

Addressing Water Scarcity in Urban Tanzania: Household Preferences, Behavioural Interventions, and Technological Adoption

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Declaration

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Abstract

Access to safe drinking water remains a critical challenge in developing countries. As of 2022, only 31% of the population uses safely managed drinking water, while the rest rely on basic, unimproved, or surface water sources. This issue is particularly severe in Dar es Salaam, Tanzania's most populous economic hub, where frequent droughts, outdated infrastructure, insufficient investments, rapid urbanisation, and population growth exacerbate persistent water shortages. Between 2019 and 2023, water demand in Dar es Salaam increased by 16%, while daily production declined by 11.72%. The escalating water scarcity forces households to rely on unsafe sources, raising the risk of contamination. Addressing these challenges requires improved water conservation and reliable supply systems. This thesis examines water-related issues in Dar es Salaam from a household demand perspective through three studies: (i) households' preferences and willingness to pay for reliable water supply, (ii) the impact of information campaigns on water-saving behaviours, and (iii) the adoption of water-saving technologies. Each study is presented in a separate chapter.

The first study (Chapter two) examines household preferences and willingness to pay for reliable water service using a choice experiment design, incorporating attributes like frequency, water quality, pressure, time of service and cost. The study reveals preference heterogeneity and utilises a random parameter logit model to capture this diversity. Findings show a preference for high-quality, drinkable tap water with good pressure, available either in the morning, afternoon or at night. The study suggests policy options to focus on improving tap water quality and pressure.

The second study (Chapter 3) assesses the impact of an information campaign on water-saving behaviours using a randomised control trial involving 1,600 households, split equally into treatment and control groups. The treatment group received water usage reports for six months, comparing their consumption to the neighbourhood median. The difference-in-difference analysis indicates a reduction in water consumption by 7.65% (1.49m^3) during the campaign and 8.18% (1.6m^3) to 11.18% (2.30m^3) in the five months following the intervention. The study underscores the effectiveness of information campaigns in promoting water-saving behaviours and recommends their use by local authorities.

The third study (Chapter 4) investigates the adoption of water-saving technologies, focusing on greywater technology. Data from 962 households is analysed using Poisson and logit models to identify factors influencing adoption. The analysis shows factors such as age, education, income, social group membership, and awareness are among the factors influencing the adoption of water-saving technologies. Further, the study uses a choice experiment and reveals preferences and willingness to pay for greywater technologies with longer lifespans, minimal contamination, and low odour, although high costs deter adoption. Marginal willingness to pay ranges from TZS599,895 (US\$260) and TZS714,890 (US\$310) for technologies with different attributes, representing 9% to 11% of the average annual income. The study recommends government incentives, such as subsidies and tax reductions, and campaigns to address misinformation and encourage technology adoption.

These studies highlight critical areas for improving water access and conservation in Dar es Salaam, emphasising the need for reliable water services, effective information campaigns, and supportive measures for adopting water-saving technologies.

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Dedication

This dissertation is dedicated to my family and friends, whose faith in me has been a source of strength and motivation. Thank you all for believing in me and for being part of this journey.

List of Acronyms

AIC	Akaike Information Criterion
ASC	Alternative Specific Constant
ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
BIC	Bayesian Information Criterion
CL	Conditional Logit
CVM	Contingent Valuation Method
DAWASA	Dar es Salaam Water and Sanitation Authority
DiD	Difference-in-Difference
DSM	Demand-Side Management
EWURA	Energy and Water Utilities Regulatory Authority
EfD	Environment for Development
FGD	Focus Group Discussions
G-MNL	Generalised Multinomial Logit
IIA	Independence of Irrelevant Alternatives
IID	Independent and Identically Distributed
LR	Likelihood Ratio
LC	Latent Class
LSE	London School of Economics and Political Science
mWTP	Marginal Willingness to Pay

OLS	Ordinary Least Squares
PhD	Doctoral of Philosophy
RCT	Random Control Trial
RPL	Random Parameter Logit
RUM	Random Utility Model
SCM	Social Comparison Messages
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
TZS	Tanzanian Shillings
UCT	University of Cape Town
UNICEF	United Nations Children's Fund
USA	United States of America
WHO	World Health Organisation
WSSA	Water and Sanitation Authority
WTP	Willingness to Pay

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Chapter 1: Introduction

1.1 Background

Water is an important resource crucial for sustaining life and driving economic activities and it holds immense significance for both households and industries. Its important role is evident in supporting livelihoods as it is used for drinking, cooking, hygiene and various household purposes. The importance of water has been acknowledged by scholars and policymakers, as evidenced by its inclusion in the 2030 Development Agenda on Sustainable Development Goals (SDGs) (Weststrate et al., 2019). This is reflected in SDG number 6 which aims to “*ensure availability and sustainable management of water and sanitation for all*” (United Nations, 2023a). This is further captured in SDG target 6.1, which states: “*By 2030, achieve universal and equitable access to safe and affordable drinking water for all*” (United Nations, 2023a). The adoption of this goal by United Nations member countries represents a significant global effort to reduce the problem of unsafe water for drinking.

In line with the 2030 development goals, developing countries have made some progress in water access and use over the past two decades. Between 2000 and 2022, the global population using safe drinking water increased from 61% to 73%, though approximately one in three people still lack access to safe drinking water (United Nations Children’s Fund (UNICEF) & World Health Organization (WHO), 2023). Although global access to safe and reliable water has improved, the sub-Saharan Africa (SSA) region still faces significant challenges. For instance, in 2022, only about 31% of the population has access to safely managed drinking

water sources.¹, while 65% had access to at least a basic water source. The remaining population relied on limited, unimproved or surface water for drinking (UNICEF and WHO, 2023). This level of access to safely managed water sources for drinking is not desirable. Limited access to safely managed water sources for drinking is problematic, as the consumption of unsafe water from sources such as surface water and open wells can lead to contamination, resulting in illness and even death (Fuente et al., 2020).

The challenges of access to safe water in the SSA region can be attributed to many factors including water scarcity induced by climate change. Over the past three decades, the region has faced significant climate change, resulting in severe droughts that have reduced water availability in dams and rivers, which are vital water sources for municipalities. Also, climate change and the associated floods in the region damage water infrastructure posing challenges for the distribution of safe (municipal) water. Scholars argue that water authorities in developing countries often supply water at below cost, making it difficult for them to maintain and upgrade water infrastructure and properly treat water to meet the expected standards of quality and quantity (Amoah & Moffatt, 2021; Fuente et al., 2021; Whittington et al., 2015). This challenge persists because governments in developing countries face limited budgets to upgrade and maintain water infrastructure, including new or infrastructure that is either outdated or destroyed by natural disasters. Moreover, in SSA inadequate water infrastructure is also associated with high rates of water service disruptions and leakages (Global Water Partnership, 2023). Hence, the supply of municipal water, which is the safest and reliable water available to many people in the region, is effectively reduced.

¹ This is very low compared to other regions. For instance, access to safely managed water was more than 99% in New Zealand, 93% in Central and Southern Asia and 99% in Northern America.

The supply-related challenges co-exist with the rising demand for water in the region, attributable to high rates of urbanisation and growing populations. Boretti and Rosa (2019) also noted a general increase in water demand, projecting that it will rise by 55% by 2050, with approximately 40% of the world's population expected to live in areas of severe water scarcity by that time. The highlighted supply and demand issues imply the existence of excess demand for municipal water in the SSA region, where the demand for municipal water exceeds its supply, leading people to resort to unsafe sources.

Tanzania, a developing country in SSA, faces similar water challenges as those mentioned above. The Ministry of Water is responsible for overall policy setting, coordination, monitoring, evaluation and regulation of water supplies through the Energy and Water Utilities Regulatory Authority (EWURA). Water is supplied by 26 Regional Water and Sanitation Authorities (RWSSA) under the supervision of EWURA, with each authority serving its own designated areas. For example, the Dar es Salaam Water and Sanitation Authority (DAWASA) covers Dar es Salaam, Kibaha, Bagamoyo, Kisarawe, Chalinze and Mkuranga. Each Authority maintains its own pricing approved by EWURA, but prices range from TZS300/m³ to TZS2500/m³ with DAWASA charging TZS1663/m³ (EWURA, 2024). Also, these authorities charge uniform prices within their municipalities for domestic water and use postpaid meters across all customer categories.

Access to safe water for households in Tanzania is increasingly threatened by rising levels of water scarcity. According to Kabote (2024) over 24 million people in Tanzania are impacted by the country's water crisis. As a result, many people do not practice proper sanitation. More

specifically, about 51% of the population lack access to at least basic water sources² with 19% of the urban population lacking access to safe and improved water sources (UNICEF and WHO, 2023)

Although water remains scarce, there has been notable progress over an improvement in the past two decades. In Tanzania, access to at least basic water services increased from 4% in 2000 to 38% in 2015 and 49% in 2022 (UNICEF and WHO, 2023). Urban areas saw a rise from 65% in 2000 to 78% in 2015 and 81% in 2022 (UNICEF and WHO, 2023). In rural areas, access to safe water improved from 51% to 61% over the same period. While these statistics indicate progress, they also highlight that access to safe water remains a challenge, which underscores the difficulty of achieving the Sustainable Development Goals (SDGs). Furthermore, Tanzania face water scarcity challenge driven by both supply-side and demand-side factors. On the demand side, urbanisation at a rate of 5.4% and a growing population are contributing to increasing the water demand (Raphael et al., 2023; World Bank, 2024). On the supply side, climate change has led to the more frequent occurrence of extreme events such as drought and floods. Recent droughts, including those between 2020 and 2023, have significantly impacted water supply. For instance, the supply from the Ruvu River's dropped from 466 million litres per day in 2022 to about 30 million litres per day (Sindato & Mboera, 2023).

In addition to droughts, floods also threaten the water supply system as they destroy water infrastructure like transmission pipes and water treatment infrastructure (Smiley & Hambati,

² These sources include piped supplies (tap water in the dwelling, yard, or plot and public taps or standpipes) and non-piped supplies (such as boreholes/tubewells, protected wells/springs, rainwater, packages water, water kiosks and delivered water including tanker trucks and small carts/tank/drum)

2019). Over the past 40 years floods have constituted about two-thirds of all natural disasters increasing from about one flood per year between 1980 and 2010 to about two floods per year between 2011 and 2022 (Fang et al., 2023). Due to financial challenges faced by water authorities, the restoration of water supply systems is often delayed after floods, resulting in a lack of access to safe water for households. Msongaleli et al. (2023) noted that the water infrastructure in Tanzania is old and dilapidated making it vulnerable to destruction from floods and strong water pressure. Additionally, water authorities face a lack of sufficient funding for infrastructure rehabilitation

The Global Water Partnership (2023) highlighted the challenges facing water supply in Tanzania, noting that the achievement of the 2030 SDGs related to water is jeopardised by inadequate financial resources for water investments, insufficient conservation and protection measures against climate change, and a lack of capacity to manage water resources. These challenges are also present in Dar es Salaam, a major economic hub with a population of approximately 5.3 million people (Tanzania Bureau of Statistics, 2022). The city depends on three surface water treatment plants, namely the Upper and Lower Ruvu plants, both situated on the Ruvu River, and the Mtoni plant situated on the Kizinga River. Approximately 50% of Dar es Salaam water demand is met through piped water from these treatment plants, while the remaining portion is supplied by groundwater. The proliferation of unregulated boreholes within the city has also been documented. However, inadequate monitoring of water quality and extraction persists, leading to significant outbreaks of waterborne diseases, particularly during the rainy season. This situation has further intensified concerns about the long-term water supply (Rugemalila & Gibbs, 2015).

Furthermore, Dar es Salaam has been experiencing significant water shortages while concurrently facing rapid urbanisation and population growth (Dakyaga et al., 2024). The city's water infrastructure, which dates to colonial times, has seen minimal improvements, leading to ongoing challenges in providing adequate water services. The trend in municipal water demand³ and supply for Dar es Salaam is illustrated in Figure 1.1. Water demand is defined by the municipality as the amount of water required by users to satisfy their needs.

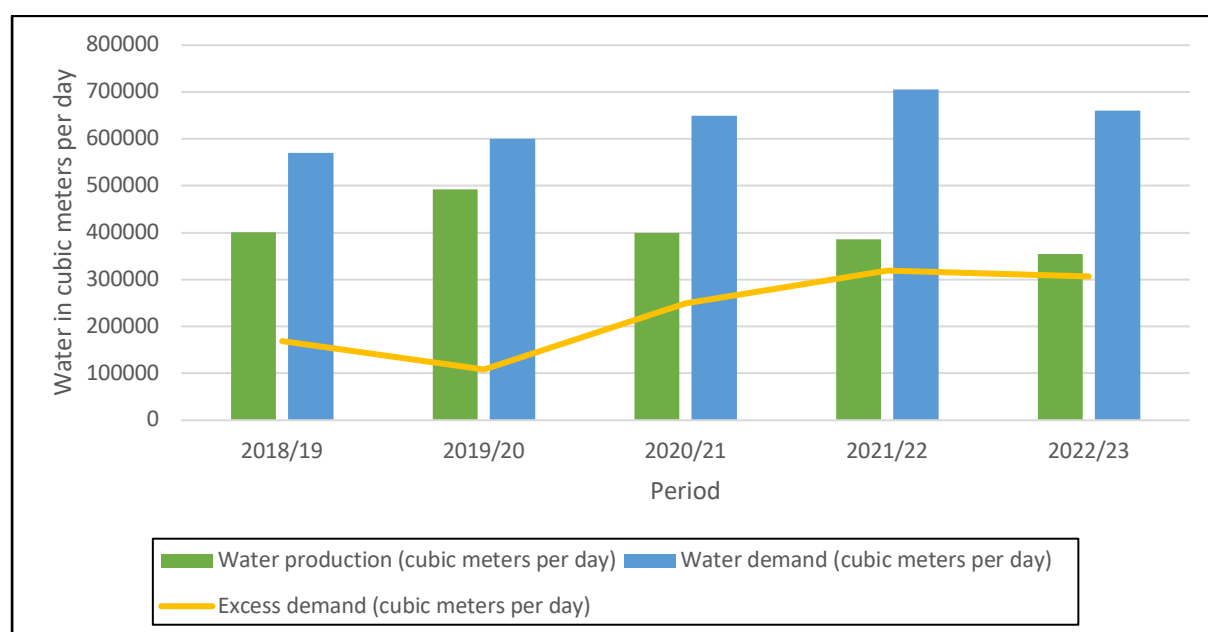


Figure 1.1: Municipal Water demand and supply in Dar es Salaam.
Source: EWURA (2024)

Figure 1.1 shows the water production and demand for Dar es Salaam over 5 years. Daily water demand increased by 16% from 570,000 m³ in the 2018/19 period to 661,000m³ in the 2022/23 period. In contrast, daily water production declined by 11.72% from 401,000m³ to 354,000m³ over the same period as illustrated in Figure 1.1, this means Dar es Salaam has been facing

³ Water demand is determined by the municipality in a 12-step process that consider per capital consumption rates based on survey data and population levels, among other issues. The process of estimating demand is illustrated in the 2020 Design, Construction Supervision, Operation and Maintenance (DCOM) manual volume 1 available at: https://design.maji.go.tz/index.php/Main_Page.

water shortage as the excess demand increased by 81.66% between 2018/19 to 2022/23. The water shortages illustrated in Figure 1.1 are due to the factors previously mentioned such as droughts and poor infrastructure. This makes it difficult for the water authority to meet the rising water demand, especially in the wake of concurrent increasing urbanisation and population growth. Several strategies are used by households to cope with the shortages, including buying from vendors and using boreholes and wells.

Literature highlights the challenges that developing countries face with water supply and advocates improvements to enhance well-being and help these countries stay on track to meet the 2030 development agenda. Several possible mechanisms to enhance the situation have been proposed. These include promoting water-saving behaviour through various strategies such as increasing water tariffs, conducting information campaigns, and encouraging households to adopt water-saving technologies by households.

Firstly, increasing tariffs enables water authorities to generate revenue which can then be used to improve infrastructure and enhance water quality. However, increased water tariffs often face public resistance and disproportionately affect low-income households, leading to reduced access to water and higher reliance on risky sources such as open wells and rivers. Understanding how much households are willing to pay for a constant water supply can be a crucial step towards determining optimal tariffs by water authorities.

Secondly, information campaigns are often regarded as alternatives to raising tariffs because they promote water conservation among households without public resistance and encourage voluntary water reduction (Lurbé et al., 2023). These information campaigns typically include the provision of tips to save water, sharing water consumption histories and delivering social

comparison messages⁴ to households, among others. The existing literature (e.g., Ferraro and Miranda (2013), Jaime Torres and Carlsson (2018), Landon et al. (2018), Brent et al. (2020), Brick et al. (2023) and Lurbé et al. (2023)) has documented the effectiveness of information campaigns in promoting water conservation behaviours among households. Yet, this literature points out that the effectiveness of information campaigns wanes off over time (Ferraro & Price, 2013).

Thirdly, technology adoption is recognised as an effective method for water conservation in both the short and long term. Various technologies can be utilised by households to save water, including high- and low-flow showerheads, dual-flush toilets, high-efficiency washing machines, rainwater harvesting systems, and greywater systems (Aina et al., 2023; Amaris et al., 2021; Thiam et al., 2021). However, very few studies have assessed greywater systems as a technology for water conservation including the preferences and willingness to pay for such a technology (Gyapong-Korsah et al., 2023). The use of greywater helps to reduce freshwater consumption by households since it can be used for carwash, toilet flushing, fire protection, green roofs, green walls, and irrigation of non-food plants. By collecting and reusing greywater, cities can remain cleaner. In urban settings, greywater is most frequently reused for toilet flushing, which has the potential to significantly lower household water consumption by as much as 30% (Mahmoudi et al., 2021). Given the effectiveness of greywater systems in promoting water conservation, it is imperative to assess their adoption as well as the preferences and willingness to pay by households.

⁴ Social comparison messages include the provision of a water consumption report to a household in comparison to a consumption level (e.g. average consumption) for a neighborhood such as a ward.

1.2 Motivation

A review of the current water supply situation in Dar es Salaam, Tanzania showed that there is a serious water scarcity situation. This is exacerbated by natural and socio-economic factors such as rapid population growth, droughts, poor water infrastructure, and urbanisation (Msongaleli et al., 2023; Raphael et al., 2023). Due to this scarcity, households experience unreliable, low tap water pressure and poor water quality which is consumed in amounts below the recommended daily thresholds of 50-100 litres per person for basic activities such as drinking, cooking, and hygiene (Howard et al., 2020). The inadequate access to safe and reliable water has significant health implications, as well as social and economic impacts at both the household and individual levels.

In terms of health, people in developing countries such as Tanzania are exposed to unsafe and unimproved water sources such as unprotected wells which are major contributors to diseases like cholera, typhoid, and diarrhoea (Whittington et al., 2015). Also, poor access to safe water compels, marginalised groups including children (and girls), to spend time fetching water for household use instead of engaging in educational activities (Cook et al., 2019). The economic impact of poor water supply includes the need to rely on costly alternatives such as water vendors who charge higher prices, disproportionately affecting the poor. Consequently, the negative effects of the water supply situation in Dar es Salaam are felt most acutely by marginalised groups such as women, children, girls, and the poor, highlighting the urgent need for improvements (Cook et al., 2019; Fuente et al., 2020).

Significant efforts have been undertaken to enhance the water supply situation in Dar es Salaam through government initiatives and collaborations with Non-Governmental Organisations. For instance, the Government of Tanzania has adopted the SDGs and national policies such as the

Water Sector Development Programmes (2006–2025) to improve the governance of water resources and ensure sustainable delivery of water and sanitation services (United Republic of Tanzania, 2022). Access to basic water sources in Tanzania upsurged from 38% in 2015 to 49% in 2022 (UNICEF and WHO, 2023). Despite this improvement, the percentage of the population in Tanzania accessing basic water services in 2022 remains lower than the average of 50% for the SSA region. The limited progress in addressing the water supply situation is constrained by inadequate budgets and frequent droughts, highlighting the need for water conservation

Against the backdrop of water supply challenges faced by the water authority and the adverse consequences of the water scarcity issue in Tanzania, water supply improvements in water supply and conservation need to be prioritised. This situation raises three key issues. Firstly, improving tap water supply improvement necessitates the need to account for households' willingness to pay for a reliable supply of water with preferred water attributes (e.g., frequency, time of service, pressure, quality, and price of water). Secondly, demand-side management approaches such as tariffs used to manage resources tend to be less effective in the long term and are associated with public resistance in developing nations like Tanzania (Dietz et al., 2009; Fielding et al., 2013). This offers an opportunity to incorporate information campaigns as a key strategy in managing water resources at the household level. Finally, to address the need for long-term water conservation, technologies such as greywater systems can be employed to recycle water for non-drinking and non-cooking household activities (Aina et al., 2023; van Vliet et al., 2021).

Empirical literature on these three issues is scarce, particularly for developing nations and Tanzania. Specifically, few studies investigate (i) household preferences and willingness to pay

for water supply improvements, (ii) the effect of information campaigns on water-saving behaviour, and (iii) the use of water-saving technologies in Tanzania. This thesis adds to the existing scholarship by advancing the understanding of how to improve water supply reliability and the development of approaches to promote water-saving behaviour among households in Dar es Salaam, Tanzania.

An investigation into preferences and willingness to pay for water supply improvements enables the thesis to augment the sparse literature by using a choice experiment valuation method. Existing studies lack consensus on preferred water supply attributes, as different studies have considered varying attributes relevant to their respective study areas. With no existing research focused on Dar es Salam, this thesis offers new contextual insights into the preferred attributes and WTP value. Furthermore, some previous studies assumed the same status quo for all attributes in choice experiment designs which may not accurately reflect real conditions. In contrast, this thesis uses individual status quo conditions, as households across the city experience differing tap water pressures, perceived water quality, frequency of supply, interludes, and supply times.

In addition, while information campaigns may be effective in promoting water-saving behaviour among households, their effectiveness varies by country and water authority (Landon et al., 2018). This thesis extends the literature by focusing on the African context, where only two studies (Brick et al., 2023; Visser et al., 2021) have evaluated the influence of information campaigns on water-saving behaviour. It introduces three new dimensions in analysis: examining a uniform pricing system instead of a block pricing system, utilising postpaid metering rather than prepaid metering, and focusing specifically on high water users rather than all water users.

Considering the growing concern over water scarcity and the imperative to conserve water, this thesis contributes to the literature on water-saving technologies by examining the adoption, preferences, and willingness to pay for greywater technology among urban households in Dar es Salaam, Tanzania. This focus tackles an important gap in the current research, which has largely been centred on developed nations. The results of this research could guide policy development, resource allocation, and targeted interventions that promote water conservation, and better use of limited water resources. Ultimately, this research is expected to lead to enhanced water management practices, greater sustainability, and increased resilience in Dar es Salaam and other urban areas.

1.3 Objectives of the thesis

In line with the research issues outlined above, this thesis has three objectives:

- i. To investigate the households' preferences and willingness to pay for reliable water supply in Dar es Salaam, Tanzania
- ii. To investigate the impact of an information campaign on domestic water-saving behaviour among urban households in Dar es Salaam, Tanzania.
- iii. To investigate the adoption, preferences and willingness to pay for water-saving technologies among urban households in Dar es Salaam, Tanzania

1.4 Thesis outline

The next three chapters address the objectives of the thesis with each objective being addressed in its chapter. The first objective is addressed in Chapter 2, the second in Chapter 3 and the

third in Chapter 4. In Chapter 2, a choice experiment is used to estimate the preferences and willingness to pay for reliable water supply improvements among urban households in Dar es Salaam, Tanzania. Chapter 3 is on a random control trial of the impact of information campaigns on water-saving behaviour among urban households in Dar es Salaam, Tanzania. Chapter 4 presents a choice experiment of the preferences and WTP for water-saving technologies among urban households in Tanzania. Chapter 5 presents a general conclusion and policy implications of the thesis.

Chapter 2: Households' Preferences and Willingness to Pay for Reliable Water Supply in Dar es Salaam, Tanzania: Evidence from a Choice Experiment Approach

Abstract

The study examines people's value for a reliable water supply in developing countries focusing on Dar es Salaam, Tanzania. It uses a choice experiment design with different attributes related to water service, such as frequency, time of service, water quality, water pressure, and costs. The assumption of preference homogeneity is tested and found to be invalid, indicating heterogeneity in preferences among respondents. To account for this, the study employs a random parameter logit model. The study finds that respondents prefer high-quality tap water that is drinkable with or without treatment, higher water pressure, and water services provided either in the morning, afternoon or night. More specifically, the study estimates the marginal willingness to pay (mWTP) for water that is drinkable with treatment at TZS250.07 (US\$0.11), and for water that is drinkable without treatment at TZS187.99 (US\$0.08). In addition, the findings indicate that households are willing to pay at least TZS367.99/m³ (US\$0.16/m³), TZS721.74/m³ (US\$0.31/m³), and TZS481.92/m³ (US\$0.21/m³) for water delivery in the afternoon, night, and morning, respectively. With respect to water pressure, the mWTP is estimated at TZS1,383.77/m³ (US\$0.60/m³) for high-pressure tap water and TZS1,128.11/m³ (US\$0.49/m³) for standard pressure tap water. These findings suggest the importance of policy options improving tap water provision, focusing on high-quality and high-pressure water services provided either in the morning, afternoon, or night.

Keywords: Water, Choice Experiment, Willingness to Pay, Random Parameter Logit, Tanzania, Dar es Salaam

2.1 Introduction

Globally, access to and use of safe and reliable water sources has raised significant concerns among policymakers and researchers over the past two decades. Between 2000 and 2022, the global population using safe drinking water increased from 61% to 73%, implying that about one in three people still lack access to safe drinking water (UNICEF and WHO, 2023). The adoption of SDGs on safe water in 2015 by United Nations member countries, which has had more significant positive effects on developing nations, represents a significant global effort to address the problem of unsafe water for drinking and its undesirable consequences. SDG 6.1 focuses on ensuring that everyone has universal and fair access to clean and affordable drinking water. Meanwhile, SDG 6.3 aims to enhance water quality by decreasing pollution, waste disposal, and the release of dangerous chemicals and substances by 2030. (United Nations, 2023a).

