people to pay for their water. A water tariff consists of prices, fees, and taxes, determining the cost of providing water. There are differing opinions on whether water utilities should be free or highly subsidized and whether the price should reflect water scarcity and cost. Traditional supply systems face risks of poor design and environmental effects, making water pricing a significant issue in today's water management.

3.7.2 Types of Water Pricing Model

In low and middle-income countries, piped water and sanitation services are significantly subsidized (Andres et al., 2020). The global water intelligence database shows that in half of cities, the average water price is below 40 cents per cubic meter. In 10%, the price is doubled to 80 cents. Most cities only cover operational and maintenance expenses. However, different water providers use a variety of tariff systems. These structures can be classified into two main categories: flat-rate charges, where the amount of water consumed does not affect the bill, and water use charges, which are based on usage, are elaborated upon below:

Fixed Tariff or Flat-rate Charge: A fixed tariff or flat-rate charge is a straightforward pricing structure with a predetermined amount payable during each billing cycle. The monthly payment is independent of the volume of water utilized. The expected amount of use is usually based on how much the house is worth, how many taps it has, the width of the main connection pipe, and the size of the meter (Mycoo, 1997). When there isn't a water meter to track how much water is used, a flat fee is usually the only fair way to set prices (Meran et al., 2021). Flat rate tariffs are a traditional water pricing system that focuses on calculating revenue or subsidies from the water sector.

However, they are criticized for not accurately representing the value of water to consumers and for not informing consumers about water consumption patterns, leading to inefficient usage behaviors. This system is inequitable, as affluent households may incur higher costs and allocate more income to water than those with lower consumption. Additionally, impoverished households in developing nations may have larger family sizes and lower asset values, leading to higher water use. Despite being the most basic and antiquated rate structure, many developed nations, including Canada, Mexico, New Zealand, and Norway, continue to implement it, as water rates are generally lower than global standards.

Water Use Charge or Volumetric Charge: Water use or volumetric charge is a method for tariff design where customers pay based on their water consumption. This 'pay-as-you-consume' system requires a metered connection for fees. It can be classified into three main categories: uniform volumetric tariff, block tariff, and increasing linear tariff. Each category has specific attributes, such as the amount of water used, the type of connection, and the charging formula.

The **uniform volumetric charge (UVC)** is a single-rate system where customers pay the same amount for each unit of water they use, regardless of their usage (see Figure 2). It is widely used in US cities like New York, Chicago, and also in Dhaka. It is popular in Sweden, France, the Netherlands, and Australia. The water bill can be calculated using the formula:

Water bill = amount of water used * flat rate per unit

UVC is easy to set up and cost-effective, as volumetric tariffs are based on the price per unit amount, making them socially acceptable. However, volumetric rates are often less than marginal costs, leading to poor households paying more for better water services. If these tariffs aren't fair, poor households may face increased costs and negatively impact government policies like universal coverage and public health security.

Volumetric Block Tariffs: A volumetric block tariff charges customers based on usage blocks, with the water rate set by the unit (m^3 or liters) of water used. The rate remains constant until the original block is reached, then changes to the next block until the maximum usage is reached. The volumetric charge may go up or down, related to higher usage, known as "Increasing Block Tariff - IBT" or "Decreasing Block Tariff - DBT."

Figure 2: *Price of Water compared to the Amount Used for Different Pricing Plans (Whittington, 2011)*

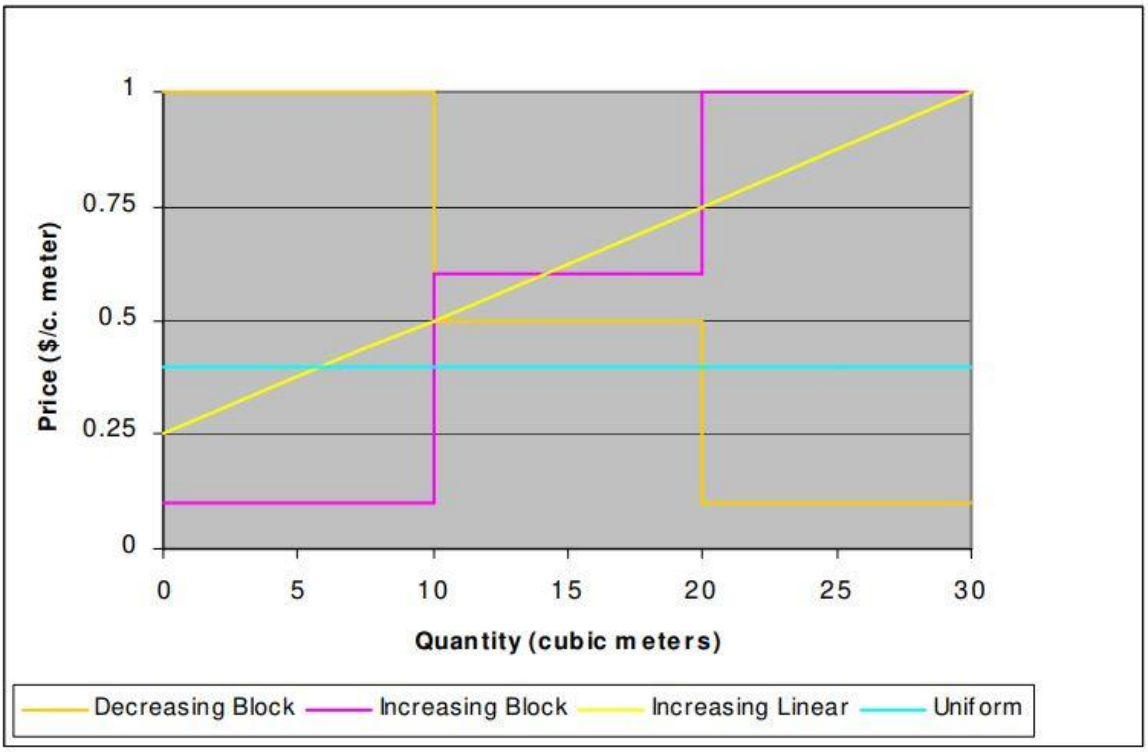


Figure 2 demonstrates that an **Increasing Block Tariff (IBT) system** is a pricing model where consumers pay less per unit of volume up to a certain amount (first block) and then pay more for any extra water use until the second block. This system is increasingly being adopted by water companies and government agencies to help poor people in developing countries. The starting block price is set below cost, regardless of the amount. Researchers argue that IBTs help collect costs, punish excessive use, and help low-income people pay for critical use. Implementing IBT is environmentally friendly and encourages fair and effective water use, making it a popular choice for water conservation.

The **Decreasing Block Tariff (DBT)** is a water pricing system that aims to encourage people to use more water by lowering the price of water used in a specific block. The DBT was designed to demonstrate the availability of raw water and promote industry growth and population growth. However, it does not reward small water users with financial benefits, and there are no rewards for saving water. DBT has been shown to decrease water usage over time, and businesses that use a lot of water may be seen as unfair or unacceptable to society. This societal perception and the decrease in water usage over time are key implications of the DBT. DBT may be politically feasible in areas where low per capita water consumption causes public health issues and where awareness efforts are limited. It could also improve economies of scale in manufacturing facilities.

The **Increasing Linear Tariff plan** is a type of water use pricing system where customers pay a gradual increase in price as they use more water. This system explains that water is expensive enough, and every extra unit of water used costs more. In Tunisia and Turkey, families are charged for all water they use based on the highest level of use. However, the system doesn't provide information on the short-term economic cost of using more water, and the utility's short-term marginal cost remains stable. This structure may not be suitable for businesses or industries that use a lot of water, as it could make the cost of using more water higher than the short-term minimal cost of supply. While increasing linear tariffs may generate revenue for water companies and improve resource use, it may not be socially accepted due to customers not understanding the increase in prices for each extra unit.

A type of water bill called a **two-part tariff** has both a fixed fee and a volumetric tariff system. The set fee is usually very small and stays the same, which helps cover the costs of running the service. For the next part of the bill, the volumetric tariff system can be used. These tariffs help water companies pay for their administrative costs and reach other goals as well. However, low-water users are hurt by the set component because it makes up a big part of their water costs.

Seasonal and regional tariffs indicate the fluctuating prices of drinkable water based on the season and location. Seasonal pricing increases during the dry season and decreases during the wet season. Regional pricing reflects the additional costs of providing services like pumping high ground. Another type of tariff model is the **Area Based Tariff**. The area may be classified based on land value, income status of the inhabitants, type of usage, cost of water production, and urbanization factors. This type of tariff model includes many dynamic factors, such as building tax and land tax, which is why practical implementation is quite challenging, especially where income inequalities are high. In Bangladesh, DWASA has taken initiatives to implement such tariffs in Dhaka City on a pilot basis.

The choice of a proper tariff model is of utmost importance in ensuring efficient management of water resources and ensuring the three components of IWRM: operational efficiency, social equity, and environmental sustainability (Kashem & Mondal, 2022). The rate of collection is also crucial for managing water fees, and low collection rates can hinder the design and implementation of tariffs. Therefore, effective collecting tools and methods are essential.

3.7.3 Water Pricing in Bangladesh

Bangladesh's water is undervalued due to low pricing and support from the government and donor agencies. The country's water policy prioritizes growth over resource management, leading to short-term water accessibility but long-term environmental degradation. Addressing groundwater pressure and surface water availability is crucial to prevent unmanageable issues and ensure a sustainable water supply. The water right is not well defined in Bangladesh. Though there are policies that impose specific water rights, the service jurisdiction is not well defined.