Even though there has been a worldwide improvement in access to potable water, households/individuals in SSA continue to face challenges in obtaining reliable sources of safe drinking water. In 2022, about 31% had access to safely managed drinking water sources, 65% had at least basic water sources, and the rest relied on limited, unimproved, or surface water for drinking (UNICEF and WHO, 2023). Poor access to safe drinking water is undesirable as it may lead to increased deaths or illness-related problems (Fuente et al., 2020). These effects predominantly impact marginalised groups, such as the poor, women and children who are highly exposed to the effects of water scarcity (Cook et al., 2019). In many parts of developing countries, children are highly exposed to medieval diseases like cholera, typhoid, and diarrhoea while girls often spend quality time for education travelling long distances to fetch water for domestic use as households seek to supplement their tap water supply (Adams et al., 2019;

Fuente et al., 2020)⁵. People living in poverty, who are connected to tap water often face a highly unreliable water supply, compelling them to depend on water vendors who charge higher prices for water whose safety is not even guaranteed. Further, due to low water pressure, the poor are forced to spend significant time collecting water. With improvements in water supply quality and reliability in SSA, the time spent hauling water could be redirected to more productive activities, such as education, childcare, wage employment, or agricultural labour. Household expenditures on water from vendors would also decrease, allowing for more spending on food security. Therefore, improving the water supply in SSA is crucial.

In SSA and other developing regions, the problem of unreliable water supply stems from water scarcity, driven by multiple factors. Climate change plays a key role, contributing to frequent droughts that reduce water levels in dams and lakes, as well as natural disasters like floods that damage water infrastructure. Additionally, governments and local authorities responsible for water supply often face budget constraints, limiting their ability to repair ageing infrastructure or invest in new water systems. This issue is exacerbated by water authorities which provide each unit of water at a price below cost, making it difficult for them to maintain and upgrade infrastructure or properly treat water to meet expected standards of quality and quantity (Amoah & Moffatt, 2021; Fuente et al., 2021; Whittington et al., 2015). The Global Commission on the Economics of Water (2023) notes that the unimproved water infrastructure is particularly problematic as it leads to frequent service disruptions and leakages. On the demand side, population growth and increasing rates of urbanisation have contributed to high demand for water to levels that public water authorities cannot meet. Boretti and Rosa (2019)

⁵ Women and girls are the most affected by distance to fetch water because of the gender norms in African settings where women are seen to be responsible for domestic work including fetching water. Hence, they spend significant time of the day hauling water sources to their homes.

estimate that water demand will rise by 55% by 2050, with approximately 40% of an anticipated portion of the global population projected to reside in regions experiencing extreme water shortages. In response, demand management measures, such as rationing tap water by limiting the hours and days of delivery, are often implemented.

The issue of reliable and improved water supply is a key concern in Tanzania. Over the past decade, efforts have focused on improving water sources and enhancing water quality through the promotion of SDGs and national policies, such as the Water Sector Development Programme. The percentage of households using safely managed water sources in Tanzania increased from 9% in 2015 to 11% in 2022 (UNICEF and WHO, 2023). This improvement in water supply and access to better water supply in Tanzania is not impressive given the 2030 SDG agenda to improve safe and affordable drinking water for all. Despite improvements in access to better water sources in Tanzania, water supply issues remain a major concern, particularly for households in urban areas. Most urban households rely on tap water, which is supplied by various regional authorities responsible for water and sanitation services, regulated by the Energy and Water Utilities Regulatory Authority (EWURA).

In Tanzania, and particularly in Dar es Salaam, these water supply issues are acute. Dar es Salaam, one of the fastest-growing cities in the world, depends heavily on the Dar es Salaam Water and Sewerage Authority (DAWASA) for household water supply. Despite DAWASA's reach, serving over six million residents, water services remain inconsistent, with frequent interruptions and concerns over water quality (Bender, 2021). Also, the quality of tap water is deemed unsatisfactory by many households who consider treating it before drinking given the health risks associated with consuming poor-quality or contaminated water. The condition in Dar es Salaam calls for an improvement in water supply and its efficient use, which can be

done with the cessation of underpricing water (Global Commission on the Economics of Water, 2023).

This study applies a choice experiment method to investigate the preferences and WTP for reliable water supply improvement in Dar es Salaam, Tanzania focusing on households using water for domestic purposes. To this end, the research question raised is, what are the attributes of water supply preferred by households using water for domestic purposes in Dar es Salaam, Tanzania and how much are they WTP for an improvement in water supply? In this context, a choice experiment is particularly useful, as it provides policymakers with insights into preferred water supply attributes and the willingness to pay (WTP) for each attribute, as well as for overall improvements in water supply (Adamowicz et al., 1998; Lancsar et al., 2017). As in any developing country, determining the WTP for reliable water supply improvement is important for Tanzania. This is because water regulatory authorities frequently encounter political pressure from both consumers and government officials to maintain low water tariffs. This pressure is intended to prevent social unrest and enhance equity. By conducting a choice experiment, authorities can gather valuable information on the minimum amount water users are willing to pay for improved water supply reliability and their preference for service attributes, which support efficient resource allocation.

The choice experiment method has been implemented in several studies to assess preferences and WTP for water supply improvements in different countries, but the context is different, and they obtained conflicting findings that are not generalisable. These studies include Adams and Vásquez (2019) in urban informal settlements in Ghana, Ahsan et al. (2021) in coastal urban areas in Bangladesh, Anteneh et al. (2019) in rural areas in Ethiopia, Uwera and Stage (2016) in rural areas in Rwanda, Ibrahim et al. (2019) in urban areas in Malaysia, Lee et al.

(2018) in rural areas in South Korea, Larue et al. (2017) in rural areas in Canada. Evidence from these studies showed that respondents have disutility in paying more for water supply improvement but the preferences for water supply attributes and WTP were different depending on the experimental design, context and methods of analysis used, among others. For example, Adams and Vásquez (2019) found that the preferred attributes by informal settlers in Ghana were management of the water authority, time of service and quality with pressure and days of service not being important. Ahsan et al. (2021) in Bangladesh however showed that the preferred attributes were pressure, days of service and quality. With a lack of consensus, a specific study for Dar es Salaam, Tanzania needs to be conducted to obtain contextual preferences. This is also the case since Dar es Salaam is the world's second-fastest-growing city with a population exceeding 6 million (Bender, 2021).

Apart from the lack of consensus in the literature, the results for the preferred attributes and WTP obtained in stated preference methods – choice experiment and contingent valuation methods (CVM) – are valid at a local level, that is, to the areas in which they are conducted. This is because preferences by households in one area cannot be reasonably assumed to be the same as those of households in other areas (Jaime Torres & Carlsson, 2018). Furthermore, cities in different countries are serviced by different water authorities such that households face different scenarios on quality, supply interruptions, tap water pressure, and days the water is available. The implication is that the value placed on each attribute by households will be different across areas or water service regions. This signifies how inappropriate it will be to extend the results of other studies in other areas to the case of Dar es Salaam and the need to have a contextual study that would inform targeted policy formulation.

This study makes several contributions by exploring the preferences and WTP for reliable water supply in Dar es Salaam, Tanzania. Firstly, there is no consensus in the literature on the preferred water supply attributes hence this study contributes to the existing literature by establishing new findings for Dar es Salaam. Dar es Salaam, the second fastest-growing city in the world with a population exceeding 6 million, faces rapidly increasing demand for water amid inadequate supply caused by outdated infrastructure, insufficient funding, and climate change. This set of unique challenges creates a distinct environment, suggesting that findings from studies conducted in cities with slower population growth or low populations and less severe infrastructural issues may not be directly applicable to Dar es Salaam.

Secondly, to my best knowledge, this study is the first to examine households' preferences and WTP for water supply improvement in Dar es Salaam City. Existing studies on Tanzania focused on rural areas and these include Lokina et al. (2006) which established that household's WTP for improved quality and reliable water supply ranged between TSH1,417 (US\$1.12) per month and TSH3,958 (US\$3.14) per month, and Burt et al. (2017), established that WTP amounts differ depending on the proposed household water treatment and safe storage system but the WTP amounts were too far below the retail price of the systems. The focus of these studies was on rural areas where households are not connected to municipal tap water implying that the preferred attributes will be different to what this study investigates. Also, income levels and lifestyles of rural and urban people are different implying the difference in preferences and value that can be placed on water attributes. Further, the study by Lokina et al. (2006) which focused on WTP for water supply improvement was conducted a long time ago and it is possible, that preferences have changed. Hence, results from these studies cannot be assumed to hold for urban areas.

Thirdly, previous choice experiment studies aimed at improving municipal water services such as (e.g., Anteneh et al. (2019) and Ahsan et al. (2021)) assumed the same status quo for all households included in the experiment, which is limiting. Households in different areas serviced by the same water authority can experience tap water with various levels of pressure, perceived quality, frequency, interruptions, and time it is available. As such, there can be large heterogeneity in the current situation of respondents which cannot be ignored, and its incorporation leads to improved model fit and enables accounting for unobserved respondent heterogeneity (Barton & Bergland, 2010; Uwera & Stage, 2016). Therefore, this study used individual status quo, and this is regarded as an important policy contribution to account for status quo heterogeneity across households. Finally, by assessing the preferred attributes of water supply improvement and the corresponding values placed by domestic consumers, this study also contributes to policymaking in Tanzania as water authorities and the government are informed on what water supply attributes are valued the most and should be targeted to recuperate the current water situation considering the need to achieve SDGs.

In this study, it is shown that households prefer receiving tap water with high or standard pressure to low pressure, prefer water that is drinkable with or without any treatment or boiling, and prefer receiving water either in the morning, afternoon or at night compared to uninterrupted supply. Further, the study shows that households' utility decreases with an increase in the cost of water use but are willing to pay for water supply improvements in Dar es Salaam.

The rest of the chapter is as follows. Section 2.2 presents a literature review and shows different methods to estimate preferences and willingness to pay for water supply improvements. Section 2.3 describes the study area and its demographic characteristics. Section 2.4 presents the

methodology of the study by highlighting the choice experiment design with different attributes for water supply improvements. It also discusses the survey instrument and how the sampling procedure was done. Lastly, it discusses the theoretical and econometric framework. Section 2.5 is on the findings which describe the sample characteristics and water supply situation faced by households. The section concludes by explaining the choice experiment results. Section 2.6 discusses the findings while the last section provides the conclusion and policy recommendations. It also provides the limitations of the study and the area for further research.

2.2 Literature review

Recently, there has been an increasing interest in research on household preferences and WTP for water service and the literature has used the stated preference methods: Contingent Valuation Model (CVM) and choice experiment (Bui et al., 2022; del Saz-Salazar et al., 2016; Dey et al., 2019; Eridadi et al., 2021; Hasan et al., 2021; Jiang & Rohendi, 2018; Kim et al., 2021; Marques et al., 2016; Meunier et al., 2019; Sempewo et al., 2021; Tenaw & Assfaw, 2022; Vásquez et al., 2021; Zvobgo, 2021) and choice experiment method (Adams & Vásquez, 2019; Ahsan et al., 2021; Ibrahim et al., 2019; Larue et al., 2017; Nur Syuhada et al., 2020; Setiawan et al., 2021; Uwera & Stage, 2016; Vásquez et al., 2021). A summary of this literature is presented in Table 2.1. A CVM is a survey method where participants express their preferences within hypothetical or contingent markets (Markandya et al., 2019). This enables researchers to assess the need for products and services that are not commonly bought and sold in conventional markets. A choice experiment involves a finite number of alternatives that make up hypothetical choice situations and respondents are asked, in repeated tasks, to select an alternative they prefer to one or more alternatives (Johnston et al., 2017).

The literature using the CVM has produced varying results regarding WTP for water supply improvement. Rodríguez-Tapia et al. (2017) assessed the WTP for water quality by considering the perceptions of households in Mexico City using a Tobit model. Their study established that households' WTP was 4.7% of the bi-monthly water bill, and it increased with a positive perception of residues in tap water, volume of water supply and trust in the management of water supply. Similarly, Bui et al. (2022) assessed WTP for an improvement in urban domestic water supply in Vietnam. They found that the average WTP was about 1.4% of the average household income and the determinants of WTP were income, maintenance of water supply infrastructure and age were the important determinants of WTP while notification of water cut-off and quality of water were not significant determinants of WTP for water supply. Dey et al. (2019) examined the WTP for safe drinking water in Tala Uzapia a coastal district in Bangladesh. They found that 90% of respondents were willing to adopt improved drinking water sources and of those, 91% were WTP for the improvement. The average WTP for safe drinking water was 30.1 BDT (US\$0.37) per 20-litre bucket, which accounted for 2-6% of the respondents' monthly income (Dey et al., 2019).

Several CVM studies have been conducted in Africa. For instance, Eridadi et al. (2021) found that Ethiopian households have a WTP of approximately 20Birr (US\$0.52) above the average current water bill with a minimum of 4Birr (US\$0.10) and a maximum of 58Birr (US\$1.52). In Rwanda, Meunier et al. (2019) explored the factors affecting marginal willingness to pay (mWTP) for enhanced domestic water. Their findings revealed that mWTP was shaped by attributes such as the availability, quality, and quantity of water. The researchers reported that the average mWTP for improved domestic water supply was US\$0.0014/litre. Zvobgo (2021) assessed WTP for a continuous supply of water in Chitungwiza, Zimbabwe and established that the average WTP was US\$40/month with the minimum being US\$2/month and a

maximum of US\$80/month. In addition, Amoah and Moffatt (2021) assessed the WTP for reliable piped water services in Ghana using the CVM, the hedonic pricing method, and the travel cost method. They found that the monthly WTP for water supply improvement were GHS47.80 (US\$15.25) for the CVM, GHS44.73 (US\$14.27) for the hedonic price method and GHS22.72 (US\$7.25) for the travel cost method, which ranged between 3-8% of household income.

Cities or countries around the world face different water supply situations and hence some studies use a choice experiment method to determine preference for water supply attributes and WTP (Adams & Vásquez, 2019; Ahsan et al., 2021; Ibrahim et al., 2019; Larue et al., 2017; Setiawan et al., 2021; Uwera & Stage, 2016). A choice experiment allows the researchers to specify attributes that are relevant and important in determining WTP, making it is a flexible method. In essence, choice experiment studies have used distinct designs comprising different attributes and their levels depending on context and objectives.

Larue et al. (2017) applied a choice experiment method to examine the WTP for water quality improvement (by reducing water pollutants) among non-farm rural residents of Quebec province, Canada. The study considered four key attributes: probable reductions in phosphorus, probable reductions in coliform, farmers' costs, and taxpayers' costs. By using random utility models (RUM), Larue et al. (2017) estimated the constant risk aversion and constant relative risk aversion and showed that projected reductions in pollutants are valued less and respondents preferred the government to increase tax and farmers to pay higher for water quality improvement. Similarly, Lee et al. (2018) investigated the preferences of farmers and consumers in South Korea regarding drinking water quality improvements through land management practices. Their study focused on three attributes: agricultural profits, water

quality grade, and biodiversity change. Using a conditional logit (CL) model, they found that while individuals preferred higher water quality, their WTP for these improvements was relatively low.

In Africa, Uwera and Stage (2016) investigated rural water services in Rwanda using a choice experiment with three attributes for domestic water use: distance, health effect and price. They also applied a CL and RPL model to show that households' utility increased as distance to a water source, health effects and price decreased. Anteneh et al. (2019) conducted a similar choice experiment in Ethiopia, focusing on water quality, water quantity, water pressure, and price as attributes. Using a mixed logit model in willingness-to-pay (WTP) space, they found that households preferred tap water that is risk-free, of high quality, with adequate pressure, and without supply interruptions, aligning with Uwera and Stage's (2016) findings.

Adams and Vásquez (2019) examined the preferences and WTP for household taps among urban informal settlements in Ghana. Using a choice experiment and based on Conditional Logit (CL) and Random Parameter Logit (RPL) models, revealed that households prefer high-quality water while minimising monthly bills and connection fees. In addition, they also showed that households preferred water management by the governing political and administrative authority compared to the Ghana Water Company Limited, and preferred receiving water for 24 hours compared to receiving water for limited hours such as from 6 p.m.-6 a.m. and 12 p.m.-6 p.m. Another comprehensive list of attributes was applied in Ethiopia by Ahsan et al. (2021) who designed a choice experiment with water quality, regularity of water supply, tap water pressure, use of filters and monthly cost as attributes. Ahsan et al. (2021) used the same econometrics models as Uwera and Stage (2016), Anteneh et al. (2019) and Adams and Vásquez (2019). Their findings showed that households in Bangladesh preferred

high-quality tap water, regularly available water and paying less for water improvement. In contrast to Adams and Vásquez (2019), they found that households preferred water with high pressure compared to low tap water pressure.

Apart from the CVM and choice experiment approach, there is a study by Burt et al. (2017) which applied a different type of experiment in rural Tanzania to evaluate preferences and willingness to pay for safe drinking water in Tanzania. They evaluated six options for household water treatment and safe storage systems using an ordinal ranking protocol. The six options were created based on the attributes: costs, availability in Tanzania, portability and efficacious, and WTP was estimated using a modified auction. Their study revealed that participants preferred boiling, using a ceramic pot filter and a flocculant disinfectant in cases where water is turbid. Also, Burt et al. (2017) established that WTP for the pot filters and disinfectants were lower than retail prices. Another study was conducted in Tanzania by Lokina et al. (2006) who examined the WTP for improved water services in Tanzania and established that WTP ranged between TSH1,417 (US\$1.12) per month and TSH3,958 (US\$3.14) per month per household.

A review of previous studies on preference and WTP for improved water supply indicates that numerous studies have investigated the preferences and WTP for water supply improvements mainly using choice experiments and CVM. Nonetheless, an investigation of the WTP and preference to pay for reliable water supply improvement in Dar es Salaam, Tanzania has not been conducted yet. While studies on similar subjects exist, their results obtained cannot be generalised to Dar es Salaam, Tanzania. This is because stated preference approaches – both CVM and choice experiment designs – are inherently local, meaning, they apply to the study site in which the survey or experiment was conducted. This means that the WTP values and

preferences for water supply improvement obtained from households in some areas cannot be assumed to apply to Dar es Salaam. Also, previous studies have been conducted in different contexts that may not apply to other areas. For example, Adams and Vásquez (2019) conducted a choice experiment among the urban informal settlements that are not connected to tap water while Burt et al. (2017) examined the improvement in water quality by assessing preference for the introduction of different household water treatment and safe storage systems among rural households that are not connected to tap water. This necessitates the need for a different study design with different and relevant attributes for Dar es Salaam. Dar es Salaam is the world's second-fastest-growing city with a population exceeding 6 million (Bender, 2021). This rapid population growth as well as the outdated infrastructure and persistent leaks contributes to water stress faced by most households. Given this situation, which is different from that of other cities, it is interesting to examine how the water supply situation can be improved.

In addition, studies such as Anteneh et al. (2019) and Ahsan et al. (2021) were conducted among urban households in different situations, but they did not account for individual status quo. In scenarios involving water supply where respondents evaluate alternatives to their current situation, it is crucial to consider individual status quo, particularly in cases of heterogeneity. This is because incorporating the current situation by using an average or mode of attribute levels for all respondents will not only eliminate the initial baseline heterogeneity but will effectively create a new hypothetical scenario which could not apply to the respondent⁶ (Uwera & Stage, 2016).

⁶ This can be the case when an individual facing high pressure is treated as facing low pressure. This will be a new hypothetical scenario and the option will not be serving the purpose of a status quo.

This study contributes to existing studies on preference and WTP for water supply improvement by assessing the preferences and WTP for reliable water supply in Dar es Salaam. The study does not only contribute to the few choice experiment studies, but it provides an in-depth examination of the preferences and WTP in Tanzania (specifically Dar es Salaam City) where little to no studies exist on the preferences for water supply improvement among connected urban households. Moreover, few studies applied the choice experiment, yet it has advantages over the CVM such as the ability to include several attributes enabling the estimation of the value of each attribute and enabling the researcher to provide the study's participants with several scenarios to understand the effect of variations in the level of attributes on their choices (Adamowicz et al., 1998; Hensher et al., 2005). More important, while previous choice experiment studies used a common status quo, this study considers the individual status quo like Uwera and Stage (2016). Individual status quo levels are taken into consideration in model estimation and analysis which allows for better modelling of the preferences given the situation. In doing so, the present study follows previous studies (e.g. Adams and Vásquez (2019), Amoah and Moffatt (2021); Lee et al. (2018) which used the CL and RPL models for the analysis.

Table 2.1: Summary of choice experiment studies

Author	Attributes	Development level, Country, City	Type of residence	Theoretical framework	Main econometric model	Main result
Adams and Vásquez (2019)	Connection fee, management, pressure, price, quality, service hours, frequency, governance	Developing, Ghana, Accra, Nima	Informal urban areas	RUT	CLM	Households are sensitive to time, quality, connection fees and monthly bills. They refer Accra metropolitan Assembly over Ghana Water Company Limited
Adams and Vásquez (2019)	Water filter, regularity of water supply, pressure, monthly cost, quality.	Developing, Bangladesh, Khulna city	Urban	RUT	RPL	Respondents are ready to pay for improvements to the water supply attributes of water quality, regularity of supply, water pressure in taps, and filtering
Anteneh et al. (2019)	Water quantity, pressure, cost, quality,	Developing, Ethiopia, Addis Ababa	Urban	RUT	RPL	Customers are willing to pay to avoid most types of water supply restrictions. Moreover, WTP is sensitive to the scope of service improvement, income, affixed price, and elicitation method
Brouwer et al. (2015)	Flow rate, storage capacity, diarrhoea prevalence, price	Developing, Kenya, Nakuru County	Rural and urban	RUT	RPL	The CV follow-up approach produces more conservative and statistically more efficient WTP values than the CE, with only limited indications of anchoring
Dauda et al. (2015)	Quality, water supply, pressure, costs	Developing, Nigeria, Damaturu	Urban	RUT	RPL	Higher education greatly influenced the households' WTP decisions
Hensher et al. (2005)	Frequency interruptions, duration of interruption, time interruption, notification of the interruption, information service during an interruption, price	Developed, Australia, Canberra	Urban	RUT	RPL	Households value reliability of water and wastewater service. Households are willing to pay to reduce frequency and length of water service interruptions. Households prefer interruptions during the weekdays.
Ibrahim et al. (2019)	Interruption, pressure, costs, quality	Developing, Malaysia, Terengganu districts	Urban	RUT	CL	This implies that good quality of water, once-a-year water supply disruption and moderate water pressure are the most preferred attributes by the consumers
Larue et al. (2017)	Reduction in phosphorus, reductions in coliform, farmers' costs, taxpayers' costs	Developed; Canada, Quebec	Rural	Risk aversion	RPL	Respondents value quality improvement and more educated ones are willing to impose greater burdens on farmers and taxpayers

Nur Syuhada et al. (2020)	Quality, frequency disruptions, pressure, price	Developing, Malaysia, Terengganu Districts	Urban	RUT	RPL	Households value water services and are willing to pay higher water price for improved services
Setiawan et al. (2021)	Quality, pressure, duration of interruption, response to customer complaints, odour, costs	Developing, Indonesia (Surabaya) and Nepal (Kathmandu)	Urban	Randomized conjoint analysis	OLS	The respondents in Kathmandu mainly value the water bill attribute and had little preference for other attributes, such as service hours, supply agency, water pressure, water quality and interruption notice. Respondents in Kathmandu are more willing to pay the proposed water bill even though their current water payment is already high.
Snowball et al. (2008)	Bacteria, discoloration, pressure, interrupted supply, water meter problems, price	Developing, South Africa, Grahamstown	Urban	RUT	CL Model, heteroscedastic extreme value model	Bacteria count, discolouration, interruptions to supply and price are important attributes of water supply.
Tarfasa and Brouwer (2013)	frequency, treatment, cost	Developing, Ethiopia	Urban	RUT	RPL	Households are willing to pay up to 80% more than their current water bill for better water supply services. The greatest value is placed on improved water quality by women and those residing in the city's poorest areas, where service levels are currently the lowest.
Uwera and Stage (2016)	Distance to non-tap sources, health effect, price, frequency	Developing, Rwanda	Rural	RUT	RPL	Respondents are willing to pay less for water supply improvements and accounting for individual status quo improves model significance and WTP values

RUT = Random utility theory, CL = Conditional logit model, RPL = Random parameter Logit.

2.3 Study area description

The study is conducted in Dar es Salaam in Tanzania (see Figure 2.1 for a map of Tanzania and Dar es Salaam). Dar es Salaam is a city on the east coast of Tanzania, which covers a total land area of about $1,393\text{km}^2$ of which the total area size for Tanzania land is $881,300\text{km}^2$ with the rest being water bodies (Tanzania Bureau of Statistics, 2012). According to the Tanzania Bureau of Statistics (2022), Dar es Salaam is the most populous region, with approximately 5.38 million residents according to the 2022 census. It consists of five administrative districts—Kinondoni, Ilala, Kigamboni, Ubungu, and Temeke—with each district serving as a municipal boundary. The total population is about 0.98 million for Kinondoni, 1.65 million for Ilala, 1.35 for Temeke, 0.32 million for Kigamboni and 1.08 million for Ubungu. Dar es Salaam is a hub of many economic activities including industrial activities and has the country's major seaport.