The Bangladeshi government has implemented various rules to manage water supplies effectively. However, the new price plan proposed in the "National Strategy for Water Supply and Sanitation in Bangladesh" has not yet been implemented (Qureshi et al., 2014). The Local Government Division is responsible for this strategy, which includes a lifeline price for the poor and a progressive tariff for piped water supply and sewerage systems. This allows towns or water utility companies to set water prices in their service areas. Some parts of Bangladesh, like Dhaka, Khulna, Chittagong, and Rajshahi, receive water from WASA. All of the WASAs are in charge of offering sewerage and water services, and each has its own set of rules for pricing. In other major municipality areas, water systems are run by local governments. Most of the 329 municipalities don't have metered connections. Instead, they use Fixed Tariffs or Flat-rate charges that depend on the size of the connection and the type of use. As of 2024, the Department of Public Health Engineering (DPHE) is given the job of providing water services in rural areas that are not covered by WASA or other municipalities. These areas are at the Upazila and Union Parishad levels. DPHE also helps cities and towns improve their water supply systems by giving them expert support. The Bangladesh Water Development Board (BWDB), the Bangladesh Agricultural Development Corporation (BADC), and the Barind Multipurpose Development Authority (BMDA) are in charge of getting irrigation water to farms all over the country.

For metered connections in Bangladesh, the uniform volumetric charge (UVC) method is usually used to figure out how much water to charge. The unit price fee changes are different in different regions of the country based on how much it costs to run and maintain the water supply. Moreover, uniform fees change based on the type of usage, such as residential, business, community, or industrial. In Dhaka, the cost of domestic use of water is BDT 16.70 per thousand liters, and for commercial purposes, the rate is BDT 46.20 per thousand liters (DWASA, 2024). In Khulna City, it costs BDT 8.98 for 1000 liters of domestic usage and BDT

14.00 per 1000 liters for commercial usage (KWASA, 2024). Households are not meter-connected in other major cities like Bogra, Naogaon, and Manikganj. For non-metered connections, a flat-rate tariff system is used in different municipalities based on the connection diameter, type of usage, and the number of floors in the building.

Nevertheless, the cost of water in Dhaka City is significantly lower compared to other Asian cities. It is also significantly lower compared to other South Asian cities, like Delhi, Kathmandu, and Jakarta (Asim & Lohano, 2015). The Water Supply Master Plan for Dhaka City references a block tariff structure as a demand management strategy (DWASA, 2014), although it has not yet received approval. The master plan includes provisions for rainwater harvesting and artificial recharge (AR), and a prototype design for household-level artificial groundwater recharge has been developed. However, DWASA could not execute rainwater harvesting and aquifer recharge system at the household level. A dual plumbing system integrating rainwater harvesting, alternative resources, and greywater reuse should be mandated for consumers. The implementation of managed aquifer recharge remains in the planning phase.

3.8 Climate

Bangladesh is vulnerable to both disasters and climate change and ranked the seventh extreme disaster-prone country in the world as per the report from the Global Climate Risk Index 2021 (Eckstein et al., 2021). Tropical cyclones, tornadoes, floods, coastal and riverbank erosion, droughts, and landslides are the major climate-induced hazards in Bangladesh. Moreover, Bangladesh has the highest mortality rate in Asia, with 520,758 fatalities resulting from 281 climate-related disaster events. Numerous areas throughout the region encountered severe temperatures in 2023. Extended heat waves impacted South and Southeast Asia in early summer. In India, intense heat waves in April and June caused approximately 110 deaths from heatstroke. A prolonged and intense heat wave affected a considerable area of Southeast Asia in April and May, extending westward to Bangladesh and eastern India and northward to southern China.

Bangladesh is highly susceptible to the impacts of climate change. The anticipated rise in temperatures may result in more severe and erratic rainfall throughout the monsoon season, as well as a heightened likelihood of devastating storms leading to more tidal inundation. The anticipated spike in extreme rainfall, coupled with significant sea level elevation, is concerning and may result in more frequent and severe coastal and river floods, as well as rainfall-induced landslides. The Bangladesh Meteorological Department (BMD) is the designated body for weather forecasts, including heat wave warnings, rainfall, temperature, and other meteorological factors in the country.

4. Evaluation Method

4.1 Sample Design

Our sample comprises 11,063 customers' monthly water billing data obtained from two major water utilities in Bangladesh: DWASA and KWASA. The data covers the period from June 2020 to December 2021. Within the sample design, we designate customers of DWASA as the treatment group and customers of KWASA as the control group. In July 2021, DWASA implemented a new water pricing system, which is considered our central policy intervention. During the study period, the control group encountered no additional tariff. To conduct the study, we examine sufficient months before and after implementing the new water tariff to construct the impact evaluation of a new tariff implementation program. The detailed sample design is shown in Table 1.

Table 1: *Design of Sample Households*

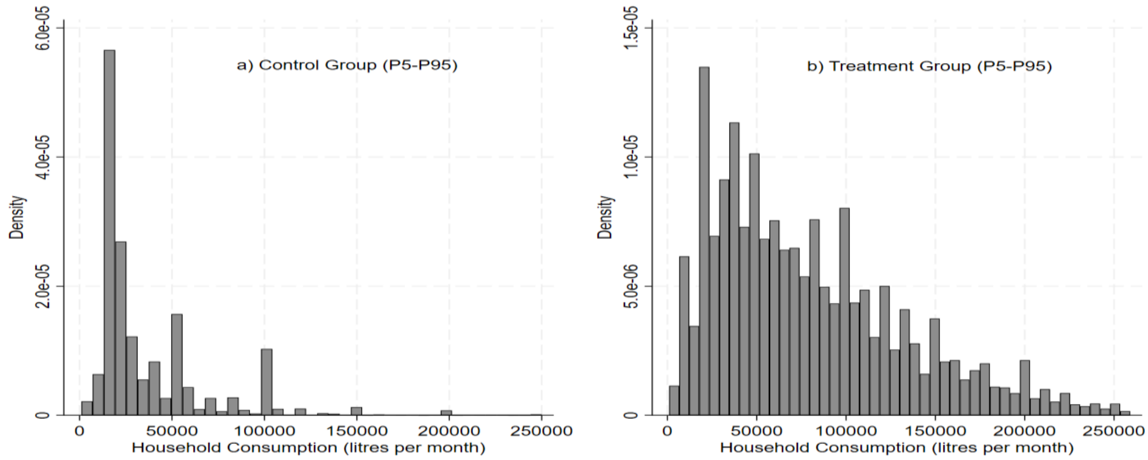
Study Period	Control (KWASA)	Treatment (DWASA)	Total
Before (Jun 2020- June 2021)	6992	4,071	11,063
After (July 2021- Dec 2021)	6,992	4,071	11,063
Total	13,984	8,142	22,126

Note. The number of customers are shown in the table.

Household-level monthly water billing data are obtained from both DWASA and KWASA. Prior to doing further analysis, it is essential to concentrate on the data collection procedure employed by DWASA and KWASA. DWASA and KWASA each have distinct revenue departments responsible for collecting monthly readings from households. At the end of the month, meter readers personally collect water consumption data from individual residences. The task requires significant personnel, and errors may occur. Outliers (extremely high consumption and zero consumption) may cloud our main analysis.

To forecast consumer water consumption trends properly about alterations in water tariffs, we analyze data ranging from the 5th to the 95th percentile for our primary analysis. We eliminate zero consumption and excessively high water consumption from our treatment and control group. Panel (a) of Figure 3 presents the histogram for the control group, and panel (b) illustrates the histogram for the treatment group considering the 5th to the 95th percentile data. Both the histograms are skewed right as the right tail is much longer than the left tail. On the left side of the graph, the frequency of the small or average water consumption household is higher than the frequency of the higher consumption household. In a real scenario, it is difficult to achieve sufficient data and perfect normal distribution.

__Figure 3:__ Distribution of Average Monthly Household Level Water Consumption



4.2 Data Collection and Description of Variables

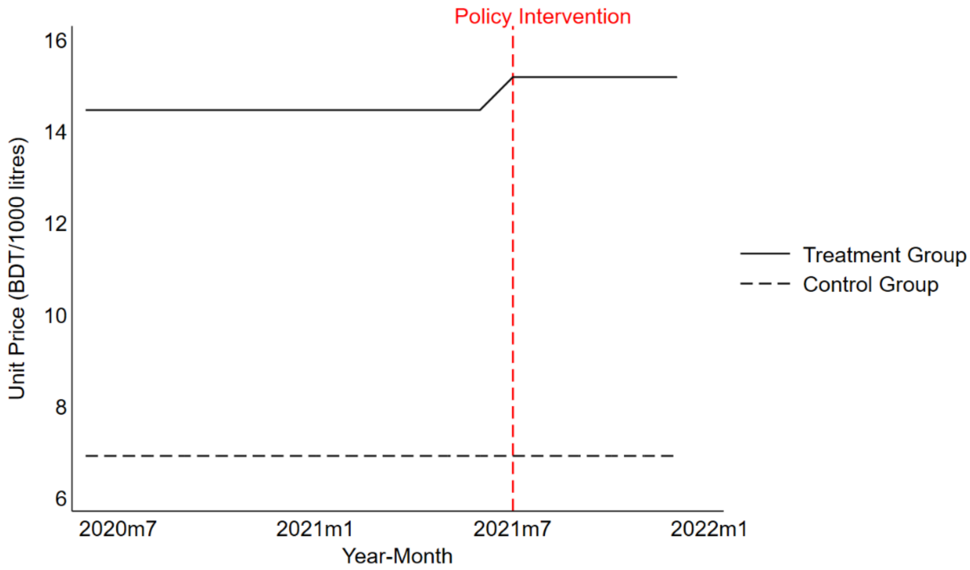
Dhaka and Khulna are the two major cities in Bangladesh. Both cities show similarities in terms of socio-economic parameters. The relevant data of this study is collected from different organizations.

4.2.1 Water Billing Data

In DWASA and KWASA, distinct revenue divisions are responsible for generating monthly water bills based on household-level bulk water meter readings conducted monthly according to a predetermined timetable by the designated Revenue Inspector. The Revenue Inspectors often gather household meter readings during the final week of the month. The readings are recorded on the meter card retained by the client and documented in the meter reading book located at the WASA office, with billing occurring during the first week of the subsequent month. During the second week of each month, customers receive a consolidated water bill from the WASA office for the preceding month. This bill encompasses customer information such as account number, location, meter number, number of stories, previous reading, current reading, water price, VAT, payment due date, and any applicable late payment surcharges. This study involves the collection of customers' water billing data from Dhaka

WASA and Khulna WASA, conducted under a non-disclosure agreement. We focus on two particular regions from Dhaka WASA: (1) Khilkhet (DMA-909) and (2) Nikunjo (DMA-910). Although Dhaka WASA offers sewerage services in certain areas of Dhaka City, our study location lacks a sewerage network. The water bill exclusively includes statistics on water consumption. In Khulna WASA, there are no sewage facilities; thus, the water bill exclusively reflects household-level water use data. Figure 4 depicts the modification in water tariffs for both the treatment and control groups before and after the intervention. The policy intervention occurred in July 2021.

Figure 4: *Unit Price per Thousand Liters of Domestic Water Consumption in DWASA and KWASA.*



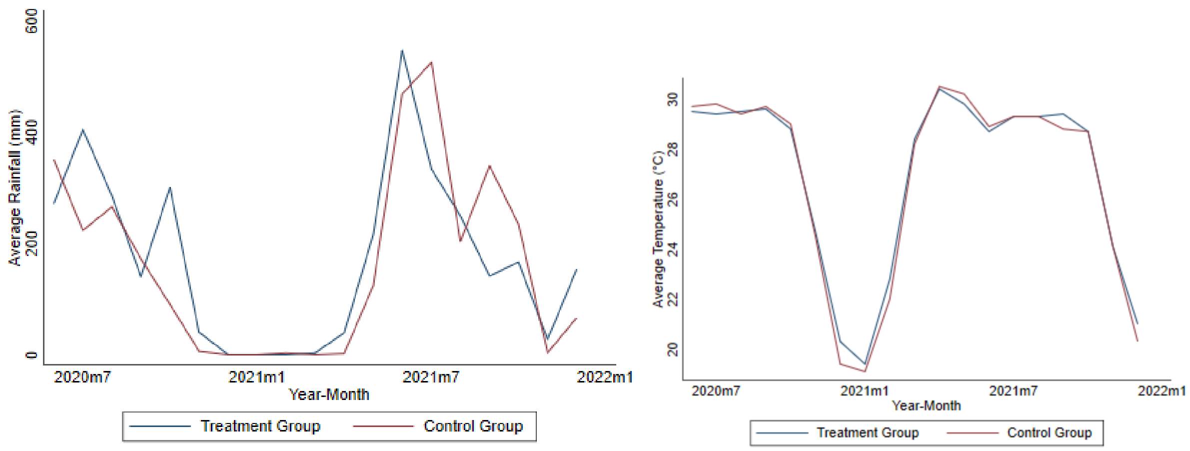
4.2.2 Rainfall Data

Water use correlates with precipitation. In numerous studies, water use is connected with precipitation. Chowdhury (2012) recognized rainwater as a crucial water resource in Dhaka city. The monthly average rainfall data obtained from BMD for Dhaka and Khulna is illustrated in Figure 5 panel (a) from June 2020 to December 2021. In our study period, we recorded a peak monthly rainfall of 546 mm in Dhaka in June 2021 and 525 mm in Khulna in

July 2021. The total annual precipitation in 2020 was 1920 mm for Dhaka and 1570 mm for Khulna. The total annual rainfall in 2021 was 1873 mm for Dhaka and 1967 mm for Khulna. Both cities experience significant rainfall during the monsoon season from June to September, attributed to the Indian Ocean Monsoon, and encounters less rainfall from October to February, designated as the winter season.

Figure 5: *Average Monthly Rainfall and Temperature Distribution across Treatment and Control Groups*

a) Average Rainfall *b) Average Temperature*



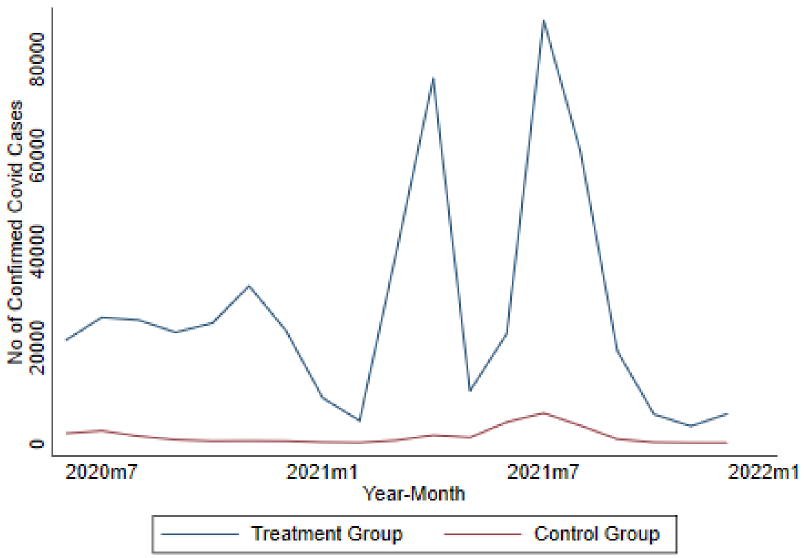
4.2.3 Temperature Data

Figure 5 panel (b) depicts the monthly average temperature fluctuations from June 2020 to December 2021 for both the treatment and control groups, as sourced from the Bangladesh Meteorological Department (BMD). Both the treatment and control groups exhibit a similar pattern, with the highest temperature recorded in April and the lowest in January of each year. In April 2021, the highest monthly average temperature recorded in Dhaka City was 30.4 degrees Celsius, while in Khulna City, it was 30.5 degrees Celsius. In April 2021, Dhaka recorded a maximum temperature of 39.5 degrees Celsius, 1.5 degrees Celsius higher than the preceding year. The maximum temperature recorded in Khula in April 2021 was 40.2 degrees Celsius, which is 3.2 degrees Celsius higher than the previous year. Both the highest monthly temperature and the monthly average temperature are rising annually for the treatment and control groups, attributable to climate change and the effects of increased urbanization in both cities.

4.2.4 COVID-19 Data

During our study period, the world has encountered a historic pandemic, COVID-19. Bangladesh is one of the countries most severely impacted by the COVID-19 pandemic. The government instituted restrictive regulations for outdoor mobility owing to the pandemic commencing at the end of March 2020. The pandemic affects both the treatment and control cohorts. Dhaka, the capital city, is the country's most densely inhabited city and the most affected by the pandemic. We employed the count of confirmed cases as a proxy for the COVID-19 pandemic. The data is obtained from the open data repository of the Directorate General of Health Services, Bangladesh (DG Health) website. Figure 6 depicts the monthly total number of verified COVID-19 cases from June 2020 to December 2021 for the treatment and control groups, as sourced from DG Health. In 2021, we noted two significant peaks in Dhaka City, although the number of confirmed cases in Khulna City remained comparatively low.

Figure 6: *No. of Confirmed COVID-19 Cases in Treatment and Control group*



4.3 Summary Statistics

Utilizing the aforementioned dataset, we construct a 19-month strongly balanced panel data set, with the unit of observation being the residential water user, as evidenced by monthly water billing records. Our overall sample comprises 11,063 households during 19 months, resulting in a total of 210,197-panel observations (11,063 x 19). Among these, 132,848 observations (6,992 x 19) belong to the control group, while 77,349 observations (4,071 x 19) are from the treatment group. Table 2, panel A, displays the descriptive statistics for the complete sample. The average water consumption is approximately 53,000 liters per household per month. Water consumption ranges from 0 to 500,000 liters per month across households.

Table 2: *Summary Statistics for Total Sample*

Variable	Observations (1)	Mean (2)	Std. Dev. (3)	Min (4)	Max (5)
Panel A: Total Sample					
Consumption	210197	53.62	72.37	0	500
Rainfall	210197	166.38	159.73	0	546
Tavg	210197	26.93	3.75	19.1	30.5
Tmax	210197	35.31	2.75	30	40.2
Tmin	210197	19.72	5.44	9	25.8
Covid	210197	11075.32	18875.23	94	88035
Panel B: Control Group (treat=0)					
Consumption	132848	27.07	35.69	0	500
Rainfall	132848	161.74	163.59	0	525
Tavg	132848	26.89	3.85	19.1	30.5
Tmax	132848	35.36	2.85	30	40.2
Tmin	132848	19.51	5.67	9	25.5
Covid	132848	1447.95	1649.91	94	6260
Panel C: Treatment Group (treat=1)					
Consumption	77349	99.23	93.57	0	500
Rainfall	77349	174.37	152.55	0	546
Tavg	77349	27.01	3.57	19.4	30.4
Tmax	77349	35.23	2.56	30.2	39.5
Tmin	77349	20.08	4.99	10	25.8
Covid	77349	27610.47	23041.40	3557	88035

Note: Consumption is measured in thousand liters per household per month, Rainfall is in mm, Temperature is in Degrees Celsius, and Covid represents no. of confirmed cases.