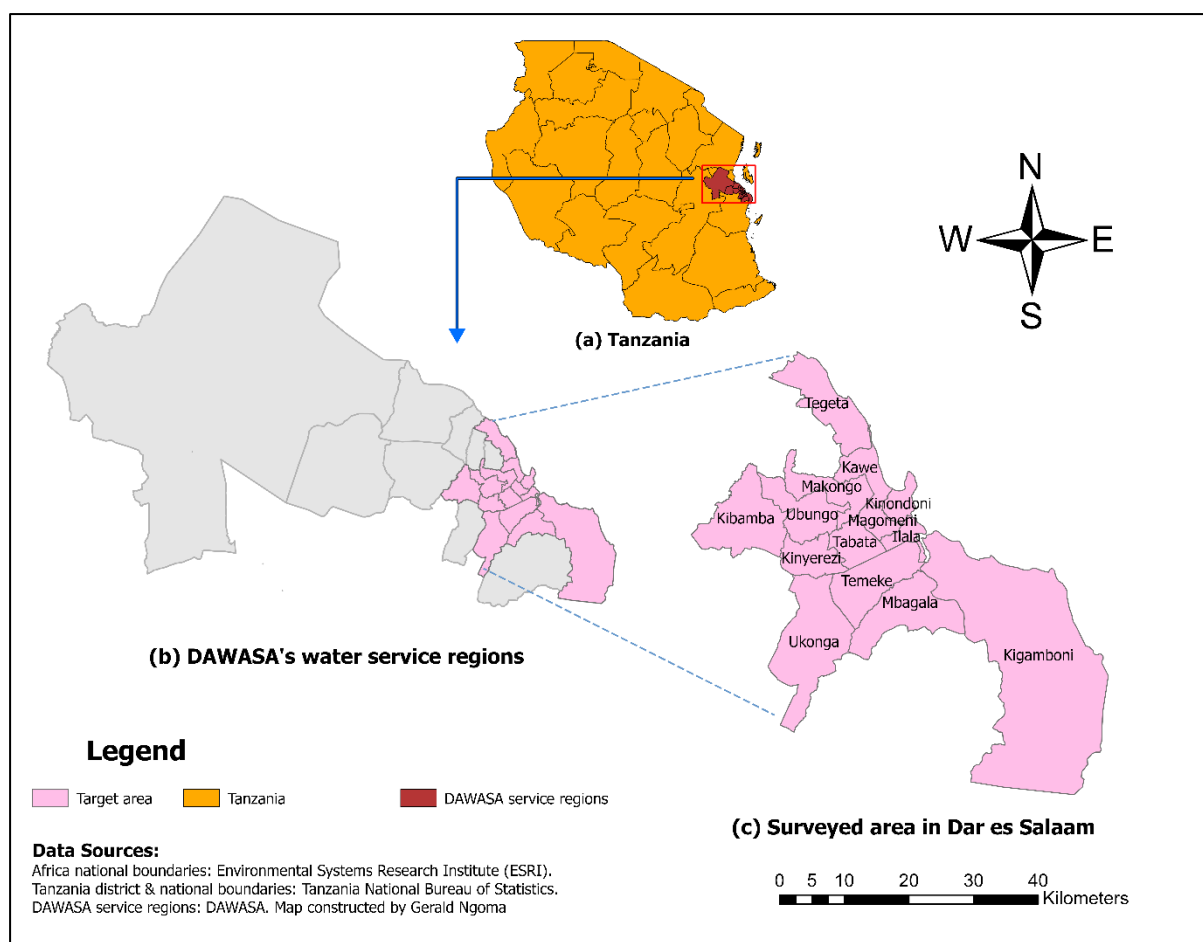


Figure 2.1: Description of the study area

Part (a) is the map of Tanzania, part (b) is on DAWASA's water service regions and part (b) shows the surveyed area.

In Dar es Salaam, water is serviced by DAWASA under the supervision of EWURA. DAWASA supplies water to 23 water service regions within and around Dar es Salaam (see Figure 2.1b for the water service regions). Some of these regions are in Dar es Salaam while others are in small towns and coastal areas surrounding the city. According to EWURA (2023), there was a total of 358,762 domestic water connections in these regions between 2021/2022 and it is expected to increase owing to elevated levels of urbanisation and formalisation of informal settlements as well as population growth. Further, DAWASA's water service region had the highest consumption level of $705,804m^3$ per day and a daily production capacity of

386,669m³ per day compared to other regions serviced by other authorities in Tanzania in 2021/22 (EWURA, 2023).

EWURA regulates the water supply environment in Tanzania including its pricing. During the period of the study, water for domestic use was priced at TZS1,663/m³. This price was higher than that of the capital city, Dodoma, which was between TZS1,170/m³ and TZS1,230/m³. (Energy and Water Utilities Regulatory Authority & Tanzania Ministry of Energy, 2022). Tap water in Dar es Salaam is safe for drinking without treatment as it is free from E. Coli contamination but some people treat it before drinking (Millennium Challenge Corporation, 2019). With respect to water pressure, it varies from low to high and is largely influenced by the geographical location of households, particularly whether they are located in low-lying or elevated (hilly) areas. Similarly, the timing of water service delivery differs across locations and is often unpredictable, with water sometimes being available in the morning, afternoon, evening, or at night. In rare cases, households may have access to water 24 hours a day; however, continuous daily supply (i.e., 24/7 availability) is uncommon and largely depends on supply conditions managed by the Water Authority.

Dar es Salaam, the largest city in Tanzania, is grappling with the effects of rapid urbanisation and population growth. The city's water infrastructure, which dates to colonial times, has been characterised by minimal improvements, leading to ongoing challenges in providing adequate water services. Despite households having access to water on paper, the reality for many residents is contaminated, inadequate, unreliable, or expensive water. This has resulted in poor or even non-existent access to water for a significant portion of the population.

Dar es Salaam relies on three surface water treatment plants, namely the Upper and Lower Ruvu plants located on the Ruvu River, and the Mtoni plant situated on the Kizinga River.

Approximately 50% of the city's water demand is met through piped water sourced from these treatment plants, while the remaining portion is from wells and boreholes. However, inadequate monitoring of water quality and extraction persists, contributing to significant outbreaks of waterborne diseases, particularly during the rainy season. Furthermore, this situation has heightened concerns regarding the long-term water supply (Rugemalila & Gibbs, 2015).

2.4 Methodology

The application of the choice experiment was guided by standard and contemporary literature for best practice in the field of environmental/natural resource economics (e.g., Johnston et al. (2017) and Lancsar et al. (2017)). This literature assisted in appropriate choice experiment design, questionnaire design and estimations as explained below.

2.4.1 Choice experiment design

According to Johnston et al. (2017), a choice experiment design involves (i) determining attributes and levels for each attribute, (ii) determining the number of alternatives in each question (iii) determining how attribute levels will be combined to produce different alternatives and (iv) determining how attribute combinations will be blocked for presentation to subsets of respondents. The study, therefore, followed the recommended practices on experimental design by starting with the selection of attributes and their levels. This process involved a literature review on the valuation of environmental resources and particularly, water. The review highlighted several factors that households consider important when determining the value placed on water. The selection of choice attributes and levels was also refined using three (3) focus group discussions (FGDs), each with 10 to 12 respondents from

Dar es Salaam⁷. In addition, the study also sought expert opinion and conducted key informant interviews with the workers from DAWASA and the Ministry of Water in Tanzania to incorporate some attributes and levels. Following these steps, five (5) choice attributes were determined: frequency of water supply, water quality, water pressure, time of the service and additional cost of water use as described in Table 2.2. The use of five attributes enabled the study to limit cognitive pressure on respondents, a problem which arises from the inclusion of too many attributes in choice experiment studies (Ahsan et al., 2021; Hoyos, 2010; Vásquez et al., 2021).

Table 2.2: Attributes for the choice experiment

Attribute	Description	Levels	Status quo
Frequency	The attribute shows the number of days water is available in a week	- 2 days - 4 days - 7 days	Same as now
Water quality	Describes the condition of water for use	- Drinkable without treatment/boiling - Drinkable with treatment/boiling - Not drinkable without treatment	Same as now
Water pressure	Describes the force at which water flows from the tap	- High pressure (takes 2 minutes or less to fill a 20-litre bucket) - Standard pressure (takes 2-4 minutes to fill a 20-litre bucket)	Same as now
Time of the service	This shows the time that households prefer to get the service	- Morning (06:00-11:59) - Afternoon (12:00-17:59) - Night (18:00-05:59)	Same as now
Additional cost of water per unit (TZS)	Additional cost per unit price of water	5; 15; 30; 50; 100	0

⁷ FGDs were conducted in August 2022. They comprised domestic water users whose dwellings are connected to piped water from DAWASA.

The first attribute is the number of days water is available in a week, which is a continuous variable capturing the frequency of water availability in a typical week. Water quality is the second attribute which was used to describe the condition of water for safe household use. Water quality had three levels namely, safe to drink without treatment, drinkable with treatment and not drinkable. Using the need for boiling or treatment as a measure of water quality is consistent with the literature (Ahsan et al., 2021; Tarfasa & Brouwer, 2013). The third attribute is water pressure, which describes the force at which water flows from the tap and can be high pressure or standard pressure as per this study. The study classified high pressure as the condition where a 20-litre bucket fills in 2 minutes or less, standard pressure as taking between 2-4 minutes to fill a 20-litre bucket and more than 4 minutes for low pressure. With high pressure, water can quickly be fetched but it can destroy water pipes and cause leakages while with standard pressure it relatively takes longer to fetch but does not damage water pipes easily.

The fourth attribute is the time of the service, which is used to capture the time that households prefer to get water. With the help of FGDs and literature, three levels were identified for time of service: morning, afternoon, and night. The morning period was defined as 06:00 to 11:59, the afternoon as 12:00 to 17:59 and the night as 18:00 to 05:59. In this design, it is observed that the night level comprised more hours than the other levels, which may increase its likelihood of being favoured by respondents due to the greater time allocation. However, its potential to dominate is likely limited, as productive activities are typically constrained during the night. Also, the night-time water availability can be less convenient due to sleep schedules and concerns about safety or practicability (e.g., not being awake or available to collect water during those hours). As such, the perceived utility of receiving water during the night was not necessarily higher than other time slots, such as afternoon or morning, which are more aligned

with household routines and productivity. The last attribute is cost described as the additional costs per unit of water (m^3) that a household could pay for a reliable water supply. Cost, which was expressed in Tanzanian Shillings (TZS) had five levels: 5, 15, 30, 50, 100⁸. The status quo for all attributes was ‘same as now’ to indicate the existing situation and for costs, the status quo is zero to indicate no increase in the price of water.

An unlabelled discrete choice experiment with three alternatives (Option A, Option B and Status quo) is determined. Option A and Option B have different combinations of attribute levels as described in Table 2.2. A Status Quo option which represents the existing conditions of water supply by the water authority is used. The inclusion of a status quo alternative is recommended by Johnston et al. (2017) and is critical to allow respondents to decline the proposed alternatives in favour of what they are currently facing. Also, including the status quo option allows the consideration of the existing heterogeneity. The Status Quo option is defined as the current water situation faced by the respondent at the time the experiment is conducted. For cost, the status quo option is defaulted to zero for all households indicating that there are no additional costs for improvements to be made while for other attributes it was described as ‘same as now.’ The study elicits the status quo that is the “same as now” situation for all respondents by allowing them to state details of their current situation in the questionnaire about quality, time of service, frequency, and pressure. The status quo option insinuates that households have no preference for an improvement in water supply. Defining the status quo in this manner prevented us from creating a new hypothetical scenario where respondents are faced with a status quo that does not reflect their current situation as Uwera and Stage (2016)

⁸ At the time the experiment was conducted, US\$1 was equivalent to approximately TZS2,300.

stated. An example of a choice card presented to respondents with all three options is presented in Figure 2.2.

The experimental design adopted in this study deliberately varies attribute levels to introduce trade-offs. Consequently, some of the attribute levels presented may be less favourable than a respondent's actual status quo – for example, offering fewer days of water availability. This design choice is intentional and allows for the identification of a broader spectrum of preferences and willingness to pay (WTP), including respondents' aversion to deteriorations in service levels. The presence of such attribute levels does not compromise the validity of the design; rather, it provides valuable insights into respondents' decision-making. In cases where an option is clearly worse than their perceived status quo, respondents are likely to strongly prefer the latter. This behaviour is informative, as it highlights their valuation of improvements and their tolerance for potential trade-offs. Importantly, this approach is consistent with established practices in the stated preference literature, which often adopt a common or average status quo rather than individual status quo. As a result, some alternatives may appear either superior or inferior to this reference point. This strategy enables the estimation of marginal utilities and trade-offs across a standardized set of scenarios, thereby enhancing comparability and analytical robustness.

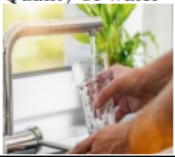
Attributes	Option A	Option B	Status quo
Number of days water is available in a week 	4 days	2 days	Same as now
Quality of water 	Drinkable without treatment/boiling	Drinkable with treatment/boiling	Same as now
Water pressure 	Standard pressure	High pressure	Same as now
Time of the service 	Morning	Afternoon	Same as now
The additional cost of water per unit (TZS) 	50	15	Zero
Which option would you prefer?			

Figure 2.2: Sample choice card presented to respondents

Source: Author

The choice experiment literature widely uses the D-efficient designs as they are optimised to minimise the standard errors of parameter estimates while simultaneously controlling for the extent of correlation between parameter estimates (Alamri et al., 2023; Mariel et al., 2021). However, the D-efficient designs often require more advanced software and prior information about parameter values, which were not readily available for this study (Mariel et al., 2021). Therefore, study employed an orthogonal design which also offers several advantages. The orthogonal design ensures that the attributes are independent of each other hence facilitating an easy estimation of the main effects (Mariel et al., 2021). Also, they are easy to construct and

interpretation. Some choice experiment studies have also used orthogonal designs (e.g., Adams and Vásquez (2019)). The orthogonal design is, however, less efficient than the D-efficient design.

Given the attributes and their levels (in Table 2.2), the study had a total of 270 possible combinations⁹ with each choice set having two alternatives and a status quo. Given this design, a full factorial design could have too many choice-sets which induce a cognitive burden on respondents (Ahsan et al., 2021; Hoyos, 2010). To reduce this problem, an orthogonal fractional factorial design using NGENE software 1.3 was preferred, which produced 16 choice sets. The study noted that 16 choice sets were still too many to be presented to one respondent and could invoke fatigue among respondents and reduce their motivation to truthfully participate. Hence, 16 choice sets were divided into four blocks and randomly assigned each respondent to one block. This implies that each of the respondents faced only 4 choice cards with 3 options. As part of this design, respondents were provided with a choice task to practice before beginning the actual experiment. This task allowed respondents to familiarise themselves with the experiment and it facilitated them to learn and make consistent decisions during the actual experiment (Szinay et al., 2021). This was very important given our experiment with 4 blocks and 4 choice tasks.

2.4.2 Survey instrument and data collection

The survey instrument had four sections related to this study (See Appendix A). The first section had general social-demographic information, the second section had information on

⁹ 3 attributes (frequency, time of service and water quality) had 3 levels, 1 attribute (pressure) had 2 levels and 1 attribute (cost) had 5 levels such that $3^3 \times 5^1 \times 2^1 = 270$ possible combinations.

household income and expenditure per month, the third section involved questions on access to water, and the last section has a choice modelling scenario for water reliability. The survey method was face-to-face personal interviews using a structured questionnaire and was done in the respondents' homestead. The survey targeted household heads who make decisions for the household. Moreover, the questionnaire was administered in Swahili since the language is common among people in Dar es Salaam. The main data collection was done using Computer Aided Personal Interviews (CAPI) through Open Data Kit. The CAPI was accompanied by visual aids throughout the entire interview period. The data was collected by trained research assistants. Ethical clearance was assessed and approved by the Ethics Committees at the UCT and the University of Dar es Salaam (UDSM) (see Appendix B). The approved questionnaire was then tested through a pilot survey of 50 households, and a pilot survey was conducted within four days in September 2022.

2.4.3 Sampling procedure and data collection

Data was collected from 962 households who uses water for domestic purposes using a multi-stage probability proportional to size sampling approach in 16 DAWASA water service regions which are illustrated in Figure 2.1. These households are referred to in this study as domestic water users. In the initial sampling phase, 16 water service regions were considered as strata, with the sample size allocated proportionally to the population of each region. The focus was on Dar es Salaam city meaning coastal and remote regions were not considered. In the second stage, the strata are based on wards. This approach accounted for the physical distribution of the domestic water users in Dar es Salaam at water service regions and ward level and it allowed the sample to be representative of the domestic users in Dar es Salaam. It also produced self-weighted means and reduced variances. The final stage involved using random numbers to select households. According to Ministry of Finance and Planning and National Bureau of

Statistics (2022), the total number of households in Dar es Salaam is 1,550,066. The study targeted domestic water users who are connected and have a non-zero average monthly consumption from the period of July 2021 to June 2022 and a total of 128,264 households met these criteria out of about 300,000 active domestic connections (households). In each selected household, the aim was to interview the household head, but any adult (18 years or older) belonging to the household could participate if the household head was absent.

2.4.4 Theoretical and econometric framework

The study used the choice experiment method based on McFadden's (1974) random utility theory. According to McFadden (1974a), individuals know their utility with certainty such that utility can be distinguished into deterministic component and stochastic component. This can be illustrated as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (2.1)$$

where U_{ijt} is the true but unobservable indirect utility associated with the observed utility V_{ijt} and ε_{ijt} is the stochastic component that are related to alternative $j \in \{1, \dots, J\}$ for individual $i \in \{1, \dots, N\}$. The stochastic component is supposed to be independently and identically distributed (IID) (Hole, 2007). In this framework, a utility-maximising individual will select an alternative j over alternative s if:

$$U_{ij} > U_{ik} \Rightarrow V_{ij} + \varepsilon_{ij} = V_{ik} + \varepsilon_{ik} \quad \forall j \neq k; j \in J \quad (2.2)$$

Following Holmes et al. (2017), the study assumed that the observed component of the individual i 's utility (V_{ijt}) is linearly related to attributes in X_{ijt} which are weighted by parameters β for all individuals:

$$V_{ij} = \beta'_i X_{ij} \quad \text{such that} \quad U_{ij} = \beta'_i X_{ij} + \varepsilon_{ij} \quad (2.3)$$

Equation (3) is the RUM where utility of an individual i is determined and can be separated into a deterministic component (βX_{ij}) and a stochastic component (ε_{ij}).

As noted by Johnston et al. (2017), it is standard to consider models that account for observed and unobserved heterogeneity. The study therefore first estimated preferences for improved water supply services using a CL model. Following McFadden (1974a), the probability of an individual i choosing alternative k in the choice set $t \in \{1, \dots, T\}$ for a CL model is given by:

$$P_{ijt}(\beta_i) = \frac{\exp(\beta'_i X_{ikt})}{\sum_{j=1}^J \exp(\beta'_i X_{ijt})} \quad (2.4)$$

The probability of the observed sequence of choices conditional on knowing β_i is given by:

$$P_i(\beta_i) = \prod_{t=1}^T P_{ijt}(\beta_i) \quad (2.5)$$

The study assumed that the β parameters have a density distribution $f(\beta|\theta)$, where θ is a vector of underlying parameters of the taste distribution such that the unconditional probability of choosing alternative k for individual i in a sequence of choices can be expressed as an integral of the conditional probability¹⁰ over all values of β (Holmes et al., 2017; Revelt & Train, 1998; Train, 2009).

$$P_{ijt}(\theta) = \int P_i(\beta_i) f(\beta|\theta) d\beta \quad (2.6)$$

¹⁰ The conditional probability is given by $P_{ijt|\beta} = \frac{\exp(\beta_i X_{ijt})}{\sum_{j=1}^J \exp(\beta_i X_{ijt})}$.

Following Revelt and Train (1998), model (2.6) was estimated using the maximum simulated likelihood approach since it does not have a closed-form solution¹¹. The estimation of equation (2.4) is done by assuming that the Independence of Irrelevant Alternatives (IIA) holds. According to Holmes et al. (2017), this assumption states that the choice probabilities between two alternatives in a choice set are not affected by the other alternatives in the choice set. This assumption implies that the removal or the inclusion of an additional alternative does not affect the choice probabilities between two existing alternatives (Train, 2009). Based on the IIA property, the model was estimated by assuming that respondents have the same preference structure such that the β parameters are the same for all respondents in the population (Hensher & Greene, 2003). Revelt and Train (1998) and Johnston et al. (2017) argued that this is a strong assumption that is not always satisfied, and an alternative model should be considered in that case. I tested this property using the Hausman and McFadden (1984) test. Considering the strict requirement of the IIA property, I estimates a RPL model following Revelt and Train (1998). As noted by Revelt and Train (1998), an RPL model accounts for preference heterogeneity by allowing the preferences to vary across respondents such that the RUM in equation (2.3) is modified in this manner:

$$U_{ijt} = \beta_i' X_{ijt} + \varepsilon_{ijt} = \bar{\beta}' X_{ijt} + \tilde{\beta}_i' X_{ijt} + \varepsilon_{ijt} \quad (2.7)$$

where X is a vector of attributes including the monetary attribute, β_i is the sum of the population mean ($\bar{\beta}$) and stochastic deviation that represents the individual's tastes relative to the average tastes in the population ($\tilde{\beta}_i$). In this model, $\tilde{\beta}_i' X_{ijt} + \varepsilon_{ijt}$ is the stochastic component of the

¹¹ The LL for the model is given by $LL(\theta) = \sum_{i=1}^N \ln P_i(\theta)$ and cannot be solved analytically. Hence the use of simulated method.

utility function which is correlated among alternatives and in sequence choice tasks. Hence, the IIA assumption does not hold in an RPL model, and this feature makes the mixed logit model more desirable than the CL model.

To this end, it has been argued that the RPL model is preferred to the CL model as it accounts for preference heterogeneity. Some studies have also established that the RPL model is preferable as it gives more accurate welfare estimates and better fit than the CL (Brouwer et al., 2010; Morey & Greer Rossmann, 2003). A Latent Class Model (LCM) is also commonly used in discrete choice experiment studies. Unlike the RPL model which assumes continuous preference heterogeneity, the LCM assumes discrete heterogeneity where individuals with similar preferences are grouped into distinct, few classes. This entails that LCM can capture a different form of individual heterogeneity other than that captured in the RPL, but each model has its own merits. For example, the LCM is a semiparametric model that relaxes the strong or unwarranted distributional assumptions about individual heterogeneity in RPL model, whereas the RPL model is a fully parametric model that offers greater flexibility in specifying individual, unobserved heterogeneity (Greene & Hensher, 2003; Lancsar et al., 2017). There are no theoretical measures to determine whether respondents' preferences are continuous or discrete, and it is inconclusive which model performs better in terms of people's behavioural issues (Greene & Hensher, 2003; Sagebiel, 2017). Therefore, the selection of an appropriate model is determined by the researcher and depends on the proposed modifications, results from preliminary data analysis, insights gained through FGD, and evidence from prior studies (Greene & Hensher, 2003; Johnston et al., 2017). Preliminary analysis using LCM showed that models with more than two classes could not be estimated due to convergence issues, making it difficult to statistically determine the optimal number of classes. Hence the study focused on the CL and RPL models.

While considering the need to ensure the parsimony of the model, I introduced interaction terms of income and attributes and compared the results with the baseline CL models with and without interaction terms and an RPL without interaction terms. Income is related to household preferences for water attributes. For example, high-income households may prefer receiving water for limited periods because they have a borehole or money to buy safe water for drinking in case of water unavailability. Also, this study's survey is conducted across the city and comprised households with different income levels. Hence, the difference in income could be a source of preference heterogeneity which is included in the study. Models with interaction terms account for the sources of heterogeneity and fit the data better (Hensher et al., 2015; Train, 2009). The study tested the significance of adding the interaction terms using the likelihood ratio (LR) test. The LR test statistic was calculated as follows:

$$LR = -2(LL_{restricted\ model} - LL_{unrestricted\ model}) \quad (2.8)$$

which is a χ^2 test with degrees of freedom = the difference in number of parameters. The study also compared the model fit using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) and a model with lower values was preferred. Choice experiment studies often include an alternative specific constant (ASC) for the alternatives to capture the status quo bias (Hensher et al., 2015; Johnston et al., 2017). In an unlabeled experiment, the inclusion of the ASC captures the status quo level hence could not include the ASC in model specification and estimation. This is because the ASC would be highly correlated with the individual status quo attributes which could bias parameter estimates (Barton & Bergland, 2010; Uwera & Stage, 2016). I estimated the RPL model with correlated terms to account for the correlation across utilities of designed alternatives.

Marginal WTP estimation

As noted by Lancsar et al. (2017), marginal willingness to pay (mWTP) should be calculated after model estimation to facilitate the convenient comparison of attribute estimates. Since discrete choice models were estimated with utility as a function of observed attributes, mWTP values were derived in the same utility space. In this process, mWTP for significant coefficients was estimated using the delta method, assuming a fixed cost coefficient while treating other attribute coefficients as normally distributed (Train, 2009). This approach is commonly used in the literature (Adams & Vásquez, 2019; Lancsar et al., 2017; Larue et al., 2017) and helps avoid the complexities associated with assuming a randomly distributed price coefficient. If the price coefficient were randomly (normally) distributed, then WTP will be a distribution, which makes it difficult to compare across models. The mWTP was calculated by dividing the mean coefficient of an attribute X by the negative of the estimated cost coefficient as follows:

$$mWTP = -\left(\frac{\beta_x}{\beta_{cost}}\right) \quad (2.9)$$

where β_x is the coefficient of the attribute X and β_{cost} is the coefficient of the cost attribute. The value of mWTP is interpreted to mean the minimum amount households were willing to sacrifice for a marginal change in the attribute on average. It can be noted that the mWTP values for the significant coefficients are estimated using the delta method since the cost attribute was assumed to be fixed (Train, 2009). The study also examined the summed WTP values for different policy mixes to have a better understanding of how much households are willing to pay for water supply improvements.

2.5 Results

2.5.1 Sample characteristics

Table 2.3 shows the socio-economic characteristics of the study's respondents, and these characteristics include gender, age, income, marital status, and household size.

Table 2.3: Characteristics of the sample

Variable	N	Mean	SD	Min	Max
Gender: dummy = 1 if male	962	0.84	0.37	0	1
Age in years	962	45.83	10.2	25	90
Marital status: dummy =1 if single	962	0.05	0.22	0	1
Marital status: dummy =1 if married	962	0.86	0.35	0	1
Marital status: dummy =1 if widowed	962	0.06	0.23	0	1
Marital status: dummy =1 if divorced	962	0.03	0.18	0	1
Education: dummy = 1 for no education	962	0.02	0.14	0	1
Education: dummy = 1 for primary education	962	0.14	0.35	0	1
Education: dummy = 1 for secondary education	962	0.41	0.49	0	1
Education: dummy = 1 for certificate/diploma	962	0.21	0.41	0	1
Education: dummy=1 for university degree	962	0.22	0.41	0	1
Income (million TZS)	962	0.57	0.31	0.05	2
Household size	962	5.10	2.00	1	18
Water consumption (liters/day)	962	289.26	617.45	10	12000

As presented in Table 2.3, about 84% of the household head are male and the average age are 45.83 years with the minimum age being 25 years and a maximum being 90 years. These findings have key implications for modeling individual preference heterogeneity. For instance, male respondents make up 84% of the sample, yet they may be less knowledgeable about household water needs and challenges compared to women, who are typically the primary users of water for domestic purposes. As a result, male respondents might prioritise certain attributes that are not the most pressing for the household, despite being the primary decision-makers. However, as ultimate decision-makers, they may still be well-informed about the water situation for the household and may act in its best interest. Similarly, marital status plays a role in preference heterogeneity.

Furthermore, the majority (86%) of the household heads were married while 5% were single, 6% are widowed and 3% are divorced. It can also be noted that the average household size was 5 people, but the minimum household size is one and the maximum is 18. The preferences of respondents may differ depending on these characteristics. The preferences of single individuals may differ from those of married individuals, particularly those in larger households or with children and elderly family members. For example, single individuals may prefer water availability at night when they are home from work, whereas married individuals in larger households may prioritize a continuous 24-hour water supply considering the water needs of the family.

Table 2.3 also evidence that 41% of the respondents had secondary education as their highest education level while 22% held university degrees, 21% had certificates or diplomas, 14.2% had primary education and 3% had no formal education. Highly educated consumers may advocate for sustainable pricing models that ensure service quality and infrastructure maintenance. The average monthly income of respondents was TZS0.57 million ($\approx$ US\$247.64) and it ranged from TZS50,000 ($\approx$ US\$19.56) to TZS 2 million ($\approx$ US\$869.57). The average income is similar to the average monthly income of TZS425,608 ($\approx$ US\$199) for urban Tanzania (Medinaceli et al., 2024)¹². Income levels influence price sensitivity as lower income individuals may prefer low-cost water supply options with predictable service schedules whereas higher income individuals may be willing to pay more for safe and clean water. On average, households used 289.26 litres per day (or 8.6 m³/month) with a minimum of 10 litres and a maximum of 12,000 litres per day. This wide variation in water usage has implications

¹² However, this income comparison is limited, as it reflects national income levels for urban areas and not necessarily the income distribution specific to Dar es Salaam. As a result, comparisons based on national figures may either overestimate or underestimate the relative affluence or vulnerability of the study sample.

for preferred water supply options. For instance, high water consumers may prioritize a more reliable supply to meet their needs.

These findings provide key insights into the characteristics of the sample, which may influence household preferences and individual heterogeneity. Therefore, in addition to examining water supply preferences across the overall sample, the study explored WTP across different population groups.

2.5.2 Water sources, coping strategies, and status quo

As part of the study, the interest was to understand the sources of water used by households for basic household use such as drinking, washing, bathing, cooking, and drinking. The results of this analysis are presented in Figure 2.3. The most used water sources are tap water, boreholes, wells, bottled water and other sources like rainwater and surface water.

The most common water source for watering gardens, trees and lawns was tap water (93.58%) followed by boreholes with a 4.13% usage rate. Tap water is the most used water source for washing clothes, houses, vehicles/motorcycles, and dishes (90.23%) with 5.2% using wells and 3.01% using boreholes. 1.56% were using other sources of water for washing. For bathing, tap water is also the main source of water with 91.79% of households using it and the second most used source is a well (4.89%) followed by a borehole (2.18%). Tap water is also the main source of water for cooking (92.4%) and drinking (84.91%) with bottled water taking a considerable proportion for drinking (10.61%). Households also use borehole water and wells for drinking and cooking.

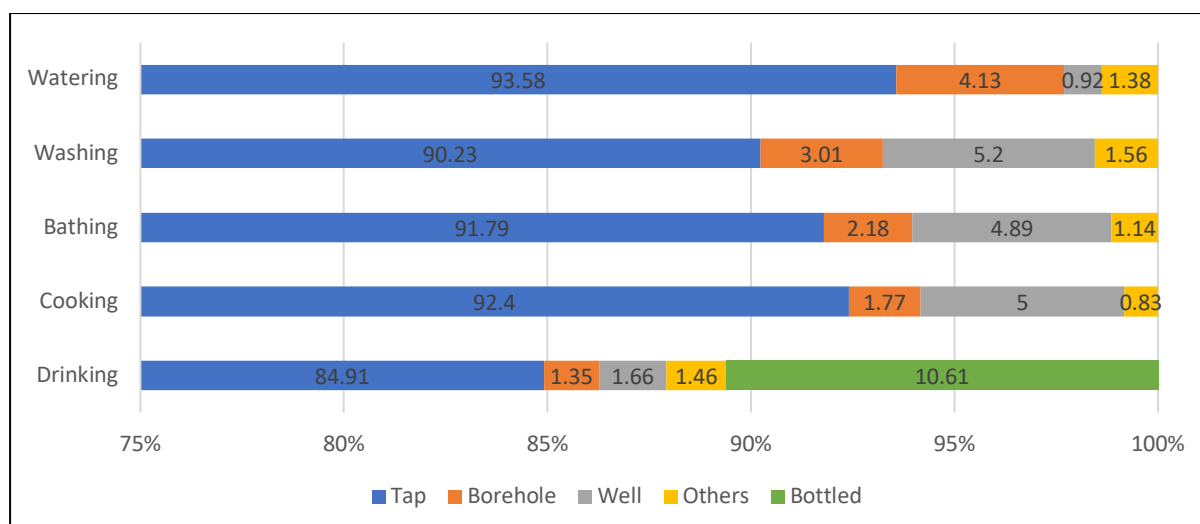


Figure 2.3: Main water sources for households

Source: Authors

The study explored households' coping strategies for tap water unavailability and their perceptions of water supply attributes at the time of the interview. Table 2.4 presents the results which are categorised by income levels, with low-income households earning below the median and high-income households earning above the median.

Table 2.4: Coping strategies and perceptions of water supply attributes by income levels

Variable	Low income	High income	Total	p-value
	N (%)	N (%)	N (%)	
Overall	503 (52.29%)	459 (47.71%)	962 (100%)	
Panel (a): Coping strategies				
Store water in a tank				
No	386 (76.74%)	291 (63.40%)	677 (70.37%)	<0.00
Yes	117 (23.26%)	168 (36.60%)	285 (29.63%)	
Store water in buckets				
No	279 (55.47%)	156 (33.99%)	435 (45.22%)	<0.00
Yes	224 (44.53%)	303 (66.01%)	527 (54.78%)	
Store water in well/pond				
No	416 (82.70%)	330 (71.90%)	746 (77.55%)	<0.00
Yes	87 (17.30%)	129 (28.10%)	216 (22.45%)	
Buy water				
No	102 (20.28%)	106 (23.09%)	208 (21.62%)	0.29
Yes	401 (79.72%)	353 (76.91%)	754 (78.38%)	
Use boreholes				

No	379 (75.35%)	387 (84.31%)	766 (79.63%)	<0.00
Yes	124 (24.65%)	72 (15.69%)	196 (20.37%)	
Panel (b): Status quo for water supply attributes				
Time of service				
Morning	226 (45.02%)	205 (44.76%)	431 (44.90%)	0.08
Afternoon	58 (11.55%)	78 (17.03%)	136 (14.17%)	
Night	187 (37.25%)	148 (32.31%)	335 (34.90%)	
24 hours	31 (6.18%)	27 (5.90%)	58 (6.04%)	
Frequency ^a	4 ^b (1.65)	4 ^b (1.63)	4 ^b (1.64)	0.48
Water quality				
Not drinkable	28 (5.57%)	12 (2.61%)	40 (4.16%)	<0.00
Drinkable with treatment/boiling	291 (57.85%)	342 (74.51%)	633 (65.80%)	
Drinkable without treatment/boiling	184 (36.58%)	105 (22.88%)	289 (30.04%)	
Pressure				
High pressure	61 (12.15%)	69 (15.07%)	130 (13.54%)	0.01
Standard pressure	301 (59.96%)	309 (67.47%)	610 (63.54%)	
Low pressure	140 (27.89%)	80 (17.47%)	220 (22.92%)	
Cost				
High	142 (28.23%)	106 (23.09%)	248 (25.78%)	0.05
Fair	356 (70.78%)	352 (76.69%)	708 (73.60%)	
Low	5 (0.99%)	1 (0.22%)	6 (0.62%)	

^aMeans and standard deviations are presented for this variable.

^bThis figure has been rounded to the nearest whole number.

Panel (a) of Table 2.4 shows that households use multiple strategies to cope with tap water unavailability and unreliability. Strategies used include storing water in tanks (29.63%), buckets (54.78%) and wells/ponds (22.45%) as well as using boreholes (20.37%) and buying water from vendors such as kiosks (78.38%). Coping strategies vary significantly by income level ($p < 0.001$), except for buying water ($p = 0.29$). Nevertheless, a large proportion of both low-income (79.72%) and high-income (76.91%) households purchase water from vendors. This has equity implications, as low-income households may be disproportionately disadvantaged. Households comprising high-income respondents are more likely to store water in tanks (36.60%) and wells (28.10%), while households comprising low-income respondents rely more on boreholes (24.65%) and bucket storage (44.53%). This indicates distinct patterns in water storage methods based on income, with higher-income respondents having more

access to infrastructure like tanks and wells, while lower-income respondents rely more on alternative sources like buckets and boreholes, often located in public spaces. Despite the differences, buying water is a widespread practice among both low-income (79.72%) and high-income respondents (76.91%), indicating persistent challenges with the reliability of water supply.

The results in Panel (b) of Table 2.4 show that respondents in Dar es Salaam have different perceptions regarding water quality, time of service, water availability, water pressure and costs. These perceptions are further disaggregated by income levels. There is a significant variation across all the respondents for all the attributes presented. For the time of service, about 45% of respondents received water in the morning, 14.17% in the afternoon, 34.9% at night and 6% received water for 24 hours. The proportion of the sample receiving water for 24 hours per day is lower than the 19.6% reported by the EWURA (2023) for the 2021/2022 period. Both low-income (45.02%) and high-income (44.76%) households mainly receive water in the morning, with high-income households more likely to have afternoon service (17.03% compared to 11.55%). A significant portion of both groups also receive water at night (37.25% for low-income and 32.31% for high-income). Only a small percentage of both groups receive 24-hour service: 6.18% for low-income households and 5.90% for high income households.

There is no statistically significant difference in the number of days water is available per week across respondents ($p = 0.48$), as both groups report an average of 4 days per week. Variation among respondents is evident when examining the proportion of those reporting specific numbers of days water is available. For instance, 22.83% receive water for 4 days, 22.62% receive water for 3 days, about 7% receive water daily, and nearly 10% receive water once a

week. The high variation in the status quo is also evident in other attributes, such as water quality. While 65.80% of respondents perceive tap water as drinkable after treatment, 4.16% believe it is not drinkable without treatment, and 30.04% think it is drinkable without any treatment. The observed heterogeneity in preferences related to water quality could plausibly be attributed to geographic location. Households residing in different areas or municipalities may have varying experiences with water infrastructure, historical exposure to contamination issues, or differing levels of trust in local service delivery. The results show significant differences in water quality between low- and high-income respondents ($p < 0.001$). More low-income respondents (5.57%) report tap water to be undrinkable water compared to high-income households (2.61%). Furthermore, 74.51% of high-income respondents perceive tap water as drinkable with treatment, while 57.85% of low-income respondents believe tap water is drinkable with treatment.

Water pressure also varied across the respondents with 63.54% perceiving that it is standard, 13.54% perceived that it is high and 22.92% receiving water with low pressure. The percentage of respondents receiving water with low pressure is similar to what was reported by Vásquez et al. (2021) who found that about 7% of the respondents in the Galapagos Islands were receiving tap water with low pressure. In addition, a significant difference was found between income groups: 15.07% of high-income groups regarded pressure as being high compared to 12.15% among the low-income group. were more likely to experience high pressure. Most respondents in each group regard water pressure as standard; however, 27.89% of low-income respondents and 17.47% of high-income respondents believe the water pressure is low. Regarding costs, the majority (73.60%) of respondents believe the price of water is fair, while only 0.62% consider it low-priced, and 25.78% perceive it as highly priced. A similar pattern is observed in both the low- and high-income groups. Specifically, over 70% of respondents in

each group think tap water is fairly priced, while 28.23% of the low-income group and 23.09% of the high-income group consider it highly priced. Notably, less than 1% in each group believe the price of water is low.

These findings on the status quo situation show substantial variation in terms of the experiment's attributes and assuming every respondent has the same status quo would be misleading. Hence, the study modeled the preference and WTP for reliable water supply by considering the individual status quo.

2.5.3 Choice experiment results

As part of the experiment, respondents were presented with three choices in each choice task: Option A, Option B, and the status quo. Each alternative was available 3,848 times. Among these choice tasks, Option A was selected in 1,919 cases (49.87%), Option B in 1,543 cases (40.10%), and the status quo in 386 cases (10.03%). These results indicate a preference for improvement over the status quo, suggesting that households generally prefer change. Given a significant proportion of respondents selecting the status quo (10.03%), the study applied a binary logit model to estimate the likelihood of choosing the status quo based on respondent characteristics and status quo attribute that are presented in Table 2.3. The results of this analysis are presented in Table 2.5.

Table 2.5: A logit model of factors affecting choice of status quo

VARIABLES	(1) Coefficients	(2) Marginal effects
Gender	0.22 (0.27)	0.02 (0.02)
Age	0.03*** (0.01)	0.003*** (0.001)
Marital status		
Single	0.22 (0.63)	0.02 (0.05)
Married	-0.29	-0.02

	(0.43)	(0.04)
Widowed/divorced	0.65	0.06
	(0.49)	(0.04)
Education		
Secondary	-0.34	-0.03
	(0.23)	(0.02)
Certificate/Diploma	-1.02***	-0.09***
	(0.33)	(0.03)
University	-0.55*	-0.05*
	(0.30)	(0.03)
Income	-0.89**	-0.08**
	(0.39)	(0.03)
Household size	0.12**	0.01**
	(0.05)	(0.004)
Water volume	-0.01	-0.001
	(0.10)	(0.01)
Constant		
Observations	3,832	3,832

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Results from the binary logit model indicate that the likelihood of selecting the status quo increases with age. Compared to respondents with primary or no education, those with a certificate/diploma and university education were, on average, 0.09 and 0.05 less likely to select the status quo, respectively. On average, the probability of selecting the status quo decreases by 0.08 when income increases by TZS1 million but increases by 0.01 for each additional household member. These results suggest that there are some population groups that are more likely to choose the status quo than others indicating different preferences.

A CL model was estimated using the methods described in the previous sections and the results are presented in Table 2.6. This analysis begins with an overall model that includes attributes only (Column 1) and then proceeds to a CL model with interaction terms (Column 2) to improve model fit and account for preference heterogeneity. The χ^2 statistics for both models are statistically significant at the 1% level, indicating that the coefficients in each model are

jointly different from zero. Notably, the model with interaction terms has a higher log likelihood value ($LL = -3796.17$) compared to $LL = -3817.76$ for the model with no interaction terms), which shows that including interaction terms improves model fit. This is confirmed by the AIC value which is lower for the model with interaction terms. The BIC, however, shows that the model with no interaction terms fits the data better. Both models have expected signs on the estimated coefficients such as cost but the model with no interactions is better in terms of statistical significance. For results in both columns, respondents are more likely to pay less for an improvement in water supply while the likelihood of preferring high-quality water, high-pressure tap water and more availability is high. The validity of the CL model was tested using the Hausman and McFadden (1984) test for the IIA condition in Stata on both the models with and without interaction terms, and the results are shown in Table 2.7.

Table 2.6: CL models

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Overall model		Started with:		Pooled model
	No interaction terms	With interaction terms	Experiment 1	Experiment 2	(Corrected for scale)
Cost	-0.003*** (0.00)	-0.003** (0.001)	-0.003 (0.00)	-0.003*** (0.00)	-0.003*** (0.00)
Time of service					
Afternoon	0.77*** (0.19)	-0.03 (0.53)	0.70** (0.27)	0.70*** (0.25)	0.77*** (0.19)
Night	1.66*** (0.19)	0.92* (0.49)	1.89*** (0.29)	1.40*** (0.25)	1.66*** (0.20)
Morning	1.13*** (0.19)	0.47 (0.54)	1.21*** (0.28)	0.99*** (0.25)	1.13*** (0.20)
Pressure					
High	1.38*** (0.18)	1.76*** (0.41)	1.52*** (0.29)	1.30*** (0.24)	1.38*** (0.19)
Standard	0.65*** (0.18)	0.81** (0.37)	0.58** (0.28)	0.69*** (0.24)	0.65*** (0.18)
Quality					
Drinkable with treatment	0.07 (0.08)	-0.02 (0.24)	-0.05 (0.11)	0.28** (0.12)	0.07 (0.08)
Drinkable without treatment	0.29*** (0.07)	0.27 (0.26)	-0.14 (0.10)	0.73*** (0.12)	0.29*** (0.09)
Frequency	0.15*** (0.02)	0.07 (0.07)	0.06*** (0.02)	0.22*** (0.02)	0.15*** (0.03)
Order					-0.02 (0.10)
χ^2	422.23***	444.83***	205.07***	266.70***	
LL	-3817.76	-3796.17	-1861	-1904	-3815
AIC	7651	7626.33	3740	3825	7651
BIC	7717	7751.35	3800	3886	7724
No. of respondents	962	962	471	491	962
No. of observations	11,541	11,541	5,652	5,889	11,538

Robust standard errors are in parentheses. LL = Loglikelihood, AIC = Akaike Information Criterion and BIC = Bayesian Information Criterion. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2.7: Testing for the IIA assumption

Option excluded	χ^2	Degrees of freedom	P-value	Conclusion
<i>Panel (a): Without interactions</i>				
Option A	374.27	9	0.00	Violated at 1%
Option B	468.79	9	0.00	Violated at 1%
Status quo	482.83	7	0.00	Violated at 1%
<i>Panel (b): with interactions</i>				
Option A	344.64	17	0.00	Violated at 1%
Option B	309.09	17	0.00	Violated at 1%
Status quo	421.41	13	0.00	Violated at 1%

These results are for a CL model without interaction terms are presented in panel (a) and results for a model with interaction terms are presented in panel (b).

Findings in Table 2.7 panel (a) imply that the IIA property is violated for the specified CL model with no interaction terms. This is because the p-values associated with the Chi-square statistics are less than 1% for all three cases implying the rejection of the null hypothesis supporting the notion that the IIA holds. Panel (b) also shows that the IIA assumption does not hold when interaction terms are included since the p-values are less than 1% level for all options shown. These findings imply that the assumption of homogeneous preference is not valid hence providing the basis for the estimation of the RPL model which accounts for heterogeneous preferences.

As previously stated, two experiments were conducted sequentially. To minimize carryover effects, respondents were randomly assigned to begin with either Experiment 1, which is related to this study, or Experiment 2, which assesses preferences for greywater technologies¹³.

¹³ Details and analysis of the second experiment are presented in Chapter Four of this thesis.

However, this design may impose a cognitive burden on respondents, potentially leading to inaccurate preferences in the second experiment.

To examine whether the sequence of experiments influenced preferences, a likelihood ratio test for equality of all model parameters was conducted, following Swait and Louviere (1993). This test compared a heteroscedastic CL model estimated using pooled data with two separate models: one for respondents who began with Experiment 1 (water supply improvement) and another for those who started with Experiment 2 (grey-water technology experiment). The results for the Experiment 1 group are presented in Column (3), the Experiment 2 group in Column (4), and the heteroscedastic CL model in Column (5) of Table 2.6.

This comparison provides an LR statistics of 87.98, which is statistically significant at 1% level. This means that the null hypothesis of equal parameters is rejected at 1% level and that the heteroscedastic CL model fits the data better compared to the other models. However, the scale parameter in the heteroscedastic CL model is very small (-0.02) and statistically insignificant suggesting no strong evidence of differences in preferences arising from the order of experiments. Since the scale parameter is insignificant, the error variance remains constant across groups, implying that the study did not detect differing levels of decision "noise" across sequences.

Overall, these results suggest that while adding heteroscedasticity improves model fit, the estimated scale parameter does not vary significantly. This implies that the improvement in fit is driven by factors other than the sequence of experiments. This is likely because necessary and recommended steps were taken to mitigate possible ordering effects and these methods include randomising the experiment order, disclosing the experimental setup to respondents in advance, incorporating an instructional choice set, introducing washout periods between

experiments, and reducing the number of choice sets. These findings indicate that heteroscedasticity exists but is not attributable to the experiment sequence. Consequently, an RPL model was estimated to capture preference heterogeneity (rather than scale heterogeneity).

An RPL model was estimated with and without interaction terms of income and water supply attributes. Notably, a high level of correlation can exist between attributes. For example, water pressure tends to be low during peak hours, a 24-hour water supply implies availability throughout the week (i.e., frequency = 7 days), and higher-quality water or more frequent supply may come at a higher cost. Failure to account for this potential correlation results in biased estimates model coefficients, inaccurate WTP estimates and flawed policy recommendations. To account for potential attribute correlations, RPL models were estimated with correlated coefficients. The results for the RPL model with and without interaction terms are presented in Columns (1) and (2) of Table 2.8. In addition, Similar models without correlated terms were estimated and the results are shown in Table C.2 in Appendix B.

Table 2.8: Coefficients of RPL models

VARIABLES	(1) No interactions	(2) With interactions
Cost	-0.0060** (0.0028)	-0.0066** (0.0028)
Time of service		
Afternoon	4.6439*** (1.4677)	2.4460** (1.2404)
Night	6.99*** (1.42)	4.80*** (0.96)
Morning	5.34*** (1.48)	3.20*** (1.13)
Pressure		
High pressure	8.03*** (2.18)	9.20** (4.33)
Standard pressure	6.50*** (2.12)	7.50* (4.45)
Quality		
Drinkable with treatment	1.78***	1.66**

	(0.40)	(0.75)
Drinkable without treatment	1.34***	1.25*
	(0.38)	(0.68)
Frequency	0.26**	0.02
	(0.11)	(0.20)
<i>Interaction terms</i>		
Drinkable with treatment $\times$ Income		0.23
		(1.01)
Drinkable without treatment $\times$ Income		0.15
		(0.81)
Afternoon $\times$ Income		3.17**
		(1.54)
Night $\times$ Income		3.32**
		(1.42)
Morning $\times$ Income		3.00**
		(1.43)
Frequency $\times$ Income		0.44
		(0.27)
High pressure $\times$ Income		-1.08
		(1.11)
Standard pressure $\times$ Income		-0.82
		(1.05)
χ^2	89.9	179.89***
LL	3***	
AIC	-3282.86	-3270.23
BIC	6655.72	6646.46
No. of Respondents	6986.64	7036.21
No. of Observations	962	962
	11,544	11,544

*Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The RPL model is estimated with 500 Halton draws. Standard errors are clustered by respondents to account for potential correlation among choices made by the same individuals.*

The results in column (1) in Table 2.8 are for an RPL model with no interaction terms whereas column (2) shows the results for a model with interaction terms. Considering a model with no interaction terms, the $\chi^2 = 89.93$ and is statistically significant at 1 % level. AIC = 6655.72 and BIC=6986.64, which are lower than that of a CL with no interaction terms. RPL with interaction terms has a statistically significant $\chi^2 = 179.89$ and lower BIC and AIC values than a CL with interaction terms. This shows that RPL models fit the data better. For the RPL

models themselves, the AIC and BIC values show conflicting conclusions. AIC is lower for a model with interaction terms while BIC is lower for a model with no interaction terms. In terms of signs, both models are similar except for frequency which is not statistically significant. Nevertheless, the preferred model for this study is the RPL model with interaction terms that account for sources of heterogeneity and has a lower AIC value and a higher LL value than the model with no interaction terms. The LR test for the additional interaction terms added to the model in Table 2.8 column (2) produced a $\chi^2 = 24.98$ with p-value = 0.003, which confirms the significance of adding interaction terms.

In the model with interaction terms, all attributes except for frequency have statistically significant coefficients. As expected, the cost variable has a negative coefficient indicating that respondents have a lower probability of choosing options with higher costs. This suggests that they are more likely to prefer lower-cost alternatives for water supply improvements. For time of service, afternoon has a statistically significant coefficient at 5% while night and morning have coefficients statistically significant at 1% level. The positive coefficients indicate that respondents are more likely to prefer receiving water either in the morning, afternoon, or night rather than having water available 24 hours per day.

Furthermore, respondents are more likely to prefer receiving tap water with high or standard pressure to water with low pressure. Regarding the quality of water, respondents' utility is likely to be higher for water that is drinkable with treatment or drinkable without any treatment compared to water that is not drinkable without any treatment. The results for tap water quality mean that high water quality is have a higher likelihood of being preferred preferred.

mWTP results

Marginal WTP values were calculated for the RPL model with interaction terms. These mWTP are compared with those from the RPL model with no interaction terms as well as the CL with and without interaction terms and the results are shown in Figure 2.4.