Table 2, panel B and C present comprehensive summary statistics for our control and treatment samples. Columns (1), (2), (3), (4), and (5) present the no. of observations, mean, standard deviation (SD), and minimum, and maximum values for the primary variables analyzed in this study: monthly water consumption (litres), monthly average rainfall (mm), monthly average, maximum, and minimum temperatures (degrees Celsius), and the number of confirmed COVID-19 cases. Table 2, panel B, shows the detailed summary of the control group. Table 2, panel C, presents the detailed summary statistics of the examined variable following the implementation of the new tariff within the treatment group. The monthly average water use per household in the control group is 27.07 thousand liters for domestic households, with a standard deviation of 35.69. For the treatment group, the monthly average water use per household is 99.23 thousand liters per household, with a standard deviation of 93.57. The data indicate that the average water consumption is higher in the treatment area due to heavy urbanization and vertical expansion of Dhaka City, although they are accompanied by a significant standard deviation, which appears questionable. Other parameters also provide evidence that there is a difference between the treatment and the control group.

To further the study, we examined the revenue department data-collection procedure and noticed that some households are not utilizing water, leading meter readers to attribute zero consumption to these households and impose a minimal bill for them. Occasionally, when the revenue personnel lack access to the household to collect readings from the meter, they charge an average bill. We also observed some exceptionally high consumption levels that are atypical for household usage. We adjust our data set by omitting zero consumption and excessively high consumption to analyze the resulting changes more precisely. We examine only the 5th to 95th percentiles and present the data statistics in Table 3 below. We analyze water use patterns over 19 months for a total of 2987 households, among these 704 households in the control area and 2283 household in the treatment area. The sample size is good enough to observe the effect of the intervention on domestic household consumption. In the restricted sample, the average monthly water consumption is 37.37 thousand liters for residential homes, with a standard deviation of 32.25 liters for the control group (Table 3 Panel B). For the treatment group, the value is 79.48 thousand liters with a standard deviation of 53.47 (Table 3 Panel C). The restricted sample summary statistics also showed that the treatment group's average consumption was higher, and the other parameters showed similar patterns.

Table 3: *Summary Statistics for Sample P5-P95*

Variables	Observations	Mean	Std. Dev.	Min	Max
	(1)	(2)	(3)	(4)	(5)
Panel A: Sample (P5-P95)					
Consumption	56753	69.56	52.44	1	259
Rainfall	56753	171.39	155.32	0	546
Tavg	56753	26.98	3.64	19.1	30.5
Tmax	56753	35.26	2.63	30	40.2
Tmin	56753	19.94	5.17	9	25.8
Covid	56753	21444.28	23015.75	94	88035
Panel B: Control Group (treat=0)					
Consumption	13376	37.37	32.25	1	250
Rainfall	13376	161.74	163.59	0	525
Tavg	13376	26.89	3.85	19.1	30.5
Tmax	13376	35.36	2.85	30	40.2
Tmin	13376	19.51	5.67	9	25.5
Covid	13376	1447.95	1649.96	94	6260
Panel C: Treatment Group (treat=1)					
Consumption	43377	79.48	53.47	1	259
Rainfall	43377	174.37	152.55	0	546
Tavg	43377	27.01	3.57	19.4	30.4
Tmax	43377	35.23	2.56	30.2	39.5
Tmin	43377	20.08	4.99	10	25.8
Covid	43377	27610.47	23041.52	3557	88035

Note: Consumption is measured in thousand liters per household per month, Rainfall is in mm, Temperature is in Degrees Celsius, and Covid represents no. of confirmed cases.

4.4 Baseline Balance

Additionally, the t-test is done to identify the baseline differences across treatment and control groups (see Table 4). Columns (2) and (4) show the control and treatment group mean before (Panel A) and after (Panel B) implementing the new tariff system. Column (5) and column (6) represent the mean differences and the standard errors. Column (7) and column (8) show the t-statistics and p-value. The results indicate that the observed mean differences in the baseline variables are statistically significant at a 1% level. The control group customers' average monthly water consumption is lower than the treatment group samples. Therefore, it indicates that our treatment and control groups are as good as random. Moreover, to find the specific causal relationship between water consumption and water pricing, all the variables are controlled in the OLS regression model to find the effect of water price increase on domestic water consumption. The difference in average monthly water consumption between the treatment and control groups is 40.72 thousand liters before the policy change (Table 4 Panel A). Following the policy intervention, the difference in monthly water between the treatment and control groups increased to 45.12 thousand liters per household (Table 4 Panel B), with a p-value of zero. The data reveal a highly statistically significant rise in consumption linked to price increase, with comparable standard errors prior to and after the policy intervention.

Table 4: *Baseline Differences: Two-sample t-test with Equal Variances*

Variables	Control		Treatment		Mean Difference (T-Test)			
	N	Mean	N	Mean	Diff	SE	t-value	p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Before Policy								
Consumption	9152	35.63	29679	76.35	-40.72	0.58	-70.75	0.00
Rainfall	9152	131.00	29679	172.62	-41.62	2.01	-20.75	0.00
Tavg	9152	26.95	29679	27.02	-0.07	0.05	-1.55	0.13
Tmax	9152	35.92	29679	35.40	0.52	0.03	16.10	0.00
Tmin	9152	19.25	29679	19.71	-0.45	0.07	-6.90	0.00
Covid	9152	1259.62	29679	26228.77	-24969.15	177.33	-140.80	0.00
Panel B: After Policy								
Consumption	4224	41.15	13698	86.26	-45.12	0.90	-50.10	0.00
Rainfall	4224	228.33	13698	178.17	50.17	2.07	24.20	0.00
Tavg	4224	26.75	13698	26.97	-0.22	0.06	-3.75	0.00
Tmax	4224	34.13	13698	34.87	-0.73	0.04	-18.15	0.00
Tmin	4224	20.05	13698	20.88	-0.83	0.08	-11.05	0.00
Covid	4224	1856.00	13698	30604.17	-28748.17	497.93	-57.75	0.00

Note: Consumption is measured in thousand liters per household per month, Rainfall is in mm, Temperature is in Degrees Celsius, and Covid represents no. of confirmed cases.

4.5 Empirical Strategy and Model

This research estimates a difference-in-differences (DID) technique using monthly customer-level 19-month panel data, including twelve months before and five months after the policy intervention, to capture the causal effect of price on domestic customers' water consumption in DWASA. The main DID model equation can be expressed as:

$$y_{it} = \alpha + \boldsymbol{\beta}(Treat_i * Post_t) + \Delta X'_{it} + \cdots \quad + \theta_i + \gamma_t + \mu_{RM} + \epsilon_{it} \qquad (1)$$

Where y_{it} measures monthly water consumption (in liters) for household i in month t. The equation controls for other factors like rainfall, temperature, and COVID factors as X'_{it}, where Δ**,** the co-efficient of control variables or effect of other factors. θ_i for household fixed effects to minimize the idiosyncratic differences, while γ_t for the time fixed effects as calendar month and billing year (i.e. month-year) to control for the time-invariant characteristics. We create another dummy region month's fixed effect, $\mu_{RM,}$ to capture the seasonal variation across regions and months. The main variable of interest in this model is the effect of $(Treat_i * Post_t)$. $Treat_i$ is a dummy variable that takes the value=1 if customer i is from the treatment group; otherwise, 0. $Post_t$ is another dummy variable that takes the value=1 if the time is after the policy intervention that is July 2021, otherwise takes 0. Therefore, the treatment effect of $(Treat_i * Post_t)$ is captured by β, which implies the average treatment effect (ATE) of being faced the tariff increase on customers' water consumption. ϵ_{it} is the error term, representing the deviation of the independent variable from the regression line. We carry out the DID estimates based on ordinary least squares (OLS) regression and monthly panel fixed effects. As we collected monthly billing balanced panel data from both DWASA and KWASA, we adopted a quasi-experimental approach including mean differences and difference in differences with household fixed effects, monthly time fixed effects, and region-month fixed effects with controls.

5. Findings

This section presents the regression results that capture the average treatment effect of the new water tariff increase on domestic water consumption in Dhaka City and the validation of our difference in differences (DID) model. Our main analysis is done with STATA, considering data samples from the 5th to 95th percentiles of our raw data set. Our treatment group consists of households that faced water price increases in DWASA, and our control group consists of households that did not face water price increases in KWASA.

5.1 OLS Regression Model Results

Water consumption may be correlated with the error term. To address this endogeneity problem, we used monthly fixed effects in our model following equation 1. The Random Effect Model permits the influence of both time-invariant and time-varying factors on the outcome. That is the rationale for utilizing the fixed effect model. In Table 5, Column 1, the OLS regression indicates that the average treatment effect of water price change in DWASA corresponds to an increase of around 4395 liters (mean consumption of 69555 liters per household per month) in monthly household water consumption considering only the time-fixed effect and household fixed effect. In Column 2, we add another fixed effect, that is, region-month fixed effect, and found an increase of 4111 liters in monthly household water consumption. In Column 3, we add meteorological factors, temperature, and rainfall as control factors with household-fixed, time-fixed effects, and region-month-fixed effects and found the effect consistent. As our study period coincides with the COVID-19 pandemic period, we further added no. of confirmed COVID cases as a control variable in Column 4 and found the result positive and consistent. All results are statistically significant at a 1 percent significance level. The adjusted R-square value is 0.04 in every case, implying that 4 % of the variation in consumption happened due to the policy intervention. The actual water tariff increased by 0.72 BDT per 1000 liters of water in domestic households. For 1 BDT change in water tariff, the demand for water consumption in Dhaka City increases by 6103 liters, which is around 9% of the mean average monthly water consumption in Dhaka City.

Table 5: *Main OLS Regression Results*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
treatXpost	4394.6***	4110.9***	3842.5***	3733.8***
	(587.1)	(686.5)	(826.0)	(833.2)
Rainfall			-5.448	-6.945
			(5.221)	(5.436)
Tavg			-2849.2	-2699.6
			(2788.0)	(2792.1)
Covid				-0.0238
				(0.0241)
Constant	57274.9***	74290.3***	134580.8**	131857.4**
	(504.9)	(728.0)	(58604.8)	(58669.5)
R-squared	0.04	0.04	0.04	0.04
Observations	56,753	56,753	56,753	56,753
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

Note: Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

From Table 5, we found that the effect of temperature, rainfall and COVID factors are statistically insignificant, the magnitude of these factor's effect on household consumption is minimal.

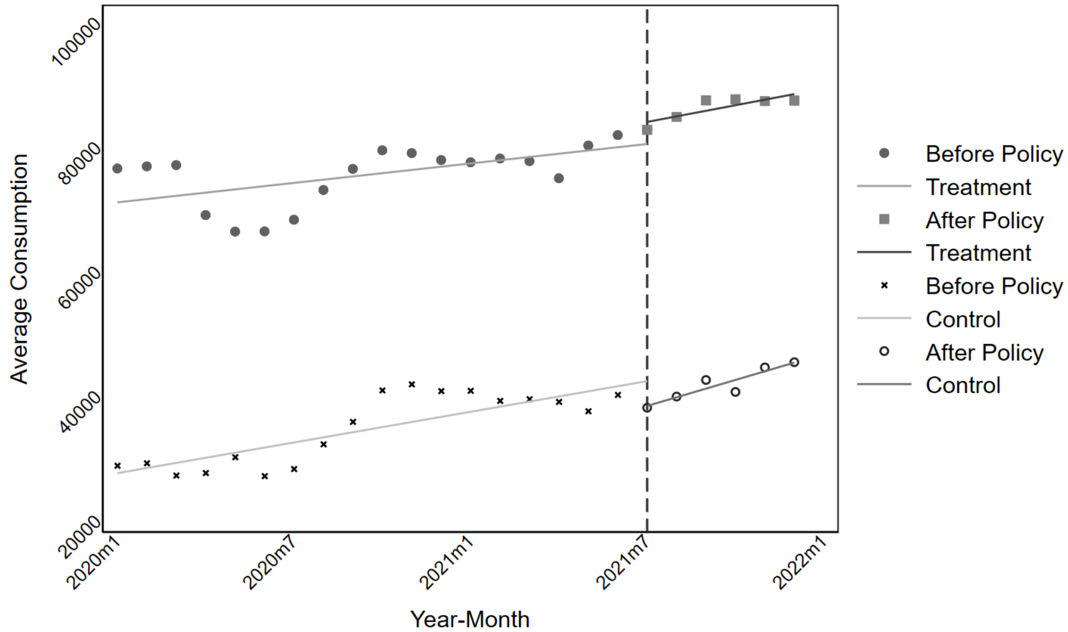
5.2 Robustness Checks

There are still concerns with the omitted variable bias that we cannot ignore. There might be important time-varying factors that could affect water consumption at the household level. This section of the paper examines the sensitivity of our primary findings derived from equation 1. To achieve this, we utilise many alternative methods to assess the robustness of our primary coefficient of interest.

5.2.1 Parallel Trend Assumption

The central assumption of the DID model is that the treatment and control group followed a similar path overtime before the treatment or in the absence of treatment. In our case, the treatment and control groups' water consumption patterns change similarly before the treatment. Figure 7 shows that the treatment and control groups followed a parallel trend before the policy intervention. After the policy intervention in July 2021, it is evident that the consumption of treatment groups increased and the consumption of the control group fell, which validates our main OLS regression results. Moreover, we conducted an event study, falsification test, placebo test, and subsample analysis to verify the validity of this trend assumption.

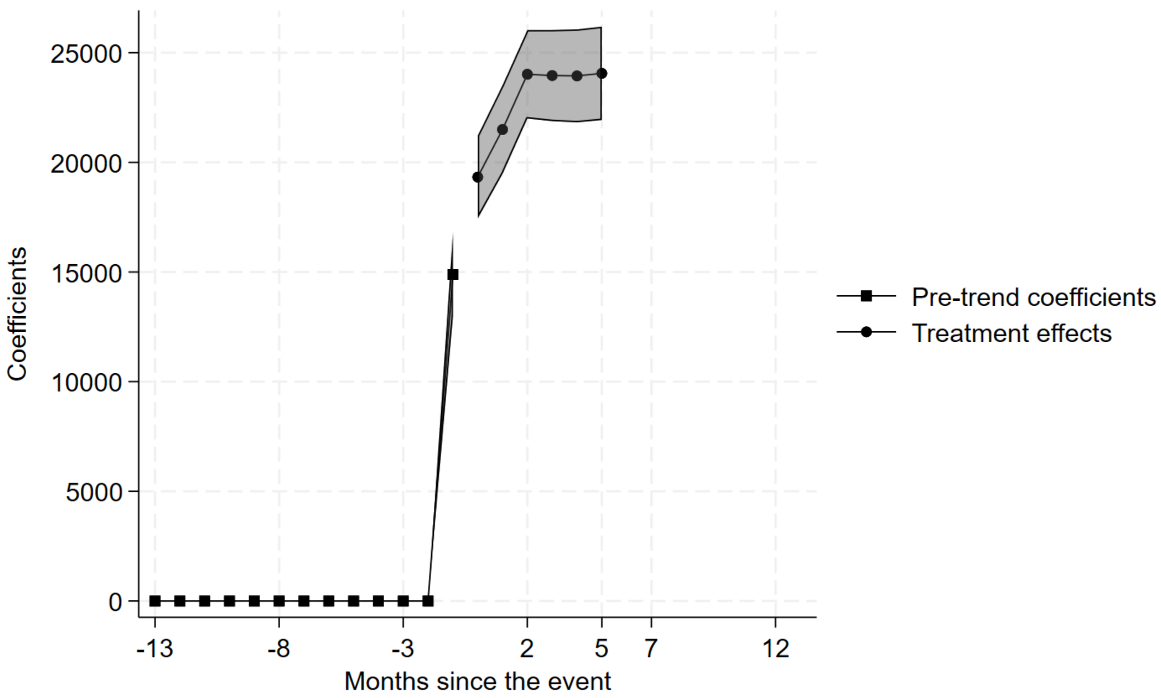
Figure 7: *Validation of DID Model and Treatment Effect*



5.2.2 DID Imputation Event Study

Event studies utilizing DID models augment the robustness of the research, elucidating the effects of certain interventions or events on the targeted outcomes. We used the DID imputation event study design proposed by Borusyak et al. (2024), which is a more advanced and flexible approach in terms of implementation. From Figure 8, the treatment effect is obvious and positive. The parallel trend assumption holds but there is some anticipation effect just before the intervention. This might be due to pre-announcement from DWASA before increasing the price. Typically, DWASA announces a price increase one or two months in advance. Additionally, DWASA has a provision to increase the water tariff by 5% annually which might act as a triggering signal and may contribute to this anticipatory effect.

Figure 8: *DID Imputation Event Study Result*

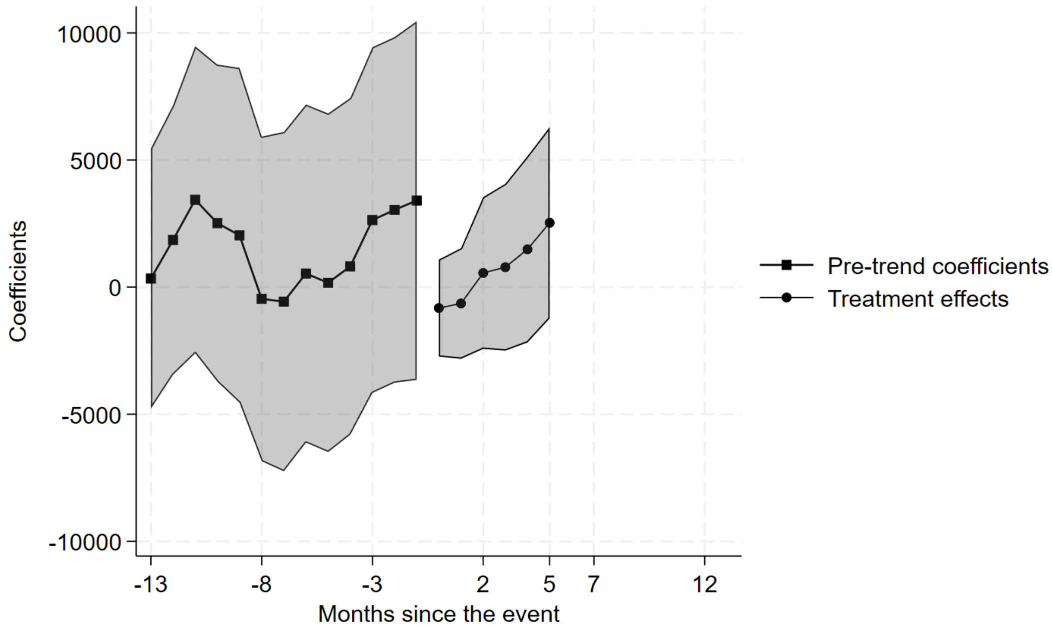


5.2.3 Falsification Test

DID models' validity relies on the premise of parallel trends assumption, which posits that, in the absence of treatment, the treatment and control groups would have exhibited analogous patterns across time. Falsification tests assess the validity of this assumption, hence enhancing the credibility of the causal conclusion. Researchers can uncover biases or confounding factors that may influence the results by analyzing pre-treatment outcomes or utilizing placebo events. Significant effects observed in periods or groups without treatment indicate that the initial results may be misleading.