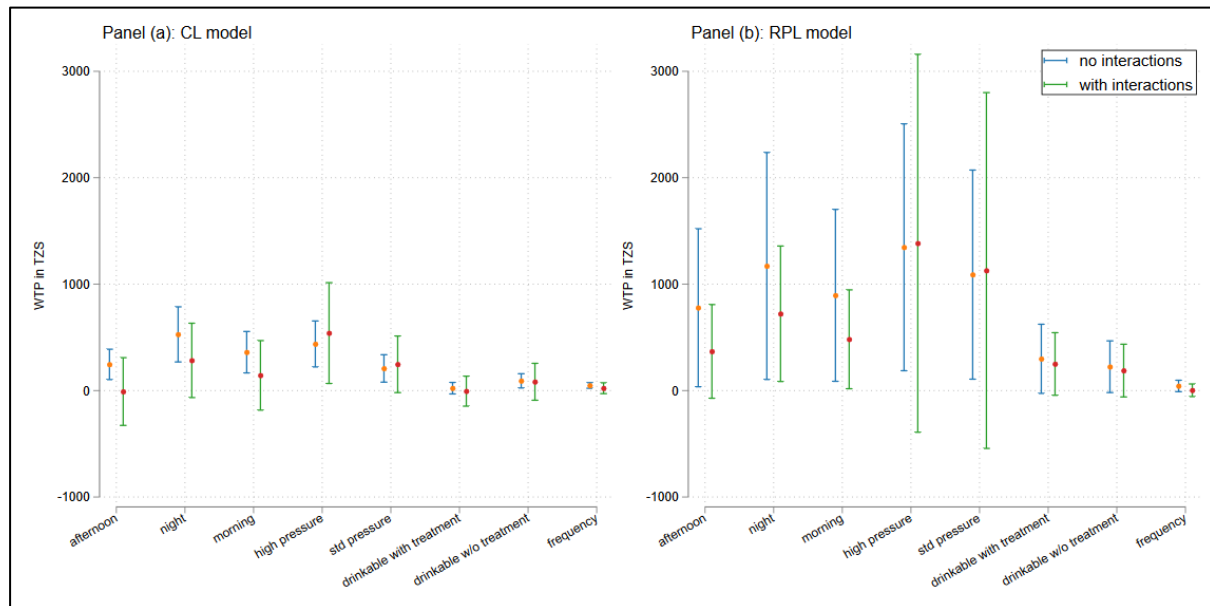


Figure 2.4: mWTP values

Source: Authors

Notes: Panel (a) shows the results of the mWTP values for an RPL model with and without interaction terms while panel (b) shows the mWTP values for a CL model. The circles represent the mWTP values for each attribute while the whiskers represent the 95% confidence interval. mWTP values for all models in TZS and US\$ denominations are presented in Table C.3 in the Appendix C

As presented in Figure 2.4, the mWTP values for the RPL models are higher than those of the CL models in general. For RPL models with and without interactions, the mWTP values are similar except for afternoon, night, and frequency with smaller values in the model with interaction terms. Overall, WTP values for each attribute are less than TZS2300 (US\$1) and the comparison shows that WTP values of the RPL model with interaction terms are sensible compared to other models.

Respondents are willing to pay more for the following attributes: afternoon, night, morning, high pressure, standard pressure, and drinkable with and without treatment. More specifically, they are willing to pay a minimum of TZS367.99/m³ (US\$0.16/m³) more for delivering water in the afternoon than for 24 hours (refer to in Table C.3 in the Appendix for mWTP values). Furthermore, respondents are willing to pay additional amounts of at least TZS721.74 (US\$0.31/m³) and TZS481.92 (US\$0.21/m³) for water that is received at night and in the morning, respectively. For pressure, respondents are willing to pay at least TZS1,383.77 (US\$0.60/m³) for tap water with high pressure and TZS1128.11/m³ (US\$0.49/m³) for tap water with standard pressure. This shows that they are willing to pay more for high pressure compared to low pressure. In addition, the results suggest that respondents' WTP is higher for high-quality water compared to low-quality water. Specifically, respondents are willing to pay an additional amount of TZS250.07 (US\$0.11/m³) for water which is drinkable after treatment (boiling) and TZS187.99/m³ (US\$0.08/m³) for tap water that is drinkable without treatment compared to water which is not drinkable without any treatment. Overall, pressure has higher mWTP values meaning that it is the most valued attribute.

Water supply WTP packages

Following the presentation of the WTP values for water supply improvement in Dar es Salaam, examples of water supply packages and the total mWTP values for each package are presented. This means several combinations of attributes are used to produce a package. For this analysis, three cases for frequency are examined: water supplied 1 day/week, 3 days per week and 7 days per week while other attributes are observed as in the previous analysis. The results for the selected water supply scenarios are in Table 2.9.

Table 2.9: WTP for selected water supply packages

	Time of service			Pressure		Quality		Frequency			WTP/m ³	
	Afternoon	Night	Morning	High	Standard	drinkable with Treatment	drinkable without treatment	1	3	7	TZS	US\$*
1			X	X					x		1874.44	0.81
2	x			X		x			x		2010.58	0.87
3	x			X			X		x		1948.50	0.85
4												
5		x		X		x			x		2364.33	1.03
6		x			X	x				X	2120.33	0.92
7	X				X		X			X	2058.25	0.89
8												
9		x		X		x				X	1960.16	0.85
10			X	X				X			2375.99	1.03
11	X			X			X	X			2118.68	0.92
12		x			X	X		X			1942.67	0.84
		x			X		X	X			2102.84	0.91
									X		2040.76	0.89

*An exchange rate of US\$1 = TZS2,300 was used.

The WTP values are almost similar for different packages shown. Table 2.9 shows that WTP values are between TZS1874.44/m³ (US\$0.81/m³) and TZS2375.99/m³ (US\$1.03/m³). The highest WTP is TZS2375.99/m³ (US\$1.03/m³) which is for tap water supplied with high-pressure for 7 days/week, is available at night and is drinkable after treatment/boiling. This is followed by a similar water supply scenario with WTP of TZS2364.33/m³ (US\$1.03/m³) where high-pressured water is supplied 3 days/week at night and is drinkable after treatment. The lowest WTP shown is TZS1874.44/m³ (US\$0.81/m³) and is for the following combination of attributes: water is supplied in the morning, has high pressure, is not drinkable without treatment and is supplied 3 days a week.

2.6 Robustness analysis

Robust tests were conducted to examine the influence of interviewing a member of the household in case the head is not available as well as to assess how the order of experiment affects the results. First, the sample size was restricted to heads of household who comprise 75.21% of the sample. Second, attributes were interacted with a dummy variable called *order*, which takes a value of 1 if a respondent started with the experiment of this study and zero if a respondent started with the experiment covered in Chapter 4. In all these cases, models with interactions of attributes and income were estimated (i.e., a similar specification to that of results in column (2) of Table 2.8). Results of this analysis are presented in Table 2.10.

Results suggest that household heads prefer paying less for water supply improvements and there is higher likelihood of preferring receiving water in the afternoon, night or morning compared to receiving water for 24 hours. Also, household heads are more likely to prefer tap water with high pressure compared to tap water with low pressure. WTP values are lower for time of service, quality and frequency but the highest WTP is for high tap water pressure as in the previous analysis with all respondents. These results are consistent with those presented Table 2.8 for all respondents including proxies for household heads. Hence, previous analysis is reliable.

Column (3) in Table 2.10 also shows that respondents are more likely to prefer paying less for water improvements and the likelihood of preferring tap water received in the afternoon, at night or in the morning is higher than that of receiving water for 24 hours. As established previously, the results indicate that water that is drinkable with or without treatment is more likely to be preferred to water that is not drinkable without treatment. WTP is highest for high pressure which is in line with the previous analysis without controlling for the order of

experiment. Thus, when the order of the experiment is controlled for, the results are still similar to those presented in Table 2.8 suggesting that the order of the experiment did not cause any significant change to preferences.

Table 2.10: Robustness analysis

	(1)	(2)	(3)	(4)
	Heads only		Order of experiment	
	Coefficients	WTP	Coefficients	WTP
Cost	-0.01** (0.002)	- -	-0.01*** (0.002)	- -
Afternoon	2.19* (1.25)	425.46 (278.00)	2.6279** (1.0373)	310.67*** (137.68)
Night	4.31*** (1.25)	839.77** (419.43)	3.9888*** (1.1597)	471.57** (183.04)
Morning	3.29** (1.29)	640.33* (347.77)	3.1562*** (1.0023)	373.13** (152.63)
Pressure				
High	8.98*** (1.82)	1747.39** (764.84)	8.1041*** (1.7868)	958.08*** (320.10)
Standard	7.13*** (1.70)	1388.83** (623.02)	6.7114*** (1.7808)	793.44*** (286.88)
Quality				
Drinkable with treatment	1.60*** (0.55)	310.79* (181.21)	2.0890*** (0.6801)	246.97*** (103.77)
Drinkable without treatment	1.64*** (0.52)	318.69** (167.98)	2.4426*** (0.5585)	288.76*** (104.64)
Frequency	0.09 (0.12)	16.67 (22.94)	0.1514 (0.1247)	17.90 (16.18)
Interactions with income	Yes		Yes	
	8,664 722		11,544 962	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

2.7 Heterogeneity Analysis

The study analysed the heterogeneity of the estimated results concerning different respondents and status quo characteristics. Specifically, it examined how preferences and willingness to pay for water improvements vary by income level, municipality, education level, gender, age, and water consumption level. The results of this analysis are presented in Table 2.11.

Income was categorised into two groups: low (below the median income of TZS 500,000) and high (above the median). The results suggest that low-income individuals are more likely to pay a lower price for water improvements, whereas price is not a significant factor for high-income individuals. In addition, low-income individuals exhibit a higher likelihood of preferring water delivery in the afternoon, night, and morning compared to their high-income counterparts. A similar pattern is observed for water pressure and quality, with stronger preferences among low-income individuals. Despite the statistical insignificance of price for the high-income group, their mWTP values are, on average, higher than those of the low-income group across all attributes.

The results suggest that preferences for all water attributes, except for frequency, are higher among younger individuals compared to older individuals. However, both groups prefer lower costs for water improvements. Regarding education, price is a significant factor only for individuals with primary or lower education and secondary education. Additionally, individuals with very low education levels exhibit a higher likelihood of preferring the given water attributes. Regarding willingness to pay, higher-educated individuals are willing to pay more for water supply improvements compared to those with lower levels of education, although the WTP values for highly educated individuals are statistically insignificant.

Concerning baseline water consumption levels, high water users are not sensitive to price, whereas low water users are more likely to prefer paying less. As a result, low water consumers favour lower payments for water consumption compared to high water users, with water pressure having the highest WTP values among all attributes. Notable differences can be observed across the five municipalities. Respondents from Ilala are more likely to choose services delivered in the afternoon, morning, or night rather than 24-hour service, with their

mWTP values also being higher. In contrast, respondents from Temeke are less likely to choose water supply in the afternoon or morning compared to a 24-hour service. Differences are also evident in preferences for frequency, which is significant for respondents in Kinondoni, Temeke, and Ubungo. Among all municipalities, Temeke exhibits the lowest preferences and WTP values.

For gender, male respondents are more likely to prefer paying less for water supply improvements, whereas price is not a significant factor for women. Women are more likely to choose water supplied in the morning, afternoon, and night rather than a 24-hour supply, a pattern also observed among male respondents. Furthermore, preferences for receiving water at high or standard pressure are stronger among female respondents, whereas men place greater importance on the number of days water is available. Among men, the highest WTP value is for high pressure, while the lowest is for frequency.

Table 2.11: Heterogeneity analysis

VARIABLES	Income (TZS)		Age (years)		Education				Water consumption (m ³)		Municipality					Gender	
	Low (≤ 500,000)	High (>500,000)	≤ 45	> 45	Primary or less	Secondary	Certificate/Diploma	University	Low	High	Kinondoni	Ilala	Temeke	Ubungo	Kigamboni	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Cost	-0.02*** (0.004)	-0.0006 (0.0020)	-0.01** (0.004)	-0.01** (0.003)	0.04*** (0.0154)	-0.01*** (0.0034)	-0.002 (0.0045)	0.001 (0.0038)	0.01*** (0.002)	0.003 (0.002)	-0.01* (0.01)	-0.01** (0.003)	0.02*** (0.005)	0.08*** (0.02)	0.01* (0.01)	0.01*** (0.002)	-0.004 (0.005)
Afternoon	9.79*** (2.65)	4.26*** (0.84)	5.67*** (1.87)	4.76*** (1.02)	11.65** (5.51)	4.36*** (1.13)	9.94** (4.01)	12.15** (4.92)	6.88*** (1.52)	2.91* (1.54)	6.19** (2.64)	13.22* (6.8)	2.84*** (0.98)	37.26* (22.32)	31.61 (20.33)	3.76*** (0.82)	10.37* (5.49)
Night	12.45*** (2.95)	6.63*** (0.98)	8.87*** (2.70)	6.97*** (1.10)	21.60** (10.34)	6.65*** (1.26)	13.62*** (4.85)	15.00*** (5.26)	9.07*** (1.71)	5.57*** (1.60)	8.55*** (2.92)	15.51** (6.88)	0.5 (0.71)	46.88* (25.96)	33.25 (20.35)	6.22*** (0.93)	12.78** (5.73)
Morning	10.41*** (2.68)	4.90*** (0.89)	6.56*** (2.14)	5.43*** (1.03)	18.15** (8.18)	4.96*** (1.10)	10.69*** (4.07)	12.97*** (4.93)	7.22*** (1.54)	3.84** (1.55)	6.46** (2.65)	14.80** (6.84)	2.81*** (0.94)	40.95* (23.86)	31.52 (20.31)	4.50*** (0.84)	11.02** (5.55)
Pressure:																	
High	9.08*** (1.51)	6.53*** (1.69)	11.07*** (3.62)	10.35*** (2.27)	18.51* (9.77)	9.25*** (1.67)	15.88** (6.20)	13.16 (8.23)	9.75*** (2.03)	8.64*** (2.27)	17.65 (28.26)	21.12** (9.97)	4.75*** (1.00)	32.88* (17.23)	2.4 (20.37)	7.93*** (1.27)	9.89*** (3.82)
Standard	7.31*** (1.37)	4.98*** (1.63)	9.26*** (3.18)	8.64*** (2.29)	11.31* (6.18)	7.37*** (1.52)	13.80** (5.76)	11.89 (8.23)	7.96*** (1.89)	7.19*** (2.23)	16.45 (28.25)	19.68** (9.92)	1.73** (0.82)	27.83* (15.39)	0.79 (20.34)	6.31*** (1.22)	8.43** (3.67)
Quality:																	
Drinkable with treatment	1.84*** (0.54)	1.79*** (0.34)	3.17*** (1.06)	1.19*** (0.44)	10.78* (5.54)	1.26** (0.55)	3.21*** (1.18)	2.43** (1.11)	2.71*** (0.53)	1.21*** (0.29)	3.20*** (0.91)	0.55 (0.35)	2.77*** (0.68)	0.98 (3.92)	2.40* (1.29)	1.63*** (0.26)	2.95*** (0.92)
Drinkable without treatment	1.46*** (0.45)	1.18*** (0.26)	2.34*** (0.83)	0.95*** (0.33)	6.18** (2.97)	1.18*** (0.44)	2.26** (0.95)	1.69** (0.86)	2.18*** (0.45)	0.83** (0.25)	1.41** (0.65)	0.15 (0.27)	2.77*** (0.65)	9.53* (5.37)	1.79 (1.24)	1.19*** (0.22)	2.01** (0.79)
Frequency	0.14* (0.08)	0.40*** (0.07)	0.21** (0.10)	0.39*** (0.08)	1.29** (0.54)	0.38*** (0.09)	0.08 (0.12)	0.40** (0.18)	0.46 (0.09)	0.19*** (0.06)	0.44*** (0.15)	0.1 (0.09)	0.46*** (0.13)	4.82** (2.02)	0.14 (0.11)	0.32*** (0.05)	0.1 (0.14)
Observations	6,036	5,508	5,928	5,616	1,872	4,740	2,448	2,484	6,600	4,896	2,112	3,516	2,628	1,860	1,428	9,648	1,896
Respondents	503	459	494	468	156	395	204	207	550	408	176	293	219	155	119	804	158

Clusters standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

2.8 Discussion

The study has shown different results concerning water supply improvement in Dar es Salaam, Tanzania. There is a high level of heterogeneity across respondents in terms of time of service, water pressure, number of days tap water is available, water quality and the perceived cost of water. The existing heterogeneity may stem from differences in how water authorities manage supply, influenced by the state of infrastructure and the income levels in different areas. It is possible that in middle-income to upper-income neighbourhoods, water authorities might not limit water supply as people in those areas can meet their water bills and this can be the case despite it being a source of inequity. Elected officials, such as councillors, often wield significant power within municipalities because they are supported by constituencies that contribute substantially to municipal budgets through rates, as well as by Tanzanian elites residing in these neighbourhoods. The observed heterogeneity in water service times – 45% receiving water in the morning, 34.9% at night, 14.17% in the afternoon, and 6% continuously – may result from water authorities' rationing practices, which distribute water at different times to ensure balance.

This study considered this heterogeneity by using individual status quo and showed that respondents prefer water supply improvement but at a reduced cost. This means that their utility decreases if water supply improvement is associated with an increase in the cost of water. This outcome is expected from a theoretical perspective as lower utility is derived by a consumer when price increases given a budget constraint. Empirical studies have also found that water supply improvement along with a price increase brings disutility (Adams & Vásquez, 2019; Ahsan et al., 2021; Nur Syuhada et al., 2020; Uwera & Stage, 2016). All the levels of time of service included have statistically significant positive coefficients which means respondents

were sensitive to the time water is supplied. The positive coefficients mean utility increases when water is supplied in the afternoon, night or morning compared to water available for 24 hours. However, this result was not expected since people tend to prefer uninterrupted supply and it contradicts the findings of other studies such as Adams and Vásquez (2019) and Setiawan et al. (2021) who showed that more hours of water supplied were preferred to fewer hours. A possible explanation for the lack of preference for the 24-hour water supply could be that respondents are used to coping methods such as using boreholes, tanks, buckets, and wells, among others. Households may have made significant investments in coping with limited water availability and view their capacity as enough for domestic use. Also, respondents may not be available at home for 24 hours and hence, they might prefer water to be supplied in the morning, afternoon, or at night when they are available. The results also indicate the existence of water rationing practices within the study area with 45% receiving water in the morning, 34.9% at night, 14.17% in the afternoon and 6% for 24 hours. Therefore, respondents possibly believe that 24-hour supply of domestic piped water cannot be guaranteed given their experiences with current water rationing practices by the municipality.

The study established that households are willing to pay at least TZS367.99/m³ (US\$0.16/m³), TZS721.74 (US\$0.31/m³) and TZS481.92 (US\$0.21/m³) for delivering water in the afternoon, night, and morning, respectively, compared to water supplied for 24 hours. The WTP is highest for water provided at night compared to afternoon and morning which could be the most preferred time. The preference for night provision of water could be because that is the time when most of the respondents will be at home or would have come back from work and is often the time when water is mostly used. This outcome may also be attributed to the experimental design, in which the night level was allocated more hours (6 p.m. to 6 a.m.) compared to the other levels.

The study found that both high and standard pressure levels had statistically significant coefficients at the 5% level. The coefficients are positive meaning that respondents derive higher utility from tap water with high and standard pressure compared to tap water with low pressure. The preference of high and standard water pressure over low water pressure is plausible since water can quickly be fetched and it can reach households' overhead reservoirs and showers and those living in uphill areas. Preference for high and standard pressure to low pressure is also expected given the current low tap water pressure in some parts of Dar es Salaam. According to Crisis24 (2021), DAWASA announced a decline in water pressure by 12% in most parts of the city in November 2021. Also, performance reports by EWURA for water utilities in Tanzania showed that low water pressure has been one of the major complaints that DAWASA has received in the past decade (EWURA, 2024). The finding related to water pressure is consistent with the results of Ahsan et al. (2021) and Dauda et al. (2015). Furthermore, households are willing to pay an additional amount of at least TZS1,383 (US\$0.60) for tap water with high pressure and TZS1,128.11 (US\$0.49) for tap water with standard pressure compared to tap water with low pressure. This result is quite intuitive since high tap water pressure can be fetched quickly. It can be noted that the WTP for high pressure is higher than that of standard pressure indicating that high pressure is more preferred. This larger WTP for tap water with high pressure compared to tap water with standard pressure could be due to the need to fetch water quickly and tap water with high pressure can reach all households even in hilly areas.

On the quality of water, the study shows that respondents prefer water that is drinkable after treatment and drinkable without any treatment compared to water that is not drinkable without any treatment. This means that high-quality water is preferred to low-quality water. The results concerning the quality of water are in line with those of Adams and Vásquez (2019), Snowball

et al. (2008), Tarfasa and Brouwer (2013) and Uwera and Stage (2016) who also reported respondents' preference for high-quality water in developing countries. Poor quality water can cause diseases like diarrhoea and cholera that can affect all people within the households with children being the most vulnerable (Cook et al., 2019; Fuente et al., 2020). Hence, households prefer water that is high quality.

Concerning mWTP for quality attribute, households are willing to pay an additional amount of at least TZS250.07 (US\$0.11) for water that is drinkable with treatment and TZS187.99 (US\$0.08) for water that is drinkable without treatment compared to water that is not drinkable without quality. These findings indicate that the mWTP is higher for tap water that is drinkable after treatment compared to water that is drinkable without any treatment, and this is the case regardless of the water authority supplying treated tap water. This finding is counterintuitive but could be due to a lack of trust in the ability of authorities to provide high-quality, drinkable water, potentially. This is due to concerns over ageing and outdated infrastructure, which increases the risks of contamination during distribution. Therefore, even if the water authority supplies water that can be drinkable without any treatment, a lack of trust can drive consumers to further treat it before consumption. Nevertheless, the difference between mWTP for water that is drinkable with treatment and water that is drinkable without treatment is small. The WTP for high-quality water is also in line with what other studies have established (Nur Syuhada et al., 2020). The mWTP for water that is drinkable either without treatment or with treatment is lower than the market price of bottled water, which ranges between TZS 500 and TZS 1,000 per 500ml—equivalent to approximately TZS1 million (US\$435) to TZS2 million (US\$870) per m³).

Several water supply improvement scenarios are assessed as illustrated in Table 2.9. An example scenario is a case where high-pressure tap water is supplied 7 days/week at night and is drinkable after treatment/boiling, with a WTP amount of TZS2375.99/m³ (US\$1.03/m³). For the policy packages I present, the WTP ranged between TZS1,874.44 and TZS2,375.99 (US\$0.81-US\$1.03) per unit which translates to 0.32-0.42% of the average household head's income. Considering the domestic water tariffs by DAWASA set at approximately TZS1,663 (US\$0.72) per unit, this would mean that the new water tariffs would be set between TZS3507.44 and TZS4038.99 (US\$1.53 -US\$1.76) per unit. Furthermore, if this study considers the average monthly water consumption of 8.6m³, it means an average household would pay a monthly water bill that is between TZS30,163.99 - TZS34,735.31 (US\$13.11 - US\$15.10). This translates to 5.29-6.09% of the average household head's income. These findings are comparable to those of previous studies such as Amoah and Moffatt (2021) which established that the WTP for water supply improvement in Ghana was between 3-8% of household income and Dey et al. (2019) which established that the WTP for safe drinking water in Bangladesh was between 2-6% of monthly income.

Consistent with previous studies (e.g., Ahsan et al. (2021), this study established evidence of heterogeneity in preferences and WTP across different subgroups. Specifically, high-income individuals, those with higher levels of education, and respondents from high water-use households were less sensitive to the cost of water improvements. Also, mWTP values for these groups are higher than that of their counterparts indicating their willingness to pay more. This is in line with the analysis of the likelihood of selecting the status quo conducted in this study, which showed that high income and educated respondents are less likely to choose the status quo implying that they value improvement more than their counterparts. In contrast, their lower-income, less-educated, and lower-consuming counterparts were less likely to pay more

for such improvements. This finding can be attributed to the point that high income individuals have greater capability to absorb additional price increase associated with improved services. Similarly, those with higher education levels may have a greater awareness of the long-term benefits of reliable and improved water supply and may therefore be more willing to invest in such improvements. High-consuming households are also more likely to experience the inconveniences or inefficiencies of the current water system and may perceive a higher value in improved supply. Conversely, lower-income and lower-consuming households may face tighter budget constraints, making them more cost-sensitive and cautious about committing to higher payments, even for improved services.

With regards to gender, differences in preferences were observed, particularly for the cost and frequency attributes. These attributes were not statistically significant among female respondents suggesting that they were not key considerations in their decision-making. In contrast, all attributes were significant among male respondents, indicating that men tended to evaluate a broader range of factors when considering water supply improvements. Notably, male respondents were more likely to prefer paying less for these improvements implying a stronger sensitivity to cost. This gender-based difference may be explained by the varying roles and responsibilities traditionally associated with men and women in household water use. In the context of Tanzania, women are more directly involved in water collection, usage and household management, which may lead them to prioritise attributes such as time of service and pressure. On the other hand, men may focus more on the financial implications of household decisions resulting to greater costs sensitivity.

Across the municipalities in Dar es Salaam, respondents from Kigamboni demonstrated notably different preferences compared to those from other areas. In Kigamboni, only two

attributes, that is, cost of service and water quality (drinkable with treatment), were found to be statistically significant, suggesting that these were the important attributes for respondents.

2.9 Conclusion and policy recommendations

This study analysed preferences and WTP for improved water services in Dar es Salaam, Tanzania. A choice experiment method was applied considering five attributes determined through literature reviews, FGDs, expert opinions from DAWASA, and the Ministry of Water. These attributes are cost, time of service, frequency, water pressure, and water quality. CL and RPL models are estimated in the study. However, the RPL model is adjudged preferable due to its ability to account for respondent preference heterogeneity. The study finds that attributes such as costs, pressure, water quality and time of service are key in determining households' utility and preferences. It was established that households prefer to pay lower amount for water supplied by the water authority. The study also finds that tap water with high pressure or standard pressure is preferred to tap water with low pressure and respondents prefer water that is available either in the morning, afternoon or at night compared to water supplied 24 hours a day. The study further reveals that respondents prefer high-quality water that is drinkable with treatment/boiling or drinkable without any need for treatment/boiling compared to water that is not drinkable without treatment. Overall, the results generally show that respondents prefer improvement in the water supply situation, and they are willing to pay for these improvements.

Regarding WTP, respondents are willing to pay a minimum of TZS367.99/m³ (US\$0.16/m³), TZS721.74 (US\$0.31/m³) and TZS481.92 (US\$0.21/m³) more for water supplied in the afternoon, night, and morning, respectively, than for water supplied for 24 hours. Furthermore, respondents are willing to pay additional amounts of at least TZS1,383.77 (US\$0.60/m³) for tap water with high pressure and TZS1,128.11/m³ (US\$0.49/m³) for tap water with standard

pressure. Regarding quality, respondents are willing to pay an additional amount of TZS250.07 (US\$0.11/m³) for water which is drinkable after treatment (boiling) and TZS187.99/m³ (US\$0.08/m³) for tap water that is drinkable without treatment compared to water that is not drinkable without any treatment.

The findings of this study have important implications for policymaking as the study demonstrates that the quality and pressure of tap water matter to respondents. Therefore, the water authority can aim to provide water with high water pressure which can reach all households including those located in hilly areas and that is of high quality such that it will not pose health risks. These improvements require significant investments by the water authority, which may not be possible given their limited funding. Therefore, they should accompany these water supply improvements with increases in the price of water as respondents are willing to pay more for improvements in water supply attributes such as pressure. These price increases can be done in stages to allow consumers to adjust to the new prices and this should not be done in a way to compel them to use alternatives to tap water such as unimproved water sources. While increasing the price of water can improve the efficiency of water supply, it also raises equity concerns, as lower-income households may struggle to afford the resulting price increases.