We also tried to validate our results by creating a setup where there should not be any treatment effects or anticipation, or pre-trends in the absence of treatment. We found some kind of treatment effect with problems of anticipation but the anticipation effect or the false treatment effect is not bigger than the original data suggested that makes our results trustworthy (see Figure 9). To further check this issue we conducted some placebos test to validate our results.

Figure 9: *Falsification Test Results*



5.2.4 Placebos

We have conducted several placebos to check if there are any other factors other than the policy intervention in the pre-intervention period for this increase in water consumption. Table 6 reports the placebo effects of false treatment in the absence of real treatment. The treat*placebo interaction coefficient is statistically insignificant for models 3 and 4, where we considered all the monthly fixed effects along with meteorological and COVID-19 factors. So, we can conclude that there is no placebo effect rather the treatment that creates the results of water demand increase in our study area. These robustness checks enhance the robustness of our findings.

Table 6: *Placebo OLS Regression Results*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
placebo1=1	-3933.3***	7831.0***	361.6	653.3
	(1214.1)	(1716.3)	(5084.3)	(5089.8)
placebo2=1	-2257.1	-15764.2***	36107.3	36090.2
	(1470.6)	(1994.5)	(34627.3)	(34627.2)
placebo3=1	1075.3	1075.3	1206.3	928.1
	(1470.6)	(1470.0)	(1595.4)	(1611.4)
placebo4=1	44.03	44.03	-10207.2	-10256.5
	(1470.6)	(1470.0)	(7020.7)	(7020.7)
placebo5=1		1130.7	-38225.9	-38231.8
	(1195.0)	(1347.9)	(26231.8)	(26231.7)
treat=1 # placebo1=1	-2176.3*	-2741.8	-612.1	-86.08
	(1284.8)	(1816.2)	(2286.3)	(2326.2)
treat=1 # placebo2=1	636.7	-1369.2	-2918.0	-3270.2*
	(1682.2)	(1681.5)	(1925.8)	(1947.1)
treat=1 # placebo3=1	-6390.9***	0	0	0
	(1682.2)	(.)	(.)	(.)
treat=1 # placebo4=1	2660.7	0	0	0
	(1682.2)	(.)	(.)	(.)
treat=1 # placebo5=1	801.6	0	0	0
	(1253.8)	(.)	(.)	(.)
Rainfall			-9.865*	-12.27*
			(5.980)	(6.294)
Tavg			-4448.5	-4454.0
			(2981.0)	(2981.0)
Covid				-0.0298
				(0.0243)
Constant	77432.3***	77432.3***	171423.6***	171998.4***
	(504.8)	(504.6)	(62689.5)	(62690.9)
R-squared	0.04	0.04	0.04	0.04
Observations	56,753	56,753	56,753	56,753
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

Note: Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.3 Average Consumption Group: Subsample Analysis (P5-P75)

For the validation of our findings, we check our main results with different sub-sample analyses. We analyze water use patterns of households consisting of 5^{th} percentiles to 75^{th} percentiles of water consumption. A total of 464 households in the treatment areas and 381 households in the control area are observed over 19 months. Table 7 shows the OLS regression results for the dataset consisting of data from the 5th percentile to the 75th percentile. The results show that for the average consumer group (mean consumption of 26706 liters per household per month), the monthly water consumption of domestic households increased by 3215 liters (12% of the mean consumption) due to policy changes. The results are statistically significant at a 1% level, considering all the fixed effects and controls in the model.

Table 7: *OLS Regression Results for Average Consumption Group (Subsample P5 to P75)*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
treatXpost	2805.6***	3440.3***	3358.8***	3214.5***
	(315.9)	(369.0)	(444.0)	(447.8)
Rainfall			0.0437	-1.944
			(2.806)	(2.921)
Tavg			650.4	849.1
			(1498.6)	(1500.6)
Covid				-0.0316**
				(0.0129)
Constant	23955.5***	26377.0***	12963.0	9266.6
	(318.5)	(377.1)	(31233.4)	(31264.8)
R-squared	0.03	0.03	0.03	0.03
N	16,055	16,055	16,055	16,055
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

Note: Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.4 Higher Consumption Groups: Subsample Analysis (P75-P95)

Further, we check for the higher consumer groups (mean consumption of 140790 liters per household per month) consisting of monthly water consumption from the 75th to 95th percentiles of our main dataset. We analyze water use patterns over 19 months for a total of 450 households in the treatment areas and 13 households in the control area. Table 8, Column 4 show the OLS regression results considering all the fixed effects and the controls. The results show an increase of 16525 liters (around 12% of the mean) in water consumption due to the policy change, which is almost five times higher than our primary sample OLS regression results and the average consumer group. The regression result is statistically significant at a 1% level and indicates that at a subsidized low water price, higher consumer groups are not responding to the price increase, which is consistent with our findings. So, water prices should be optimally increased to make it an effective tool for demand control in the megacity of Dhaka. Moreover, we find a large change in water consumption for changes in temperature among the higher consumer group, though the results are marginally significant at the 10% level.

Table 8: *OLS Regression Results for Higher Consumption Groups (Subsample P75 to P95)*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
treatXpost	14612.3^{***}	16009.9^{***}	16334.0^{***}	16524.9^{***}
	(3899.6)	(4542.9)	(5465.6)	(5514.1)
Rainfall			41.99	44.62
			(34.55)	(35.97)
Tavg			35045.8^{*}	34783.0^{*}
			(18448.7)	(18476.9)
Covid				0.0418
				(0.159)
Constant	123891.5^{***}	131412.5^{***}	-610498.6	-605815.3
	(1305.2)	(4602.7)	(390991.3)	(391419.8)
R-squared	0.05	0.06	0.06	0.06
N	8,797	8,797	8,797	8,797
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

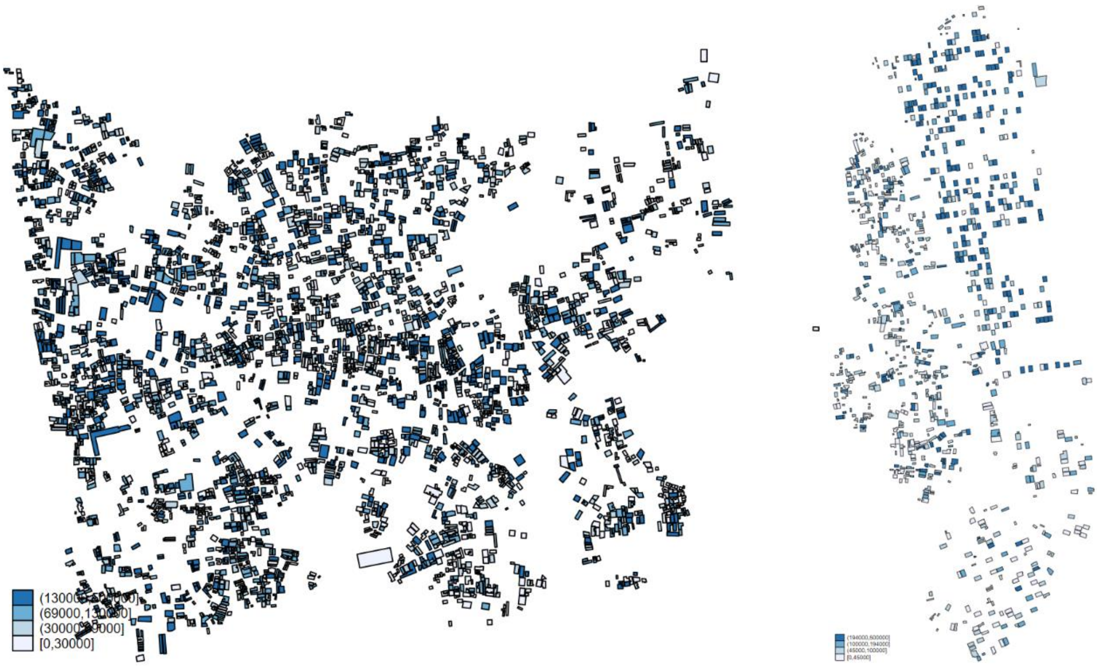
Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.5 Different Treatment Area-Based Subsample Analysis (P5-P95)

Additionally, our primary treatment group is divided into two principal regions. One location is Khilkhet (DMA-909), and another is the Nikunjo region (DMA-910). Socio-economic disparities may exist among these areas. Figure 10 shows the household intensity and consumption pattern in both areas.

Figure 10: *Household Intensity and Water Consumption Pattern in a) Khilkhet b) Nikunjo Area*

(a) *(b)*



We check for both areas to see if there are any interesting findings to support our claim. We analyze water use patterns over 19 months for a total of 1763 households in the Khilkhet (DMA-909) compared with 704 households in the control area. Table 9 shows the OLS regression results for the Khilkhet area. The results show that the increase in water tariff results in an increase in water demand by 5416 units, which is higher than the main OLS regression results and statistically significant at 1% level. The effect of the COVID-19 pandemic is negative and statistically significant, but the magnitude is small for the Khilkhet area. However, the effect of temperature and rainfall is insignificant.