Therefore, special attention should be on low-income earners whose income may not be sufficient to meet their needs. Thus, considering that water is a basic good that everyone should access in its high quality, subsidies can be offered, and significant government investments can be made to improve water infrastructure to accommodate high water pressure and to enhance the quality of water. Subsidies will ensure that poor people, who are not able to use boreholes or buy water for basic use like cooking and drinking, are not forced to abandon tap water for

unsafe and unimproved sources. This way ensures that the country stays on track to meet sustainable development goals related to improve access to water and that the equity and efficiency goals are sustained. Also, public-private partnerships can be a viable option for the Government of Tanzania or water authorities since they can face financial constraints to subsidise or invest to enhance water supply. Further, the findings imply the need to prioritise the preferred attributes such as standard pressure and water that is drinkable with treatment/boiling if there are limited funds to improve in all attributes. Overall, these policy implications entail the need for policymakers to review the water supply situation and price while considering the need to balance production and consumption.

This study applies a choice experiment among households in Dar es Salaam, Tanzania. This focus imposed a limitation in the direct generalisability of these findings to other areas/cities in Tanzania as the choice experiment findings are directly applicable only to the site where it was conducted. This limitation applies to Tanzania since different water supply authorities supply water in different cities across Tanzania. This implies a different status quo as viewed by water users. This study was also limited by the scope of variables collected during the survey and did not include additional contextual factors, such as municipal-level characteristics, which may play a significant role in shaping respondents' choices. Consequently, further studies can be conducted in other areas using the choice experiment to elicit preferences and WTP for water supply situations or apply methods that enable the generalisability of this study's findings to other cities. Also, future research could provide deeper insights into water consumption patterns, particularly by exploring long-term behavioural responses, socio-economic influences, and the effectiveness of various conservation interventions.

Chapter 3: Impact of an Information Campaign on Domestic Water-Saving among urban households in Tanzania: A Case Study of Dar es Salaam City

Abstract

This paper investigates the effect of an information campaign on domestic water-saving among households in Dar es Salaam, Tanzania. The campaign was designed as a randomised control trial experiment involving sending water usage reports comparing a household consumption level to a neighbourhood median consumption level. A total of 1,600 households were recruited into the experiment with 800 being allocated to treatment and the rest to a control group. The treatment group received water usage reports for a period of six months from January 2023 to June 2023 and the control group did not receive any social comparison information. A difference-in-difference estimation method was applied, which revealed that the information campaign affected water consumption level as it declined by 1.49m³ (7.65%) during the intervention period and 1.62m³ (8.18%) to 2.30m³ (11.18%) on average in the first five months post the intervention. Overall, these findings suggest that the information campaign motivates households to save water. The study highlights the effectiveness of information campaigns in promoting domestic water-saving behaviour among households and recommends the use of information campaigns by the water authority in Dar es Salaam to save water.

3.1 Introduction

Water is crucial for sustaining life and driving economic activities, holds immense significance across various sectors including agriculture, industry, health, and the environment. Its vital role has been acknowledged by scholars and policymakers, evident in the inclusion of increasing water access as part of the SDG-6 (Weststrate et al., 2019). Recognising the basic needs of individuals, WHO recommends a daily water requirement of 50-100 litres for activities such as drinking, cooking, and cleaning (Howard et al., 2020). However, the domestic consumption rates for some households in many countries surpass this threshold, indicating a need for enhanced water conservation efforts and more sustainable water use practices.

The high demand for water mounts unprecedented pressure on current and future water resources, making water conservation a major global concern in recent years (Goette et al., 2019). With over 2 billion people residing in countries facing high water stress, the need for universal access to this vital resource has become paramount (WHO and UNICEF, 2021). Severe droughts, attributed to climate change, have adversely impacted water supply security in various regions across the globe (Pörtner et al., 2022). Notable examples include California, where a severe drought sternly limited water availability for a large population (Mann & Gleick, 2015), and Cape Town, South Africa, where a prolonged drought led to dwindling reservoirs and the looming threat of “day zero,” signifying complete depletion of potable water supplies for a city of 3.7 million people (Aina et al., 2023; Thiam et al., 2020; Visser et al., 2021). These instances of water scarcity are exacerbated by natural and socio-economic factors such as climate change, unsustainable water consumption practices, rapid population growth, low precipitation, droughts, limited water infrastructure, and urbanisation (United Nations, 2024). Consequently, this could lead to severe consequences such as reduced agricultural

productivity, economic losses, conflicts, migration, waterborne diseases, and compromised overall health and well-being (Mpandeli et al., 2018).

Despite Tanzania's abundant water resources, access to safe and clean water remains a significant challenge for many communities in the country. Furthermore, with Tanzania transitioning from a low-income to a middle-income country in 2020, the sustainable utilisation of water for domestic, agricultural, and industrial use became increasingly critical. The Ministry of Water (2020) has projected a shift in household water sources from public taps to private taps, resulting in a tenfold increase in per capita water consumption. This shift is anticipated to have substantial implications, as the estimated daily water consumption per person for low, medium, and high-income households is 70, 130, and 250 litres respectively (Ministry of Water, 2020). These figures indicate a considerable volume of water consumed by an individual. Mapunda et al. (2018) highlighted that only 23% of informal settlers in Tanzania have access to public water supply while 68% rely on informal water providers whose authenticity is questionable and 9% rely on water from streams, ponds, and rivers.

Tanzania exhibits regional disparities in population density and distribution. Coastal areas such as Dar es Salaam, Tanga, and Mtwara, as well as northern regions like Kilimanjaro and Arusha, experience higher population concentrations compared to other regions. The consequential strain on resources, including water, in these areas is evident. Tanzania, while predominantly rural, is witnessing drastic urbanisation, with one of the highest rates of urbanisation in Sub-Saharan Africa at 5.4% (World Bank, 2024). By 2030, approximately 54% of the population is projected to reside in urban areas, with Dar es Salaam, accommodating 40% of the country's inhabitants, expected to reach a population of 10 million (World Bank, 2017). A significant portion of this population is expected to reside in low-income and informal settlements. Hence,

adequate water supply and sanitation services in growing urban centres are vital for both economic and human development outcomes. However, the providers of water supply and sanitation services in urban Tanzania, particularly in Dar es Salaam, have struggled to meet the increasing demand due to economic and population growth. As a result, both affluent and marginalised low-income households have been affected, with the latter being disproportionately impacted (World Bank, 2017).

While there is excess demand characterised by interrupted water services, it is still important to save water. This is because saving water helps reduce pressure on existing water systems and ensures the limited supply can reach more households over longer periods even with an unreliable supply (Zhu, 2025). Also, promoting water saving behaviour can reduce peak demand, which may ease the strain on water distributional systems and improve overall service reliability. Moreover, conserving water in this period is essential for households experiencing inconsistent water supply, as it helps maintain access to water during shortages (Schultz et al., 2019). Finally, promoting water conservation in this period can help promote equitable distribution especially when supply is rotated and help build resilience by preparing families to cope with better outages or droughts.

In the realm of domestic water conservation, demand-side management (DSM) assumes a significant role by focusing on curbing water consumption through the management of demand rather than an augmentation of supply-side management (Inman & Jeffrey, 2006; Russell & Knoeri, 2020; Ziervogel et al., 2010). While DSM is valuable, it cannot fully replace supply-side improvements in areas facing water shortages. Both demand and supply policies must work together to achieve long-term water security as focusing solely on one approach risks inefficiencies and unsustainable water management in rapidly growing urban areas. The

fundamental objective of DSM is to promote sustainable water usage and optimise the efficiency of water resources. DSM strategies primarily target modifying consumer behaviour to encourage more judicious water utilisation. Within the context of domestic water conservation, DSM encompasses a range of interventions, including the promotion of water-efficient appliances, rectifying leaks, and fostering behavioural changes such as adopting shorter showers and shutting off taps while brushing teeth. By reducing overall water consumption, DSM contributes to the conservation of water resources, alleviates strain on water infrastructure, and ultimately leads to reduced water bills for consumers. Therefore, DSM serves as an indispensable instrument for advancing the cause of sustainable water utilisation and the efficient management of water resources (Kahneman, 2003).

Efforts to promote water conservation, raise awareness about water-related issues, and integrate water considerations into broader development strategies are crucial for achieving a water-secure future. Recognising the finite nature of water resources and adopting proactive measures are essential in mitigating risks and building resilient societies capable of addressing the global water crisis (Aina et al., 2023; Fielding et al., 2013). Specifically, ensuring future water security in urban areas necessitates addressing water demand management and household water conservation. Implementing strategies that promote water conservation at the household level can entail long-term shifts in attitudes and behaviours, making them a valuable solution for securing future water supplies (Fielding et al., 2013). In addition, voluntary demand management strategies can complement other approaches such as regulations and the development of water-efficient infrastructure, enhancing their overall effectiveness (Fielding et al., 2013).

Policymakers frequently turn to informational campaigns in times of brief, disruptive crises or when implementing economic or regulatory solutions is impractical. Informational and social-marketing campaigns possess two notable advantages over traditional policy instruments when it comes to promoting conservation efforts. Firstly, they tend to generate less public reactance, and secondly, they have the potential to bring about more lasting and profound changes in behaviour due to the educational nature of the campaigns (Dietz et al., 2009). Moreover, informational campaigns can be swiftly implemented and are often more cost-effective (Andor et al., 2022). Consequently, it is not surprising that conservation campaigns have become an integral part of regulatory strategies for natural resource management, particularly in the domain of water management (March et al., 2017; Saurí, 2013). These campaigns are frequently introduced or emphasised during times of shortages or crises, alongside other policy measures such as price increases, quotas, and regulatory interventions (Katz et al., 2016).

In this study, an information-based approach to water conservation was adopted to examine the impact of Social Comparison Messages (SCMs) on water-saving behaviours among urban households in Dar es Salaam. This approach involved sending households water usage reports that included comparisons with the median consumption within their neighbourhood. The rationale behind this intervention is that comparative feedback can encourage individuals to adopt new conservation behaviours or modify existing ones (Schultz et al., 2019). The idea is that when people know more about water scarcity, they are more likely to adjust their attitudes positively towards water conservation (Syme et al., 2000). Drawing on behavioural science, the intervention aims to enhance environmental awareness and stimulate behavioural change (Wang et al., 2025). When households receive feedback indicating that their water consumption is higher than that of their neighbours, this may prompt a desire to conform to perceived social norms, thereby motivating reductions in usage. In this way, the intervention reinforces

descriptive norms (i.e., what others do) and potentially injunctive norms (i.e., what others approve of) (Fielding et al., 2013; Koop et al., 2019). In addition, the personalised feedback provided in the SCM reports improves awareness of one's own consumption patterns, which is critical for behavioural change. Many households may be unaware of their usage levels or how they compare to others. By making this information salient, the intervention establishes a feedback loop that instils a sense of accountability and promotes the visibility of water-saving behaviours within the community (Koop et al., 2019).

SCMs leverage social influence to motivate individuals by establishing a normative standard and fostering a sense of competition or peer pressure. By highlighting how one's water usage compares to others, SCMs can effectively encourage behavioural change and promote sustainable water practices (Schultz et al., 2019). Also, it is important to note that there is potential for significant water reductions even though the demand for water is generally rising. Studies such as Vidal-Lamolla et al. (2024) have shown that demand-side measures, such as efficient water appliances, public awareness campaigns, and pricing strategies, can lead to reductions in average monthly water consumption ranging from 8.1% to 15.6%, depending on the context.

The Random Control Trial (RCT) method is used with two groups of households, randomly allocated into control, and treated groups, and analysed differently. The study designed a behavioural experiment involving sending water usage reports to a targeted (treated) group of 800 households informing them on their monthly water consumption level compared to the neighbourhood's median water consumption level. I conduct this experiment in collaboration with DAWASA which physically delivered social comparison information. Using a DiD estimation method, the study establishes that SCMs contributed to a decline in water

consumption by an average of 1.49m³ (7.65%) in the intervention period and averages between 1.62m³ (8.18%) – 2.30m³ (11.18%) during the first five months post the intervention.

The study's contributions to this experiment are manifold. Firstly, this study contributes to the literature on social norms' impact on conservation behaviours in the context of domestic water use in developing countries in general and Africa in particular. Existing literature includes studies in a developed country, United States of America (USA) (Brent et al., 2020; Ferraro et al., 2011; Ferraro & Price, 2013; Landon et al., 2018; Schultz et al., 2016) and developing non-African countries, namely Colombia (Céspedes & Morales-Pinzón, 2020; Jaime Torres & Carlsson, 2016; Jaime Torres & Carlsson, 2018), Israel (Katz et al., 2016) and Costa Rica (Datta et al., 2017). Few studies have been conducted in African countries and these are Visser et al. (2021) and Brick et al. (2023) in South Africa. This study draws from this literature and applies an RCT in Tanzania where no studies have been conducted to examine the impact of information campaigns on domestic water savings.

More specifically, the study builds upon the research conducted by Brick et al. (2023) examining the impact of social information on water-saving behaviours within a unique pricing and metering context to that of South Africa. It introduces three new dimensions: examining a uniform pricing system instead of a block pricing system, utilising postpaid metering rather than prepaid metering, and focusing specifically on high-water users rather than all water users. In a uniform pricing system, there is often a lack of incentive to conserve water because all customers are charged the same price per unit of water consumed, while in block pricing, there is an incentive for conservation because the price per unit of water increases with consumption, incentivising users to use water more efficiently to avoid higher charges.

Moreover, the study assesses the effects of social information on water-saving behaviours in Tanzania's postpaid metering system. With postpaid meters, more water is wasted since users do not pay upfront and only become aware of their water usage when they receive their bills. With prepaid meters, users are aware of their consumption and credit balance, hence may take measures to conserve water to make their credit last longer. Finally, the study examines the effects of social information on water-saving behaviours among Tanzania's high-water users. By focusing on this specific group, the study offers targeted insights into a demographic that may have unique responses to water conservation interventions. Thus, the study contributes to a deeper understanding of responses to interventions aimed at promoting water conservation and facilitates the development of targeted strategies to address water management challenges effectively. Overall, the study's exploration of these additional dimensions (uniform pricing, postpaid metering, and high-water users' response) enhances our understanding of water conservation strategies in African countries, with implications for policy and practice beyond Tanzania.

Secondly, investigating how social information influences water conservation practices among urban households in Tanzania, with a specific focus on Dar es Salaam city, contributes significantly to the achievement of SDG 6 - clean water and sanitation. By investigating the role of information in promoting water-saving behaviours, this study enhances the understanding of sustainable water resource management and raises awareness about the importance of sustainable water practices. Thirdly, through its findings and evidenced-based recommendations, this study informs policymakers, water utility service providers, and relevant stakeholders on the effective design and implementation of information campaigns, strategies, and interventions to foster behavioural change and enable urban households to participate in water conservation efforts actively. Understanding the impact of information on

water-saving behaviours can inform the design and implementation of targeted interventions and policies to address water scarcity challenges in Tanzania's urban areas.

The rest of the paper is arranged as follows. Section 3.2 reviews the literature on the impact of information provision and awareness campaigns to nudge households to save water. Section 3.3 outlines the methodology of the study which specifies the experiment design used for this case RCT approach and pre-intervention analysis. Section 3.4 presents and discusses the findings. The last section provides conclusions and policy implications. It also discusses the limitations of the study and areas for future research.

3.2 Literature review

A growing literature has focused on investigating the impact of different behavioural messages containing certain information and two approaches are common – RCTs and quasi-experimental approaches. With RCTs, households are randomly allocated to treatment and control groups while with the quasi-experiment approach, treatment allocation is influenced by certain characteristics. Studies using RCTs have been conducted in developed countries (Brent et al., 2020; Ferraro et al., 2011; Ferraro & Price, 2013; Landon et al., 2018; Schultz et al., 2019; Schultz et al., 2016) and developing countries (Brick et al., 2023; Céspedes & Morales-Pinzón, 2020; Jaime Torres & Carlsson, 2018; Katz et al., 2016; Visser et al., 2021).

Moreover, studies in developed nations predominantly focused on the USA with emphasis on several States and cities. These include Ferraro et al. (2011) in Cobb County in Atlanta, Georgia, which randomised households into one control group and three treatment groups: (1) the technical advice group which received information on effective methods to reduce water use, (2) the weak norm treatment group, which received both technical information and an

appeal message to reduce water consumption, and (3) the strong social norm treatment group which received technical advice to reduce water consumption, appeal messages and comparison of household water use to the median water use for the county level. Ferraro et al. (2011) showed that norm-based information approaches are effective in household water conservation, but the effect was stronger for the strong norm social group, which also tends to have a lasting impact on water demand. In a follow-up research, Ferraro and Price (2013) used the same data from the RCT by Ferraro et al. (2011) to examine the heterogeneity in treatment effects which shows that the norm-based approaches were more effective among high-water users compared to low-water users.

In San Diego, California, Schultz et al. (2016) found evidence that the descriptive norms (tips and information comparison) and aligned norms (tips and a descriptive message accompanied by a happy or sad face representing social approval or disapproval) led to a decline in household water by 26% and 16% less than the control group, respectively. In another city in California, Sacramento, Schultz et al. (2019) examined the role of monthly personalised messages on water conservation among households using smart water meters during a period characterised by extreme drought as well as voluntary and mandatory water restrictions. Using average water consumption levels comparisons and a multi-level regression model, they showed that households that received personalised messages reduced water consumption by an average of 8.35% compared to the control group with the effect being higher among high water users who reduced consumption by 13.5% compared to the low water users who reduced water consumption by 5%.

Still in the USA, Brent et al. (2015) examined the effect of social comparisons on household water use in three cities in California. Water usage reports were used in comparing household

water use to the city average as well as efficient neighbours. They showed that households in the treatment group reduced water consumption by 5.1% on average compared to the control group in one utility while in another utility they reduced water consumption by 4.9%. Hodges et al. (2020) also investigated the role of communication in household water use in Central Coast, California focusing on three types of communication: information, motivation, and behavioural skills. Hodges et al. (2020) used a DiD model to show that all message types reduced water consumption relative to the control group with water declining by about 509 gallons (1.93m³) per household in the first month.

Brent et al. (2020) examined the responses of households to SCMs focusing on two treatment groups without using a no-information control group in Nevada. The first treatment group received tips, personalised information, and a comparison of household water use (in kilogallon) to the median water use of similar households in the neighbourhood. The second treatment group received similar information to that of the first treatment group, but the social comparison message was framed in terms of relative performance toward achieving a 10% water reduction goal. Using a regression framework, they showed that water consumption declined by about 1.5% in both treatments, which is in similar ranges to that of Ferraro et al. (2011) and Ferraro and Price (2013). Fielding et al. (2013) in Queensland, Australia used a random intercept model to show that information campaigns led to a reduction in water by 11.3 litres per person per day. Similar to Brent et al. (2020), Wang et al. (2022) in Shandong Province, China did not use a non-information control group as the aim was to examine the effects of different types of messages: normative persuasion methods, informative persuasion conditions and intergroup social comparison. They employed an analysis of variance to show that intergroup social messages were more effective than other types of messages.

Jaime Torres and Carlsson (2018) investigated the indirect impact of a social awareness campaign designed to promote water conservation among residents in Jericho. They designed a field experiment in which households in the treatment group received water use reports comprising three issues: social comparison component, information components and opting out component. The social comparison components involved a comparison of household use to the mean consumption level and efficiency level in the neighbourhood as well as categorising households into groups: excellent, average and room to improve. The information component category included an explanation of the environmental implications of being in a specific category and the opting-out component provided households with an opportunity to stop receiving the feedback. Using a DiD model, the study found that within the initial six months after the intervention, targeted households reduced their water consumption by 6.8%, while non-targeted households experienced a 5.8% reduction in water use.

Another RCT was conducted by Céspedes and Morales-Pinzón (2020) who investigated the role of feedback information on household behaviour in the cities of Pereira and Dosquebradas in Mexico with a focus on water and electricity consumption. Using a Dunnet test, they showed that the information feedback led to a decrease in water consumption by about 15%. Thus, despite being conducted in different cities, Jaime Torres and Carlsson (2018) and Céspedes and Morales-Pinzón (2020) reached a similar conclusion that social message comparisons are effective in reducing households' water consumption. A similar conclusion was established by Katz et al. (2016) in Petach Tikva, Israel using a DiD on an RCT investigating the effectiveness of campaigns in encouraging water conservation. Specifically, Katz et al. (2016) showed that water-saving campaigns may be efficient in promoting water-saving as the treatment group reduced water consumption by 7.6% over five weeks with a 10% reduction in peak times.

Visser et al. (2021) conducted an RCT involving 105 schools in Cape Town, South Africa to examine the effects of two behavioural interventions aimed at promoting responsible water usage. The interventions included providing thorough water usage data feedback through smart meters and implementing an inter-school competition. The results showed that both interventions led to a significant reduction in water consumption, with reductions ranging from 15% to 26% in the participating schools. Specifically, the feedback on water usage data was shown to be particularly effective in reducing nighttime water consumption, suggesting improved water management by the school staff. On the other hand, the inter-school competition demonstrated greater effectiveness in reducing daytime water usage, indicating improved water conservation practices among the pupils. Further, Brick et al. (2023) conducted a large-scale RCT to test seven different behavioural messages among households in Cape Town, South Africa. Each of the 7 treatment groups received a message including water-saving tips, consumption graphs, gain/loss, social norms, intrinsic motivation, social recognition and public good. They employed a DiD model, which indicated that all treatments reduced water consumption with the reductions ranging between 0.6%-1.3%, on average.

Studies that have been reviewed so far employed RCTs in different environments. One study by Landon et al. (2018) in Texas, USA adopted a quasi-experiment approach in which households targeted to receive information were in neighbourhoods and had annual average household water use that is more than 378m³. They employed a DiD model estimated with a fixed effects model to show that the targeted group, which received SCMs reduced water consumption by about 2.40m³ equivalent to 3% relative to the baseline period. They further showed that the social norm comparison messaging promoted water-savings over time with the effect increasing in each succeeding year and it was most effective among high water users. Regardless of using a different experimental approach, Landon et al. (2018) reached the same

conclusion as other studies that used RCTs (Brent et al., 2020; Ferraro et al., 2011; Ferraro & Price, 2013; Fielding et al., 2013; Hodges et al., 2020; Landon et al., 2018; Schultz et al., 2019; Schultz et al., 2016).

The empirical literature review indicates that while water scarcity is a pressing issue in many countries, particularly in urban areas, limited attention has been given to the specific impact of information provision and awareness campaigns on domestic water-saving behaviours within urban households. The review has shown that most of the studies have been conducted in developed countries mainly in the USA and few studies exist in developing countries. Of note, only two studies have been conducted in Africa by Visser et al. (2021) on Cape Town schools and Visser et al. (2021) among Cape Town households. Moreover, the study by Brick et al. (2023) was conducted in the City of Cape Town characterised by a block pricing system is used instead of a uniform pricing system and a smart meter system instead of postpaid metering. In a uniform pricing system, there is often a lack of incentive to conserve water because all customers are charged the same price per unit of water consumed, while in block pricing, there is an incentive for conservation because the price per unit of water increases with consumption, incentivising users to use water more efficiently to avoid higher charges. With postpaid meters, more water is wasted since users do not pay upfront and only become aware of their water usage when they receive their bills while when prepaid meters are used, users are aware of their consumption and credit balance, hence may take measures to conserve water to make their credit last longer.

Therefore, there is a gap in investigating the role of information campaigns on household water usage behaviour in a different setting with uniform pricing and postpaid metering systems. The City of Dar es Salaam in Tanzania presents a different scenario with uniform pricing and a

post-paid metering system and assesses how households' response to information campaigns may offer important insights that can be extended to similar environments beyond Tanzania.

Another striking result from previous studies examining the heterogeneity of information campaigns is that they are more effective among high-water users and less effective among low-water users (e.g. Ferraro and Price (2013) Landon et al. (2018) and Brent et al. (2020)). Yet, previous studies focused on all types of households – low and high-water users – although they provided evidence of the responses of high-water users. Focusing on the high-water users, however, can provide nuanced insights into the behavioural responses of this group including their response to both when they are receiving feedback and when they are not. This would contribute to a deeper understanding of responses to interventions aimed at promoting water conservation and facilitate the development of targeted strategies to address water management challenges effectively. Therefore, there is a gap in the detailed understanding and analysis of behavioural responses to norm-based information campaigns for high-water users.

3.3 Methodology

3.3.1 Experimental design

To examine social norms as behavioural factors for water conservation, an RCT approach was employed building on previous studies (such as Allcott (2011); Ferraro et al. (2011); Ferraro and Price (2013); Jaime Torres and Carlsson (2018); Katz et al. (2016); Visser et al. (2019)). RCTs are effective in measuring the impact of interventions by reducing selection bias (Gertler et al., 2016). Goette et al. (2019) have shown that this method is suitable for analysing behaviour changes in a particular phenomenon. This is done through the random allocation of respondents to a control group and at least one treatment group compared with the control group.

The intervention aimed to increase households' awareness of their water usage by comparing it to that of their neighbors. Research, such as the study by (Ferraro & Price, 2013)., has shown that social comparison can be more effective than other types of messaging directed at households. This is why the present study implemented social comparison measures (SCMs). This is the reason the current study adopted the SCMs. In this context, the neighbourhood was defined as median water users in a specific cluster (ward) where the household receiving the report is located. The intervention was done by sending a short-written report to the treated group regarding their monthly water consumption levels compared to their neighbours (see **Figure 3.1** for a sample water consumption report for the intervention).

	DAR ES SALAAM WATER SUPPLY AND SANITATION AUTHORITY ISO 9001:2015 Certified DAWASA Building, Dunga/Malanga Road, Mwananyamala Area P.O. Box 1573, Dar es Salaam-Tanzania Tel +255 22 2760006/+255 22 2760015 Fax: +255 22 2762480 Email: ceo@dawasa.go.tz Website: www.dawasa.go.tz info@dawasa.co.tz / 0800110064 / *150*00# (Bure)											
<table> <tr> <td>Dear customer A/C No.</td> <td>A123A4567890</td> </tr> <tr> <td>Reference No.</td> <td>1234567890</td> </tr> <tr> <td>Your Bill for</td> <td>April 2023</td> </tr> <tr> <td>Your own total water consumption for 04 month is</td> <td>3 units.</td> </tr> <tr> <td>Your neighbors' median consumption for 04 month is</td> <td>4 units.</td> </tr> </table>			Dear customer A/C No.	A123A4567890	Reference No.	1234567890	Your Bill for	April 2023	Your own total water consumption for 04 month is	3 units.	Your neighbors' median consumption for 04 month is	4 units.
Dear customer A/C No.	A123A4567890											
Reference No.	1234567890											
Your Bill for	April 2023											
Your own total water consumption for 04 month is	3 units.											
Your neighbors' median consumption for 04 month is	4 units.											

Figure 3.1: Sample water consumption report used in the study

Source: Authors

The reports were delivered physically in printed form by DAWASA for six months starting month-end of January 2023 to the month-end of June 2023. DAWASA was used deliberately to deliver printed copies of water usage reports to gain trust from households as well as for

ethical and validity considerations. Moreover, printed copies of social comparison information enabled us to increase visibility and facilitate ease of interpretation compared to other methods like telephoning, emailing or phone messaging (Céspedes & Morales-Pinzón, 2020). The control group continued to receive their normal monthly water bills without any additional information. This RCT study was first registered on 27 October 2022 on the AER-registry and is available at <https://www.socialscienceregistry.org/trials/10285> (RCT ID: AEARCTR-0010285).

3.3.2 Sample size, sampling, and treatment assignment

The study targeted households using water for domestic purposes and using piped water from DAWASA. The target population was filtered to remain with high-water users, who were defined as those domestic water users consuming water that is above the median daily consumption in each ward. The target was high-water users because they are more likely to adjust their behaviour in terms of water use compared to low users who mostly use water for necessities. The target for piped households with water authority was due to the ease of tracing their monthly consumption without visiting them physically. DAWASA, which was a collaborator, was collecting monthly water meter readings as they usually do. Since this study was randomised at the ward level to reduce spillover effects and contamination of the control group, I keep wards with at least 20 households. It should be noted that the study targeted households who were not sharing meters and focused on standalone residential properties with individual household meters. However, there is no information on the overall proportion of shared meters among all domestic users in the DAWASA service area to provide more contextual information to the reader.

The process of filtering households to come up with the eligible population is done using water consumption data from July 2021 to June 2022 obtained from DAWASA. This data was used as the sampling frame and utilised in all procedures of sample size determination, sampling, and randomisation. To obtain an eligible target population for the study, I retained domestic users and regions that were within Dar es Salaam city and active domestic users who had a non-zero average monthly consumption from the period July 2021 to June 2022.

The final targeted eligible population had 128,264 domestic water users who were geographically divided into 110 wards and 16 water service regions. Using power calculations (see Appendix D.1 for details), I obtained a minimum of 1600 households as an optimal sample size, and I adopted a sample size of 1600 households for both the treatment and control groups.

To obtain the sample of the study from the eligible population, a two-stage stratified probability sampling procedure was used. In the first stage, 80 wards were sampled from the 16 water service regions. This was done using probability proportional to the size of water regions. This approach was relevant as it accounts for the physical distribution of the domestic users in Dar es Salaam at water service regions and ward level, allowing for the sample to be representative of the domestic users in Dar es Salaam. Randomisation is done at the ward level; hence 40 wards were allocated to the treatment group, and the remaining 40 wards were in the control group. In the second and ultimate stage, 1600 households from 80 wards were sampled using a probability proportional to the size of wards method in each of the treated and control arms.

3.3.3 Data

The monthly water usage figures for households were provided by DAWASA for the period before the intervention (baseline) and after the intervention. Access to data was provided from

July 2021 to December 2023 including data used in sampling, baseline analysis, intervention, and post-intervention analysis.

3.3.4 Econometric approach

The estimator of interest is the average treatment effect (ATE), calculated as

$$\hat{\tau} = E[Y_{it}(1) - Y_{it}(0)] \dots\dots\dots (3.1)$$

where $Y_{it}(1)$ and $Y_{it}(0)$ are the potential outcomes for the household i 's water consumption at time t for the treated and control groups, respectively (Ferraro & Miranda, 2017)¹⁴. As noted by Gertler et al. (2016), the ATE can be calculated in different ways including the regression framework. This study estimates the ATE using a difference-in-difference (DiD) estimator in a regression framework following the previous literature (Brick et al., 2023; Ferraro et al., 2011; Ferraro & Price, 2013). The regression model that allows the study to examine the effect of social norms on water conservation behaviours by households in 2×2 DiD design is specified as:

$$Y_{it} = \alpha + \beta Treatment_{it} + \gamma Post_{it} + \delta(Treatment_{it} \times Post_{it}) + \eta Bill_{i,t-1} + \mu_{my} + \varepsilon_{it} \dots\dots\dots (3.2)$$

where Y_{it} is water used by household in cubic meters (m^3), $Treatment_{it}$ is treatment indicator indicating whether a household is in a treatment or control group, $Post_{it}$ is the post-treatment dummy variable showing whether the treatment has started or not, $(Treatment_{it} \times Post_{it})$ is

¹⁴ In a randomized experimental design, ATE is the same as the Average Treatment effect on the treated (ATT) because the conditional, mean independence assumptions are satisfied.

the interaction term for the treatment indicator and time indicator, $Bill$ is the water bill for the previous month, μ_{my} indicates month-by-year dummy variables and ε_{it} is the error term. In model (3.2), δ which is the coefficient of $(Treatment_{it} \times Post_{it})$ indicates the DiD's ATE of the intervention, β provides the difference in water consumption by households in treatment and control group and γ indicate the difference in water use between the two time periods. Regardless of the treatment being exogenous due to randomisation, I included lagged water bills and month-by-year dummies as control variables to improve the accuracy of estimates.

In this study, households received treatment over time (from January 2023 to June 2023) and treatment is received by all targeted households at the same time each month meaning treatment is not staggered. The study estimates model (3.2) using a fixed effects estimator and with standard errors clustered at the ward level. A fixed effects estimator is suitable in impact evaluation studies as it provides unbiased estimates of the ATE whilst requiring minimal knowledge of the individual units of observation (Imbens & Wooldridge, 2009; Landon et al., 2018). Further, the use of a fixed effects estimator means that the study was not able to estimate the parameter β , the coefficient of the variable treatment since the household's treatment status did not change in the base, intervention, and post-intervention periods. This is also expected since a fixed estimator cannot estimate time-invariant variables as they are averaged out (Angrist & Pischke, 2009). This means factors such as household size and property size that can affect household water consumption are controlled for assuming they do not systematically change between pre-and post-treatment periods. Using DiD implies invoking the parallel trend assumption and some loss of degrees of freedom since more estimators are to be obtained, but this enables to control for time-fixed effects and variables such as water bills which may influence water consumption.

Recent literature on DiD concurs that the unbiasedness of the DiD estimator relies on the parallel trend assumption (Callaway & Sant’Anna, 2021; Rambachan & Roth, 2023; Roth et al., 2023). The parallel trend assumption states that the difference in water usage between the treatment and control group should be constant over time in the absence of the treatment implying that only the intervention will induce differences from this common trend (Cunningham, 2021). The parallel trend assumption can be examined by both visualising the trends and statistically testing for any difference between the control and treatment groups in the pre-intervention period. This study employs both approaches to the parallel trend’s assumption.

3.3.5 Balancing and baseline analysis

The analysis of the pre-intervention period comprised balancing checks for randomisation, the intervention period, and parallel trends assumption checks. I determined the eligible targeted population and randomised wards into treatment and control groups and selected sample households using data from June 2021 to July 2022. Before the intervention, I checked for balancing using this data set. The results for balance checks on average monthly water consumption, median monthly consumption, average monthly water billing, and total water billing, total collection and average monthly collection are in Table D.1 in the Appendix. With the p-values being greater than 5%, the results show no evidence of statistical difference between treatment and control groups considering average monthly consumption, median monthly consumption, total billing, and average monthly billing.

Treatment was continuous in the period January 2023 to June 2023. The first water usage report was sent at the end of January 2023 and the last usage report was sent at the end of June 2023. Considering that residential water usage is post-paid, household response to the monthly

intervention is recorded in the next month after receiving the water usage report. For example, the first report was sent at the end of January, with the household's response to the report (intervention) being captured in February's water bill report; the second report was sent at the end of February, but the household behavior for the report is captured in March's bill statement. In other words, the household received treatment in one month and I observed the effects in the next month throughout the intervention period. For this design, data for February 2023 – July 2023 was used to examine the behavioural effects of sending water usage reports during the intervention period.

Moreover, water consumption is usually characterised by seasonal variations with water usage being higher/lower in some seasons/periods. The study, thus, found it intuitive to cater for seasonal variations by considering the base period as the same months in the previous year corresponding to the intervention period, an approach also used by Jaime Torres and Carlsson (2018) and Brick et al. (2023). Thus, the pre-intervention or base period data is the February 2022-July 2022 period with the intervention period data for February 2023-July 2023 being used. In Table 3.1, findings for a balancing test for the baseline period and trend tests are presented and in Figure 3.2, the trends in water consumption are visualised.

Table 3.1: Balance and trend assumption tests (February 2022 to July 2022)

VARIABLES	Dependent variable = water consumption		
	(1)	(2)	(3)
	Balance test	Trend analysis	Trend analysis
Treatment	-2.51 (2.35)	-13.63 (11.35)	-11.48 (11.23)
February 2022			11.87 (7.53)
March 2022			5.06 (7.79)
April 2022			14.95* (8.48)
May 2022			2.54

			(6.86)
June 2022			13.47*
			(8.02)
February2022 × Treatment			-1.42
			(8.37)
March2022 × Treatment			-1.38
			(9.40)
April022 × Treatment			-2.93
			(9.94)
May2022 × Treatment			0.52
			(7.98)
June2022 × Treatment			-2.78
			(9.27)
Pre-trend		-1.33	
		(1.31)	
Treatment × pre-trend		0.18	
		(1.43)	
Constant	124.76***	130.75***	116.78***
	(6.96)	(9.70)	(9.07)
Observations	9,600	9,600	9,600
R-squared	0.00	0.00	0.00

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors are clustered at the ward level. The dependent variable is a normalised consumption variable.

Column (1) in Table 3.1 shows the balancing test results with the coefficient of the treatment variable being -2.51 and statistically insignificant at the 5% level. These results are obtained from a regression of the household's monthly water consumption on the treatment variable, which is estimated with ordinary least squares estimator¹⁵. This indicates that there is no statistical difference in water consumption between the treated and control groups for the period February 2022 – July 2022.

¹⁵ This model is algebraically specified as $Y_i = \alpha + \beta Treatment_i + \varepsilon_i$ where Y_{it} is household i 's monthly water consumption in kiloliters, $Treatment_{it}$ is the treatment indicator variable = 1 for the treatment group and zero for the control group, and ε_{it} is the error term. The constant β measures the difference in consumption between treatment and control group and α measures the average consumption for the control group. This model was estimated with Ordinary Least Squares regression (OLS).

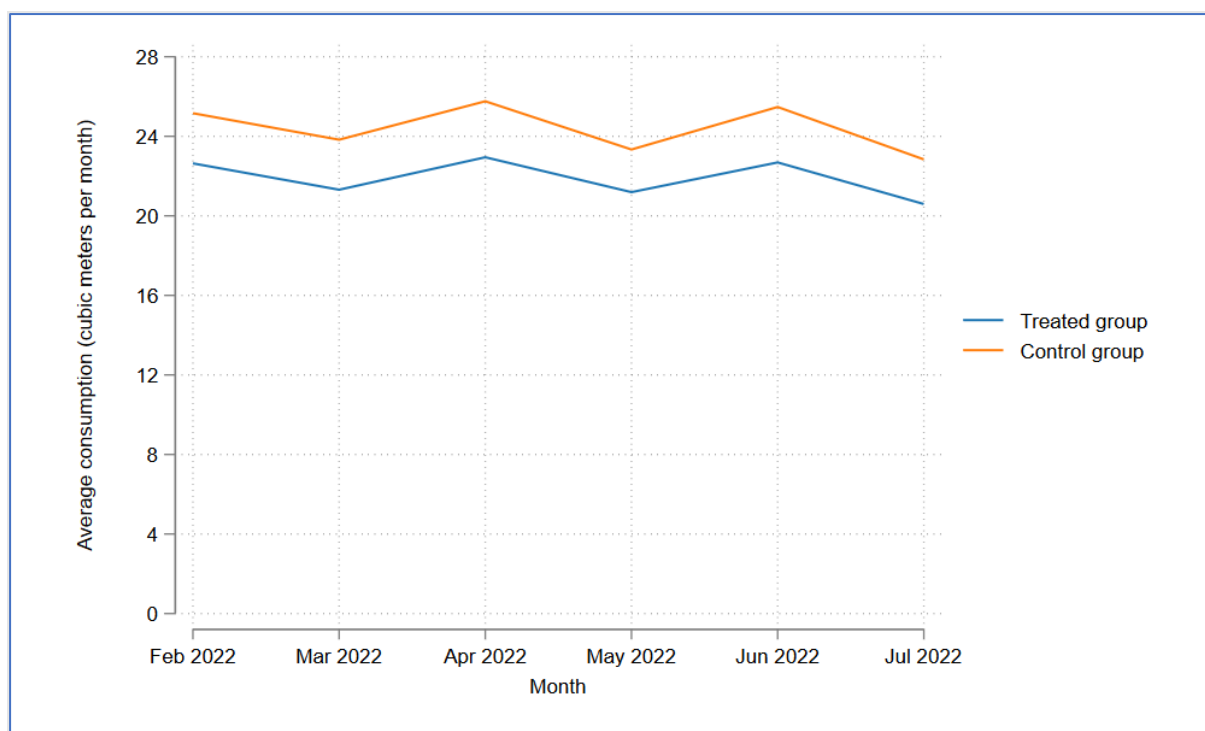


Figure 3.2: Trends in households water consumption (February 2022 - July 2022)

Source: Authors

Figure 3.2 shows that the trends for average monthly water consumption are comparable between February and July. The figure also shows that water usage is systematically higher for the control group than for the treated group. In addition, water consumption declined from 25.16 in February to 22.84 in July for the control group and from 22.63 in February to 20.59 in July for the treated group. Although the decline is small, it is evidence of seasonality in water usage.

The results of a formal test of the parallel trends are depicted in column (2) and column (3). The study first estimates a model with water consumption per month as the dependent variable while pre-trend (a constant linear time trend for February 2022 to July 2022) and interaction of

treatment and pre-trend variables are explanatory variables¹⁶. The results of this model are shown in column (2) of Table 3.1. For this case, the interaction term is not statistically at the 5% level showing that there was no statistical difference in water consumption between the treated and control groups over time. This is evidence of the same trend between the treated and control groups. The treatment indicator and the pre-trend is also not statistically significant.

In line with Brick et al. (2023), this study also estimates a model of water consumption per month as the dependent variable with monthly dummies as well as interactions of month dummies and treatment variables as explanatory variables¹⁷. The results for this model are shown in column (3) of Table 3.1. Only April and June dummies have statistically significant coefficients (at 10% level) showing that water consumption was higher in April and June by 14.95% and 13.47% compared to July, respectively. Interaction terms for month dummies and treatment variable not statistically significant indicating no differences in water consumption between the treated and control groups in the pre-intervention period. Hence, the results in column (2) are in line with the results in column (3) implying the validity of the parallel trend assumption in the pre-intervention period.

¹⁶ This model is specified as $Y_{it} = \alpha + \beta Treatment_i + \delta Pretrend_t + \gamma(Treatment_i \times Pretrend_t) + \varepsilon_{it}$. The coefficient γ shows whether the trend assumption is satisfied or not. The dependent variable is water consumption per month in m³.

¹⁷ This model is specified as $Y_{it} = \alpha_o + \alpha_1 Treatment_i + \sum_{t=1}^n \alpha_{2t} Month_t + \sum_{t=1}^n \alpha_{3t} (Month_t \times Treatment_i) + \varepsilon_i$ where *Month* is a dummy variable indicating the month in question for $Month \in \{February, March, \dots, July\}$ and $(Month \times Treatment)$ is an interaction of Month in question and treatment variable. The month of July was the base period. Standard errors were clustered at ward level. The coefficients of interaction terms show whether the trend exist or not.

3.4 Results and Discussion

3.4.1 The intervention period

Since households in Dar es Salaam use post-paid water meters and households were receiving water usage reports at the end of each month from January 2023 to June 2023, the effect of the intervention is first recorded in February 2023. Hence, with the full intervention period being January 2023 – June 2023, the corresponding data capturing household's response is for the period February 2023 – July 2023. A DiD estimation for this period with the February 2022 – July 2022 data representing the base period data is then applied. The results of the DiD estimation are shown in Table 3.2.

Table 3.2: ATEs in the intervention period

VARIABLES	(1) Feb	(2) Feb-Mar	(3) Feb-Apr	(4) Feb-May	(5) Feb-Jun	(6) Feb-Jul
Treatment × post	-1.18 (1.43)	-1.34 (1.29)	-1.51 (1.05)	-1.55* (0.90)	-1.39* (0.81)	-1.49* (0.77)
Post	-2.86*** (0.99)	-4.13*** (0.95)	-5.42*** (0.72)	-5.27*** (0.79)	-5.20*** (0.74)	-6.11*** (1.00)
Water bill (-1) (000's)	-0.17*** (0.05)	-0.06*** (0.02)	-0.02 (0.01)	0.01 (0.01)	0.03** (0.01)	0.05*** (0.01)
Month-by-year dummies	No	Yes	Yes	Yes	Yes	Yes
Constant	29.41*** (1.58)	24.83*** (0.78)	25.18*** (0.70)	21.81*** (0.68)	23.01*** (0.62)	19.75*** (0.89)
Observations	3,200	6,400	9,600	12,800	16,000	19,200
R-squared	0.15	0.04	0.03	0.04	0.04	0.05
No. of households	1,600	1,600	1,600	1,600	1,600	1,600

*The dependent variable is household monthly water consumption (m^3). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors clustered at ward level in parenthesis.*

Results in Table 3.2 and Figure 3.2 show the behavioural effects of the intervention during the intervention period. Water usage reports are sent at the end of each month of the intervention period; hence the study estimated the ATEs using available intervention data up to the end of the month in question. This allows us to trace the evolution of ATEs for this study, which is

shown as the coefficient of the interaction term (Treatment $\times$ post). Column (1) – Column (5) shows the cumulative ATEs after every month of sending water usage reports and column (6) shows the effect for the full intervention period where data for February – July is used. The results presented in Table 3.2 and Figure 3.2 are for models with month-by-year dummies. Models with no month-by-year dummies are also estimated and the results are presented in Table D.2 in Appendix D.2. As shown in Table 3.2, the coefficient of the interaction of Treatment and Post is not statistically significant in column (1)-column (3). The study observes statistical significance (at 10% level) and positive effect of the intervention from column (4)-column (6). Regardless, the ATEs have comparable magnitudes through the intervention period. These findings show that the cumulative impact is realised in the fourth month of sending water usage reports.

Focusing on the full intervention period (February to July), a positive impact of sending water usage reports on household water consumption can be observed. Sending water usage reports leads to a decrease in household water consumption by 1.49m³ on average. Figure 3.3 visually presents the results and shows that the ATEs are relatively stable during the intervention period, although they are not statistically significant in the first 3 months.

Coefficients of Post are negative and statistically significant at 1% level in all results shown in Column (1) – Column (6) implying that monthly water consumption was lower in the post period compared to the base period by 2.86-6.11m³ on average. For the lagged water bill, the coefficients are negative and statistically significant at 1% in column (1) and column (2) implying that an increase in the previous month's water bill by TZS1,000 was associated with a reduction in water consumption in the current month by 0.17m³ for the month of February and 0.06m³ for February – March period. This is expected since households could have limited

income hence, they tend to reduce water consumption in the current period if they paid more in the previous month. However, the coefficient of the water bill is positive for the February–June and February–July periods, indicating that household water consumption in the current period was associated with increased consumption during these intervals. This result was unexpected, as one would typically anticipate a negative relationship due to conservation efforts and the need to save money. A possible explanation lies in seasonal variations: these months coincide with cooler conditions in Dar es Salaam, during which households may take longer, warmer showers and rely more heavily on tap water for activities such as gardening due to reduced rainfall. Hence, the increased water usage may reflect behavioural and environmental factors specific to these months.

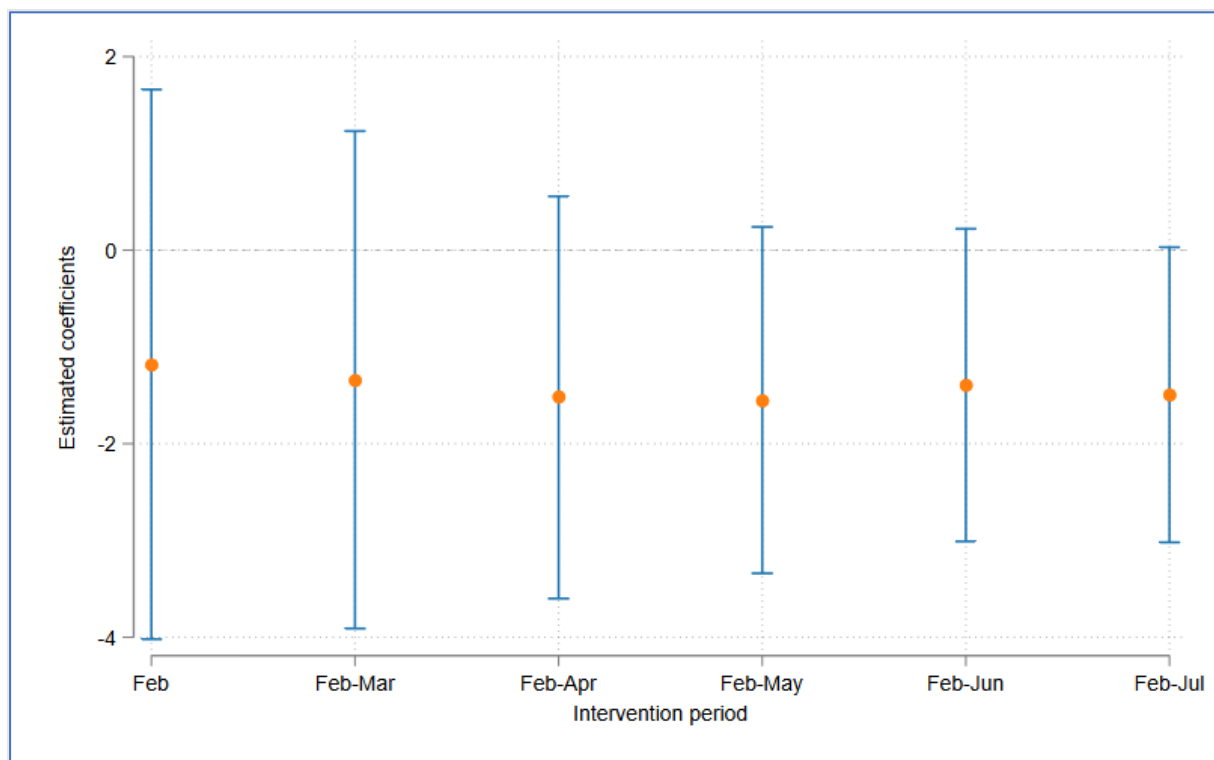


Figure 3.3: ATEs in the intervention period

Source: Authors

These findings show evidence of the positive effect of social comparison information on water-saving behaviour since water usage declined by 1.49m³ during the full intervention period. The results lend credence to the social norms theory, which posits that people's behaviour is influenced by their perceptions of what is considered normal or acceptable within their social group. The study's findings are consistent with previous RCT studies which found a positive effect of social normative comparison on household water-saving behaviour (Brent et al., 2020; Brent et al., 2015; Brick et al., 2023; Datta et al., 2017; Ferraro & Price, 2013; Jaime Torres & Carlsson, 2018). Although the impact was found to be positive, the results appear relatively weak, as the effect only becomes evident in the third month following the dissemination of reports. A potential explanation for this delayed response is that households required time to adjust their water use behaviours and were therefore unable to react immediately to the information provided. This is plausible given the study's context in a developing country, where many households are low-income and may face financial constraints that hinder their ability to adopt water-saving technologies or implement conservation measures promptly. Previous studies provided above reported statistically significant water reductions in the first month of sending reports.

For easy comparisons with previous literature and contextualisation of study's findings, ATEs in percentage forms are estimated. The study follows Allcott (2011), Jaime Torres and Carlsson (2018), Brent et al. (2020) and Andor et al. (2022) to estimate a regression model with household monthly water consumption normalised by post-period average consumption for the control group and multiplied by 100, as a dependent variable. This allows us to interpret the ATEs as average percentage changes in water consumption. Brent et al. (2020) noted that this approach enables the preservation of treatment effects of very high-water users, which are normally reduced by a logarithmic transformation. In this approach, a similar model

specification to the one in model (2) was used, which yields the results in Table 3.2. The results of models with no interaction terms are also estimated and are presented in Table D.2 and Figure D.1 in Appendix D.

Similar to the findings in Table 3.2, the study established statistical significance from the 4th period of sending water usage reports. Specifically, the ATE for the full intervention period is -7.65 indicating a 7.65% reduction in water consumption by the treated group compared to the control group. These findings are consistent with previous RCT literature taking a norm-based approach to behavioural changes in the context of water conservation. The impact according to Ferraro et al. (2011) was 4.8%, Katz et al. (2016) found a 7.6% reduction, Jaime Torres and Carlsson (2018) found a 6.8% reduction, Datta et al. (2017) found a 3.7-5.6% reduction and Brick et al. (2023) found a 0.6%-1.3% reduction in household water consumption.