Table 9: *OLS Regression Results for Subsample P5 to P95 for DMA-909*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
treatXpost	5370.8***	5630.3***	5633.9***	5416.5***
	(586.5)	(685.9)	(825.4)	(832.6)
Rainfall			-1.157	-4.152
			(5.217)	(5.432)
Tavg			-1059.3	-759.9
			(2785.9)	(2789.9)
Covid				-0.0476**
				(0.0240)
Constant	53278.1***	70569.4***	92747.8	87271.0
	(536.7)	(726.7)	(58446.2)	(58509.7)
R-squared	0.05	0.05	0.05	0.05
N	46,873	46,873	46,873	46,873
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

Note: Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10 shows the OLS regression results for the Nikunjo area (DMA-910) based on 520 treated households with the same 704 control households over the study period. We found the effects of the policy change on water consumption is not statistically significant at a 5% significance level. So, we can say that our main intuitive finding is that an increase in water price at a low water tariff situation increases the water demand in megacities like Dhaka. It is difficult to generalize these findings to other megacities as the other meteorological and other factors might be different in different megacities.

Table 10: *OLS Regression Results for Subsample P75 to P95 for DMA 910*

Variables	Consumption (1)	Consumption (2)	Consumption (3)	Consumption (4)
treatXpost	1085.0	-1040.4	-2231.2**	-1971.1*
	(756.0)	(882.8)	(1062.1)	(1071.4)
Rainfall			-20.00***	-16.42**
			(6.714)	(6.990)
Tavg			-8917.9**	-9275.9***
			(3584.9)	(3590.0)
Covid				0.0570*
				(0.0309)
Constant	47055.5***	64778.8***	251028.7***	257772.6***
	(757.2)	(843.8)	(74344.9)	(74431.1)
R-squared	0.03	0.03	0.03	0.03
N	23,256	23,256	23,256	23,256
Household FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Region-Month FE	No	Yes	Yes	Yes

Note: Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6. Discussions and Limitations

Although Bangladesh met its Millennium Development Goals (MDGs) of reducing the population lacking access to improved drinking water sources three years early and demonstrated significant advancements in sanitation, progress towards attaining SDG-6 remains challenging. The World Bank (2022) reports that 98% of the population has access to at least basic drinking water services, 59% utilizes safely managed drinking water services, 31% employs safely managed sanitation services, and 59% has access to at least basic sanitation services. Regrettably, Bangladesh's water stress level or withdrawal intensity is 5.72, indicating a significantly high status of groundwater extraction to meet the country’s water demand (World Bank, 2022). This signifies the nation's strain on its water resources, highlighting the challenge to the sustainability of its water usage and underscoring the necessity for appropriate supply and demand management strategies. Moreover, Bangladesh faces a significant groundwater attenuation problem due to extensive extraction, rapid population growth, urbanization, and inadequate regulation. Only 10% of the population has access to piped water. Out of 329 municipalities, only 151 have basic systems, but these serve a limited population. Issues include maintenance, quality, connectivity, operational costs, and service standards. Additionally, 20% of urban dwellers face arsenic contamination and 55% face E. coli contamination. Technical proficiency in piped water supply and fecal sludge control is lacking. Municipalities need assistance to manage water and sanitation systems efficiently, strengthen their operational and financial frameworks, and implement demand management policies.

In several literatures, water pricing is an established method for managing water consumption in urban areas. In the context of Dhaka city, we observed a rising demand for water in residential families. This is because the tariff structure does not represent the actual cost of water production. Furthermore, under the UVC tariff system, there are no restrictions on excessive usage, leading to the normalization of water waste among users, particularly those with high consumption rates. This study emphasizes that subsidized uniform volumetric rate fails to prove as an effective policy to control water demand, especially among high consumer groups. This study can be replicated to municipalities across the country. Most of the municipalities are using flat rate charge due to the shortage of water meters. Moreover, most of the tariff in municipalities are not compatible with the production cost of the water. So the government is also losing lot of revenues. Though water is a valuable resource, the people of the municipalities care less due to the low water tariff. Due to a lack of consciousness, they are unaware of the fact that the one drop of water they are wasting could save others' lives.

Moreover, landlord-tenant disputes constitute a significant concern in Dhaka City. In most realistic scenarios, the renter remits a predetermined monthly payment to the landlord, who subsequently covers the water bill. Since the consumers do not directly pay the water bill but rather a consolidated lump sum, they are indifferent to the entire water bill. This issue occurs due to the absence of individual meter systems for each flat.

Block tariff is a mechanism to uphold the three pillars of IWRM: economic efficiency, environmental integrity, and equity in developed nations. In Dhaka City, which is characterized by significant income inequality, the lower tariff block could be improved to align with fundamental water requirements. Subsequently, additional blocks could be augmented to enhance the accurate appraisal of water resources. Although the prior water master plan of DWASA proposed a block tariff, it was not adopted by DWASA. In the results section, we observe that among the high consumer group, a price rise of 1 BDT corresponds to a monthly average consumption increase of 22,952 liters, indicating that high users are indifferent to this minimal price change and, therefore, augment their water usage.

Our study found the insignificant influence of rainfall and temperature on average monthly water consumption. This might be due to the seasonal characteristics of Dhaka City. In Figure 5, we observed that the city faces higher rainfall during hot weather. Moreover, as there are no systematic rainwater harvesting facilities in Dhaka City, so the results look consistent. Household-level rainwater harvesting systems and groundwater recharge systems could greatly help increase the household's self-sufficiency and are also important to environmental sustainability.

In a developing nation such as Bangladesh, the societal viewpoint about water is that it is a fundamental right, with less awareness of the prudent utilization of this precious resource. In a metropolis like Dhaka, implementing preventive measures such as fostering public awareness regarding appropriate water usage, conducting community-based focus group meetings, utilizing information technology to establish social agreement, and adopting water-saving technologies might significantly mitigate water wastage and conserve water resources.

7. Conclusion

Water pricing is the ultimate stage of water resource management. Numerous literary works have shown evidence supporting the efficacy of water prices as a policy tool for managing water demand and ensuring cost-effectiveness. However, in Dhaka, where water prices are heavily subsidized and dependent on a complex billing structure, the marginal increase in water costs leads to a slight rise in water consumption in the short term. When the cost of water is low and subsidized, raising the price may not be an effective strategy for managing demand. Therefore, it is recommended that non-pricing techniques, such as increasing awareness, be encouraged to ensure effective demand-side management. Provisionally, DWASA adjusts the water price from April to July each year, aligning with the drought period. Transferring the period of price adjustment to the winter season can assist in managing demand during the drought periods.

Moreover, this empirical study proposes that water pricing should be optimized based on the cost of water production to control water demand in megacities effectively. Using a block tariff system could be a more practical approach in Dhaka to regulate the excessive water use by high-volume users. This system would charge lower rates for lower levels of water usage and higher rates for higher usage. Additionally, it may be beneficial to concentrate on implementing an area-based water tariff system targeted explicitly towards the low-income community in Dhaka city, given the significant disparities in income levels. DWASA is planning to switch to an area-based tariff. This study reveals that a price increase resulted in higher water demand. Therefore, DWASA should consider this rapid surge in demand while implementing the new price system.

Finally, a proper evaluation of the existing tariff system is required to capture the behavioral mechanism of water consumers' consumption due to price increases and develop a new tariff system. This study could assist water utility managers in incorporating several aspects, such as meteorological and seasonal variations, exogenous shocks like COVID-19, and urbanization factors, into practical demand projections. Due to insufficient data, this study needs to consider household income status and age demographics as factors affecting water usage in Dhaka City. However, additional research is required to investigate these issues and thoroughly comprehend water use patterns in megacities.

8. Future Research Plan

In addition to robust statistical data, field surveys remain significant for obtaining factual results. Consequently, for forthcoming research endeavors, several recommendations include the acquisition of primary data from water management specialists, WASA officials, and trainees, employing DDD, and incorporating additional variables in the econometric model such as household income, urbanization factors, and groundwater levels, as well as conducting analyses at the district and city level in Bangladesh.

References

Andres, L., Espineira, G., Joseph, G., Sember, G., & Thibert, M. (2020). *Estimating the magnitude of water supply and sanitation subsidies*. The World Bank.

Arfanuzzaman, M., and Rahman, A. A. (2017). Sustainable water demand management in the face of rapid urbanization and groundwater depletion for social-ecological resilience building. *Global Ecology and Conservation*, *10*, 9–22. https://doi.org/10.1016/j.gecco.2017.01.005

Asim, S., & Lohano, H. D. (2015). Households' willingness to pay for improved tap water services in Karachi, Pakistan. *The Pakistan Development Review*, 507-524.

BBS. (2023). Population and Housing Census 2022, National Report (Volume I), Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning. https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/b343a8b4_956b_45ca_872f_4cf9b2f1a6e0/2024-01-31-15-51-b53c55dd692233ae401ba013060b9cbb.pdf

BBS. (2024). Socio-Economic and Demographic Survey 2023, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning. http://nsds.bbs.gov.bd/storage/files/1/SEDS_2023_Report.pdf

Bennear, L. S., Lee, J. M., & Taylor, L. O. (2013). Municipal rebate programs for environmental retrofits: An evaluation of additionality and cost-effectiveness. *Journal of Policy Analysis and Management*, *32*(2), 350–372. https://doi.org/10.1002/pam.21692

Borusyak, K., Jaravel, X., & Spiess, J. (2024). Revisiting event-study designs: robust and efficient estimation. *Review of Economic Studies*, rdae007. https://doi.org/10.1093/restud/rdae007

Brelsford, C., & Abbott, J. K. (2021). How smart are 'water smart landscapes'?. *Journal of Environmental Economics and Management*, *106*, 102402. https://doi.org/10.1016/j.jeem.2020.102402

Chang, Y., Kwon, K. D., Kim, D. W., Kim, M. K., & Kim, M. J. (2023). Subsidy for Water Savings During 2015 Drought in Korea. *Available at SSRN 4474601*.

Chesnutt, T. W., Pekelney, D., & Spacht, J. M. (2019). Water Conservation and Efficient Water Rates Produce Lower Water Bills in Los Angeles. *J. Am. Water Work. Assoc*, *111*, 24-30.

Chowdhury, M. Z. A. (2012). *Resource optimization for Dhaka city water supply system using WEAP model* (MSc Thesis (WRD)). Bangladesh University of Engineering and Technology, Dhaka.

Cook, B. I., Ault, T. R., & Smerdon, J. E. (2015). Unprecedented 21st century drought risk in the American Southwest and Central Plains. *Science Advances*, *1*(1), e1400082. https://doi.org/10.1126/sciadv.1400082

Cooper, B., Burton, M., & Crase, L. (2011). Urban water restrictions: Attitudes and avoidance. *Water Resources Research*, *47*(12). https://doi.org/10.1029/2010WR010226.

De Oliver, M. (1999). Attitudes and inaction: A case study of the manifest demographics of urban water conservation. *Environment and Behavior*, *31*(3), 372-394. https://doi.org/10.1177/00139169921972155

Diffenbaugh, N. S., Swain, D. L., & Touma, D. (2015). Anthropogenic warming has increased drought risk in California. *Proceedings of the National Academy of Sciences*, *112*(13), 3931-3936. https://doi.org/10.1073/pnas.1422385112

DWASA. (2014). *Water Supply Master Plan for Dhaka City*. Ministry of Local Government, Rural Development and Co-operatives.

https://dwasa.portal.gov.bd/sites/default/files/files/dwasa.portal.gov.bd/page/c0a3b947_9ad9_429a_8a3f_e320e33fea06/2021-01-17-16-51-f23ad05cc0f676fe25cca345e2def230.pdf

DWASA. (2024). *Annual Report 2022-2023,* 46. Dhaka Water Supply and Sewerage Authority. https://dwasa.org.bd/site/page/a87b7dc4-6139-4da2-b1ef-bf5960b234d6

Eckstein, D., Künzel, V., & Schäfer, L. (2021). *The global climate risk index 2021*. Bonn: Germanwatch.

Ferraro, P. J., Miranda, J. J., & Price, M. K. (2011). The persistence of treatment effects with norm-based policy instruments: evidence from a randomized environmental policy experiment. *American Economic Review*, *101*(3), 318-322. https://doi.org/10.1257/aer.101.3.318

Ferraro, P. J., & Price, M. K. (2013). Using nonpecuniary strategies to influence behavior: Evidence from a large-scale field experiment. *Review of Economics and Statistics*, *95*(1), 64–73. https://doi.org/10.1162/REST_a_00344

Haque, M. M., Hagare, D., Rahman, A., & Kibria, G. (2014). Quantification of water savings due to drought restrictions in water demand forecasting models. *Journal of Water Resources Planning and Management*, *140*(11), 04014035. https://doi.org/10.1061/(asce)wr.1943-5452.0000423

Inman, D., & Jeffrey, P. (2006). A review of residential water conservation tool performance and influences on implementation effectiveness. *Urban Water Journal*, *3*(3), 127–143. https://doi.org/10.1080/15730620600961288

Kashem, S., & Mondal, M. S. (2022). Development of a water-pricing model for domestic water uses in Dhaka city using an IWRM framework. *Water*, *14*(9), 1328. https://doi.org/10.3390/w14091328

Kenney, D. S., Klein, R. A., & Clark, M. P. (2004). Use and effectiveness of municipal water restrictions during drought in Colorado 1. *JAWRA Journal of the American Water Resources Association*, *40*(1), 77–87. https://doi.org/10.1111/j.1752-1688.2004.tb01011.x

Kılıç, Z. (2020). The importance of water and conscious use of water. *International Journal of Hydrology*, *4*(5), 239–241. https://doi.org/10.15406/ijh.2020.04.00250

Macian-Sorribes, H., Pulido-Velazquez, M., & Tilmant, A. (2015). Definition of efficient scarcity-based water pricing policies through stochastic programming. *Hydrology and Earth System Sciences*, *19*(9), 3925–3935. https://doi.org/10.5194/hess-19-3925-2015

Martins, R., & Fortunato, A. (2007). Residential water demand under block rates–a Portuguese case study. *Water policy*, *9*(2), 217-230. https://doi.org/10.2166/wp.2007.004

Meran, G., Siehlow, M., & von Hirschhausen, C. (2021). *The economics of water: Rules and institutions* (p. 301). Springer Nature. https://doi.org/10.1007/978-3-030-48485-9

Morera, M. C., Monaghan, P. F., & Dukes, M. D. (2019). Evolving response to smart irrigation controllers in high water-use central Florida homes. *AWWA Water Science*, *1*(1), e1111. https://doi.org/10.1002/aws2.1111

Moshfika, M. (2021). Development of adaptation strategies to groundwater level declination in Dhaka city.

Mycoo, M. (1997). Water provision improvements: A case study of Trinidad. Willingness to pay, pricing policy, cost reduction and institutional strengthening.

Nations, U. (2015). Transforming our world: The 2030 agenda for sustainable development. *New York: United Nations, Department of Economic and Social Affairs*, *1*, 41.

Olmstead, S.M. (2010). The economics of managing scarce water resources. *Review of Environmental Economics and Policy 4*(2), 179–198. https://doi.org/10.1093/reep/req004

Olmstead, S. M., & Stavins, R. N. (2009). Comparing price and nonprice approaches to urban water conservation. *Water Resources Research*, *45*(4). https://doi.org/10.1029/2008WR007227

Palazzo, J., Liu, O. R., Stillinger, T., Song, R., Wang, Y., Hiroyasu, E. H., ... & Tague, C. (2017). Urban responses to restrictive conservation policy during drought. *Water Resources Research*, *53*(5), 4459-4475. https://doi.org/10.1002/2016WR020136

Qureshi, A. S., Ahmed, Z., & Krupnik, T. J. (2014). Groundwater management in Bangladesh: An analysis of problems and opportunities.

Renwick, M. E., & Archibald, S. O. (2018). Demand side management policies for residential water use: who bears the conservation burden?. In *Economics of Water Resources* (pp. 373-389). Routledge.

Roy, K., Bari, Q. H., Mostakim, S., & Argha, D. B. P. (2019). Water supply history of Khulna City. In *6th International conference on integrated solid waste & faecal sludge management in South-Asian Countries, KUET, Khulna, Bangladesh* (pp. 1-13).

Russell, S., & Fielding, K. (2010). Water demand management research: A psychological perspective. *Water resources research*, *46*(5). https://doi.org/10.1029/2009WR008408

Schleich, J., & Hillenbrand, T. (2009). Determinants of residential water demand in Germany. *Ecological economics*, *68*(6), 1756-1769. https://doi.org/10.1016/j.ecolecon.2008.11.012

Seo, G., & Cho, Y. (2020). Exploring effects of water price on residential water demand for water management. *The Journal of Industrial Distribution & Business*, *11*(10), 39–48. https://doi.org/10.13106/jidb.2020.vol11.no10.39

Sisser, J. M., Nelson, K. C., Larson, K. L., Ogden, L. A., Polsky, C., & Chowdhury, R. R. (2016). Lawn enforcement: How municipal policies and neighborhood norms influence homeowner residential landscape management. *Landscape and Urban Planning*, *150*, 16-25. https://doi.org/10.1016/j.landurbplan.2016.02.011

Stoutenborough, J. W., & Vedlitz, A. (2014). Public attitudes toward water management and drought in the United States. *Water Resources Management*, *28*, 697-714. https://doi.org/10.1007/s11269-013-0509-7

Tsai, Y., Cohen, S., & Vogel, R. M. (2011). The Impacts of Water Conservation Strategies on Water Use: Four Case Studies 1. *JAWRA Journal of the American Water Resources Association*, *47*(4), 687-701. https://doi.org/10.1111/j.1752-1688.2011.00534.x

Visser, M., Booysen, M. J., Brühl, J. M., & Berger, K. J. (2021). Saving water at Cape Town schools by using smart metering and behavioral change. *Water Resources and Economics*, *34*, 100175. https://doi.org/10.1016/j.wre.2020.100175

Whittington, D. (2011). Pricing water and sanitation services. In P. Wilderer (Ed.), *Treatise on Water Science* (pp. 79–95). Oxford: Elsevier.

Wichman, C. J. (2014). Perceived price in residential water demand: Evidence from a natural experiment. *Journal of Economic Behavior & Organization*, *107*, 308-323. https://doi.org/10.1016/j.jebo.2014.02.017

Wichman, C. J., Taylor, L. O., & Von Haefen, R. H. (2016). Conservation policies: Who responds to price and who responds to prescription? *Journal of Environmental Economics and Management*, *79*, 114-134. https://doi.org/10.1016/j.jeem.2016.07.001

World Bank. (2022). *SDG Indicators Microdata Bank*. Bangladesh: World Bank. Retrieved from: https://data.worldbank.org/country/bangladesh?view=chart