From a household perspective, a 1.49m³ reduction in water consumption implies saving about TZS2,725.66 per month ($\approx$ US\$1.19/month). This is calculated with a price of water by DAWASA of TZS1663/m³ + 1% EWURA's fee. From the perspective of the Water Authority, a reduction in water consumption by households implies a decrease in revenue. With 800 households in the treated group, this implies a TZS2,180,528/month ($\approx$ US\$950/month) reduction in Authority's revenue. Further, with an average consumption per person in a low-income household being 0.07m³/day (Ministry of Water, 2020), a five-people low-income household will consume 0.35m³/day. These results, therefore, imply that 1.49m³ saved each month by high-water users would be sufficient to be used by a low-income household with five people for about 5 days. Further, this insinuates that a five-people low-income household uses about 10.5m³/month and 1.49m³/month saved by a high-water user household means 800 high-water users could save 1,192m³/month due to the intervention (equivalent to a subsidy level of

TZS2,180,528/month or about US\$950/month). Hence, about 114 low-income households could be served each month from the water-saving of 800 high-water users at a subsidy of about US\$8. This support could be raised through applicable government programs such as subsidies. This analysis, however, assumes that low-income users are typically low water consumers which is a contentious issue in the literature, particularly in the context of developing countries (Cook et al., 2021; Hussien et al., 2016; Katz, 2020). This presents a potential limitation of this analysis as low-income households are not necessarily low water users (Cook et al., 2021). While this study did not collect income data, billing records, property observations, and qualitative field notes suggest that high users often reside in larger homes with multiple water-consuming amenities (e.g., gardens, washing machines, car washing), and in some cases operate informal water-based businesses. Hence, a positive correlation between income and water consumption is assumed.

These findings point to the effectiveness of social norms in promoting water-saving behaviour by households. Even though this has potential revenue loss to the Authority, the gains associated with water-saving behaviour far outweigh the revenue loss to the Authority. This is because Dar es Salaam City is experiencing water scarcity amid climate change, and high rates of urbanisation and informalisation necessitate the need to save water (Kabote, 2024; Mvena, 2016). Furthermore, saving water reduces energy used in pumping, treating, and distributing water; hence, by saving water, energy required to supply water to residents can be reduced. This has further implications for energy production and greenhouse gas emissions. In addition, saving water provides financial incentives: when less water is used money on water treatment and distribution is also reduced.

3.4.2 Post-intervention impact

The study considered the post-intervention impacts of the intervention for the first 5 months after the intervention. This means data for the period August 2023-December 2023 and the corresponding base period are used. Full results of the post-intervention impact are presented in Table 3.3.

Table 3.3: Post-intervention impact

Variables	(1) After 1 month	(2) After 3 months	(3) After 5 months
Treatment × Post	-1.10 (1.11)	-2.05** (1.03)	-1.62* (0.85)
Post	-0.13 (0.72)	0.68 (1.14)	-4.72*** (0.71)
Water bill (-1) (000 's)	0.19*** (0.04)	-0.01 (0.06)	0.06 (0.05)
Month-by-year dummies	No	Yes	Yes
Constant	13.67*** (1.39)	18.86*** (2.51)	19.51*** (1.13)
Observations	3,200	9,600	16,000
R-squared	0.16	0.01	0.03
No. of households	1,600	1,600	1,600

The dependent variable is the household's monthly water consumption (m³). *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at ward level in parenthesis.

Column (1)-column (3) in Table 3.3 shows the effect of the social comparison for selected periods after sending water consumption reports to households was halted. ATEs for each of the five months are presented in Table D.4 in the Appendix and visualised in Figure 3.4.

For the first month without water consumption reports, the ATE is not statistically significant. The table highlights that the ATE is statistically significant after 3 months (at a 5% level) and after 5 months (at 10% level). After 3 months, water consumption declined by 2.05 m³ and by 1.62 m³ after 5 months. This is equivalent to a 9.88% decline after 3 months and an 8.18% decline after 5 months when the dependent variable is water consumption normalised by the

post-period average control group consumption. Compared to the control group, the treated group reduced consumption by 9.88% and 8.18% after 3 and 5 months, respectively, without receiving treatment.

The results show that the program encourages water-saving among households in Dar es Salaam, although the impact is now higher than that of the intervention period. For the intervention period, statistically significant ATEs were between -1.34 and -1.55 while for the post-intervention period, ATEs were between -2.05 and -2.30, indicating higher program impact in the post-intervention period. These differences are remarkable since households may take time to adjust their behaviours owing to an intervention. It might have taken time for households to adjust their behaviours by looking for alternative and sustainable ways to save water by bathing for less time and using less water, for example. These findings also imply that the treatment period of six months was long enough for households to come up with water-saving methods (Céspedes & Morales-Pinzón, 2020). These findings are in line with the findings of Brick et al. (2023), which established the positive impact of social information comparison on water-saving behaviour in Cape Town after the intervention ended. Brick et al. (2023) showed that the social information campaign had a sustained increasing treatment effect for the first 18 months after the end of the intervention. However, these findings are relatively weak, as a negative and statistically significant impact is observed only after three months without the distribution of water usage reports, and the magnitude of this effect diminishes over time. This outcome highlights the limited effectiveness of the intervention, suggesting that without continued delivery of the reports, the impact on water consumption tends to diminish over time. Nonetheless, to draw more definitive conclusions, data spanning a longer time frame may be required to assess sustained behavioural changes in water consumption in the absence of regular feedback

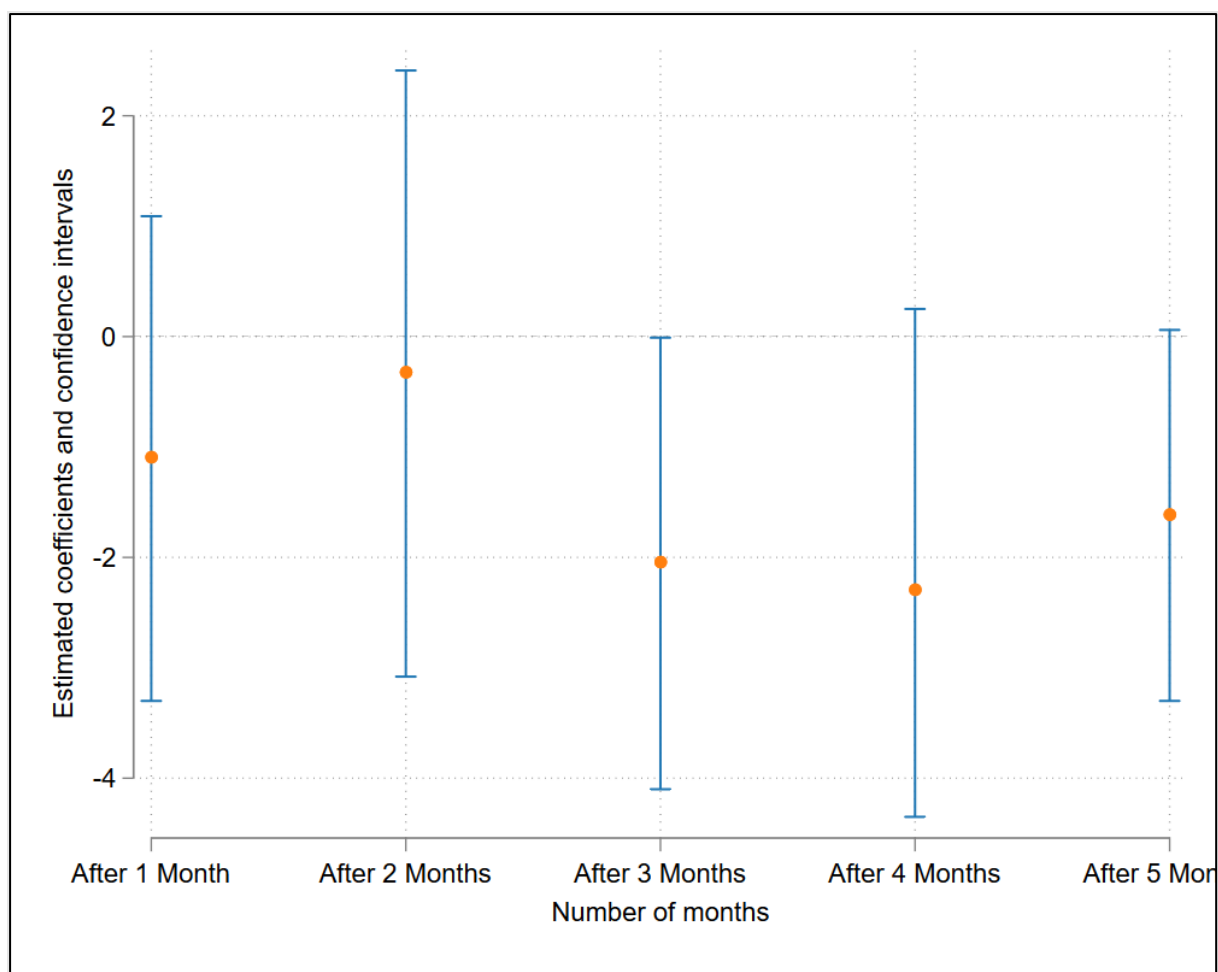


Figure 3.4: Impact in the post-intervention period

Source: Authors

3.4.3 Combining the intervention and post-intervention period data

Further, the study estimates the impact of the intervention considering both the intervention period and post intervention period using similar specifications as in previous analyses. The results of this analysis are reported in Table 3.4.

Table 3.4: Results for the combined intervention and post-intervention period

VARIABLES	(1)	(2)
	Consumption	Normalised consumption
Treatment × Post	-1.34** (0.58)	-6.87** (2.96)
Post	-3.28***	-16.78***

	(0.49)	(2.51)
Water bill (-1) (000's)	0.08***	0.40***
	(0.02)	(0.12)
Constant	18.95***	96.90***
	(0.93)	(4.73)
Observations	36,800	36,800
R-squared	0.03	0.03
Number of households	1,600	1,600

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Column (1) in Table 3.4 shows the results of the model with the dependent variable being consumption while column (2) contains results for a model with normalised consumption as the dependent variable. This means column (1) contains changes in monthly consumption while column (2) shows coefficients that can be interpreted as percentage changes. Results in column (1) shows that the intervention leads to a reduction in monthly water consumption by 1.34m³. Further, considering a model with normalised consumption, targeted households reduce monthly water consumption by 6.87% compared to the untargeted groups. These findings are consistent with the results of the previous analysis which independently analyse the intervention period and post-intervention period. This further shows that the intervention period is effective in reducing water consumption as in other studies (Andor et al., 2022; Brick et al., 2023; Jaime Torres & Carlsson, 2018; Katz et al., 2016).

3.5 Conclusion and policy implications

This paper examined the role of a social information comparison program on households' saving behaviour, which involved providing households with monthly water consumption levels compared to the median consumption level in their neighbourhoods. The paper draws from a few studies on water and energy conservation and designs an RCT. The study allocates 800 households to treatment and 800 households to the control group, with the treated group

receiving water usage reports in comparison with the neighbourhood median. The intervention was introduced for six months from January 2023 to June 2023. The study employs a DiD and estimate the ATEs during the intervention period and five months after the intervention ended.

The study showed that the intervention had no immediate impacts as the impact was first realised in the fourth month of sending water usage reports. For the full intervention period, average treatment effects showed that targeted households reduce water consumption by 1.49m^3 corresponding to a 7.65% decline if a dependent variable is consumption normalised by the post-treatment consumption of the control group. Furthermore, the ATE for the five months after the intervention shows that the treated group reduces water consumption by 1.62m^3 , which is equivalent to an 8.18% decline if normalised consumption is used as the dependent variable. These findings show the effectiveness of information campaigns, particularly social information comparison programs in motivating households to save water.

Findings of this study have important policy implications. Considering the water scarcity situation and the growing demand for domestic water in Dar es Salaam, this study recommends the use of information campaigns by water authorities to encourage households to save water. Information campaigns are less costly, less difficult to implement and less likely to face public and political resistance compared to alternative demand management instruments such as tariffs. Further, using information campaigns by DAWASA implies that the inequity effects of water demand management instruments such as tariffs which fall heavily on the poor are absent. Promoting water conservation is recommended in this paper despite the policy having the potential to reduce revenue to the Water Authority. This is because using less water is imperative considering the current water scarcity situation, the potential to save money in

treatment and supplying clean safe water for drinking to households and the potential to save energy from treating, pumping, and distributing water to households.

This study was conducted among higher water users within a uniform pricing setup. The findings not only demonstrate the effectiveness of social comparison messaging in promoting water conservation among high use households but also highlight important equity and policy implications. Specifically, the observed reductions in water consumption by high-use households suggest that water savings could help improve access for low water users who typically use less water and face greater income constraints. In this way, demand-side interventions such as social comparison messages can support a more equitable distribution of water resources, enabling low use households to access water more easily, while high water use households, who may have more means to adopt alternative sources or technologies, contribute more to conservation efforts. To ensure the financial sustainability of water authorities, these interventions could be complemented with a block pricing structure, where higher water users pay progressively more per unit of water. By combining informational campaigns with progressive pricing, utilities can both manage demand effectively and promote equity, ensuring that water is more affordable and accessible for low-income households while still covering operational costs. Since the focus of the study was on high water users, the results may correspond to upper bound effects meaning that low water users are likely to have lower impacts to those reported in this study. Further, this implies that low water users in the current period can be high water users in the future period and these results can still be applicable to them.

The findings show that information campaigns can effectively reduce household water consumption suggesting strong potential for non-price interventions to support sustainable

resource use. However, this success must be considered alongside the operational realities of water utilities. Reduced consumption can lead to lower revenue for utilities, which may hinder their ability to maintain and upgrade infrastructure especially in areas where access to clean water is already limited. Therefore, while demand-side management through behavioral interventions is promising, it must be integrated into a broader strategy that ensures utilities remain financially sustainable. This could involve the already suggested models like the tiered pricing models, cross-subsidies or policy support to offset revenue losses.

This study is without limitations. Firstly, although some effects are observed I still consider the intervention period of six months to be relatively shorter to ensure adequate behavioural changes necessary to guarantee the effectiveness of the campaigns. Secondly, I had access to data for only five months after the intervention ended. This means I could not estimate the longer-run impacts of the intervention to examine if the ATEs could wane off with time as established in studies on household behavioural effects of social norms (e.g., Ferraro and Price (2013) and Ayres et al. (2012)). Thirdly, the study uses a simplified version of water usage reports for the experiment and therefore could not explore the cost-effectiveness of the information campaign. Lastly, I only test for social norms, and could not determine if they are more effective compared to other types of messages to better advise water authorities in Dar es Salaam.

Future research can use a longer intervention period and examine the impact of the program for longer periods e.g. at least 12 months after the intervention ended. Furthermore, future research can include different types of social messages e.g. tips to save water and social recognition messages and compare which ones are more effective in motivating households to save water.

Chapter 4: Adoption of water-saving technologies among urban households in Tanzania

Abstract

This study investigates the adoption of water-saving technologies by households in Dar es Salaam, Tanzania with a focus on greywater technology. The study uses data on 962 households in Dar es Salaam and employs a Poisson and Logit models to examine the factors affecting the adoption of water-saving technologies. Further, a choice experiment is conducted to examine the preferred attributes of greywater technologies and the corresponding WTP. The conditional logit, generalised logit and latent class models are used to analyse the choice experiment data. The Poisson model reveals that age, education, income, membership in social groups and awareness of water-saving technologies are the factors affecting the adoption of water-saving technologies. The choice experiment reveals that households prefer greywater technologies with more lifetime, less contamination and lower smell but the high cost of acquiring and maintaining the technology yields disutility. The marginal WTP for greywater technology ranges between TZS599,895.33 (US\$260.82) and TZS714,890.78 (US\$310.82), which is between 9% and 11% of the average annual income for a household head. The study recommends governments and water authorities to encourage households to adopt greywater technologies through subsidies and lower taxes and to use campaigns to tackle misinformation and perceptions against greywater as well as the use of credit schemes to promote the adoption of greywater technology.

4.1 Introduction

Access to enough water of high quality has implications for health outcomes, food security, agricultural productivity, and industrial growth. Water underlies the lives of humans, animals, and plants and provides support for most economic activities. Indeed, water is a major foundation of life and livelihoods. At the household level, clean water is required for drinking, cooking, bathing, washing, and other household needs. The decline in water availability for human consumption is made worse by the depletion of groundwater sources and freshwater bodies and increasing contamination and wastage of suitable water thus undermining the quality of life and human survival (Carrard et al., 2019; Dwivedi et al., 2018; Hasan et al., 2019; Koop et al., 2019; Tzanakakis et al., 2020). There are more than 2.4 billion globally people still lacking access to safe domestic water while between 2 and 3 billion population globally suffer from water scarcity for at least a month every year (United Nations, 2023b). These figures, by business-as-usual projections, are expected to increase from 930 million in 2016 to 1.7-2.4 billion people by 2050. (United Nations World Water Assessment Programme, 2018).

The complexities of water scarcity in low-income, medium, and developing countries are enormous, and diverse and have far-reaching dimensions (Josephine, 2019; Oki & Quiocho, 2020). Most of these countries, by their relatively poor economic status with several competing development goals, do not have the financial capacity to invest in efficient water supply infrastructure to ease the drain on freshwater sources (Lakmeeharan et al., 2020). Rapid population growth coupled with the pace and structure of urbanisation in developing countries further worsens water scarcity. Besides, the pace of expansion in urban centers in these countries is often not matched by commensurate scale in urban infrastructures and facilities

capable of sustaining the underlying urbanisation process. As a result, many resources, typically water resources in urban areas, get overburdened and eventually scarce relative to the demands.

Attempts to solving water scarcity problems have engaged policymakers and stakeholders now to DSM such as changing household behaviour, using tariffs and restrictions, and promoting the use of water-saving technologies (Aina et al., 2023; He et al., 2021; Koop et al., 2019; Legrouri et al., 2012; Millock & Nauges, 2010; van Vliet et al., 2021). Changing household behaviour can be seen as a short-term solution and it requires incentives, disincentives, education and persuasive communication while the use of water-saving technology is seen as a sustainable solution for water management at the household level. Water-saving technologies are easy to install and use, hence saving time and energy. Therefore, if the study combines changing behavior and water-saving technology, the findings can potentially reduce water scarcity.

Tanzania which is among the middle-income countries in Africa, faces challenges related to inadequate and inconsistent water supply, poor water quality, and affordability issues in urban areas (McGranahan et al., 2016). Several investigations in Tanzania have revealed the presence of significant injustices, inequalities, and disparities in accessing water (Nganyanyuka, 2017; Smiley, 2016). These issues are often rooted in the historical legacy of insufficient infrastructure dating back to the colonial era (Dill & Crow, 2014; Munro & Kweka, 2021). There are concerns regarding the sustainability of the piped water supply in Tanzania especially in Dar es Salaam city which is served by DAWASA. The current production capacity of DAWASA is $399,693m^3$ per day, while the estimated demand stands at $649,711m^3$ per day (EWURA, 2022). This discrepancy raises doubts about DAWASA's ability to fulfil its legal

obligation of providing clean drinking water to every citizen. Furthermore, achieving the SDGs target of universal water and sanitation coverage by 2030 seems unlikely in this context. The city is projected to fall short by approximately 300 million litres per day (Munro & Kweka, 2021).

To address water scarcity, a comprehensive approach is needed, combining both supply and demand management measures. This entails promoting technological advancements to encourage the widespread adoption of water-saving efficient technology, as well as fostering behavioural changes that contribute to water conservation (Thiam et al., 2021). Greywater systems are among the water-saving technologies that have received attention worldwide and current research tries to look at greywater technologies including their adoption by households. Greywater systems refer to methods used to collect, treat and reuse greywater, which is wastewater generated from domestic activities such as bathing, laundry and handwashing (excluding toilet wastewater) (Awasthi et al., 2024).

Despite extensive research on water-saving technology adoption in urban households, particularly in developed nations like Australia (Fuenfschilling & Truffer, 2016), a consensus regarding the underlying factors remains elusive, particularly in the context of developing countries. The literature primarily focuses on the institutional conditions and governance structures that facilitate the transition to sustainable water-saving technologies in urban areas. However, Thiam et al. (2021) argue that studies exploring low-income countries predominantly concentrate on economic, social, and sanitation issues related to water access (Cook et al., 2016; Fuente et al., 2016) and the effects of changing water tariffs on access for impoverished households (Whittington & Nauges, 2010; Whittington et al., 2015). Furthermore, limited evidence exists regarding the adoption of greywater systems in Tanzania, a low-middle-income

country grappling with water scarcity, particularly in urban households (Jha et al., 2019). To bridge this knowledge gap, this study utilises a choice experiment methodology to explore preferences and WTP for greywater systems by households in Dar es Salaam.

Approaches to water management in regions facing significant water shortages have frequently emphasised drastic measures such as adjusting tariffs and enforcing stringent programs to curb residential water consumption (Aina et al., 2023). Nevertheless, recent studies showed that establishing an effective water-pricing system is particularly difficult in areas with acute water scarcity (Grafton et al., 2020). In many cases, lower-income users bear a disproportionate cost for water compared to higher-income users, who generally enjoy lower rates relative to their general expenditure (Aina et al., 2023). Moreover, political will frequently hamper the effective implementation of stringent water restriction programs (Cooper et al., 2011), and their enforcement proves challenging, particularly in countries with limited institutional capacity to monitor water-use efficiency. Research has demonstrated that strict regulations tend to lose their efficacy over time as drought severity diminishes and individuals revert to their usual consumption habits (Ehret et al., 2021). To tackle these challenges, various water-saving technologies have proven to be effective. However, the widespread adoption of these technologies in Tanzania has been hindered by numerous factors and among these technologies is the greywater system (Jha et al., 2019). Therefore, the main research question raised in this study is: Are urban households in Tanzania willing to adopt water-saving technologies particularly greywater technologies amidst water scarcity? Two specific research questions are raised in this study: (i) what are the factors that affect households' adoption of water-saving technologies in Dar es Salaam, Tanzania? (ii) do households prefer adopting greywater technologies and what are the preferred attributes and WTP for the preferred greywater attributes?

Considering these questions, the study shows that a household's adoption of water-saving technologies is influenced by education level, technology awareness, income, household size and social capital. Also, households adopt more water-saving technologies as they grow old and when income increases as well as when they are members of social groups and have heard about water-saving technologies. The choice experiment revealed the importance of smell, the need for training, contamination, and the cost of technology as the preferred attributes for a greywater technology that is introduced in Dar es Salaam, Tanzania. In general, households are willing to pay a minimum of TZS389,320 (US\$169), TZS424,912 (US\$185), TZS137,230 (US\$60) and TZS189,146 (US\$82) more for a greywater system with medium contamination, low contamination, medium smell, and low smell, respectively.

The study makes a significant contribution to the field of water resource management and sustainable development by investigating the willingness to adopt water-saving technologies among urban households in Tanzania. By contributing to filling a crucial gap in the existing literature, which has predominantly focused on developed countries, this study sheds light on the factors influencing the adoption of water-saving technologies in a specific context of Tanzania, where limited research has been conducted on this topic. Further, this study provides valuable insights and practical recommendations to enhance the adoption and diffusion of water-saving technologies in urban households in Tanzania. The findings of this study have the potential to inform policy formulation, water resource allocation, and targeted interventions that promote water conservation, and better use of limited water resources, thereby leading to improved water management practices, increased water sustainability, and enhanced resilience in urban areas of Tanzania.

The rest of the chapter is organised as follows. Section 4.2 describes different water-saving technologies that can be adopted by households with a key focus on greywater technologies. Section 4.3 provides a review of literature that underpins the use and factors influencing the adoption of water-saving technologies and further highlights studies which look at preferences and willingness to pay for greywater technologies. Section 4.4 outlines the methodology used to empirically estimate willingness to pay for greywater technologies and provides answers to the research questions. Section 4.5 presents the descriptive and empirical results of the study while section 4.6 provides a discussion of the findings. The last section 4.7 summarises the study and provides possible policy options that can be drawn from the study. It also provides the limitations of the study and possible areas for further research.

4.2 Description of greywater-saving technologies

Water-saving technologies that can be adopted by households include a greywater system, bathroom faucet, kitchen faucet, shower head, efficient toilet, dishwasher and washing machines and water tanks for harvesting rainwater. According to the literature, ease of use, costs, lifetime, and other socioeconomic characteristics influence households' choice of water-saving technologies. The use of the greywater system is seen as directly linked with improving water quality and mitigating water scarcity (Mahmoudi et al., 2021; Morel & Diener, 2006). Greywater comprises wastewater coming from baths, showers, kitchen sinks and washing machines except for black/toilet water. Greywater contains lower concentrations of microbial contents and chemical characteristics compared with sewage water. According to Amaris et al. (2021), the household sector can produce approximately 50% of the total wastewater. The use of greywater reduces the consumption of fresh water by households since it can be used for carwash, toilet flushing, fire protection, green roofs, green walls, and irrigation of non-food

plants. Through a collection of greywaters, cities remain clean. The most common use for greywater reuse in urban areas is flushing toilets, which can greatly reduce the water demand of homes by up to 30% (Mahmoudi et al., 2021). The greywater system has been widely used in developed countries but less in low- and middle-income countries. Worldwide, there has been concern on health-related issues regarding the use of greywater technology. This includes the likelihood of contamination of the technology, the expected smell and the ease of use and installation of the technology. Further, costs of purchasing and installation remain a barrier to adoption by most households. In addition, households are likely to adopt durable technology.

The greywater system comprises different technologies ranging from simple to advanced methods of handling, managing, and treating grey water for both potable and non-potable uses. Thiam et al. (2020) provided examples of the technologies. The simple technology can be described as the stand-alone greywater tank and is not connected to the plumbing structure that is linked to the toilet while the advanced technology treats the greywater and returns it to the system. A simple technology is illustrated in Figure 4.1 and advanced technology is illustrated in Figure 4.2. Both technologies collect, store, and treat greywater from various sources within the households (bath, kitchen, laundry, shower etc.). Morel and Diener (2006) grouped the greywater system treatment into primary treatment and secondary treatment. Primary treatment includes primary treatment in ponds, use of sedimentation/septic tank, flotation/grease trap and coarse filtration. Secondary treatment includes the removal of organic matter and reduction of pathogen and nutrient loads, which uses different methods such as anaerobic filtration, vertical and horizontal filters, and a pond system (Morel & Diener, 2006). In the choice experiment, the study proposed a simple greywater technology which costs between TZS1,500,00 (US\$500) to TZS2,300,00 (US\$1,000). A simple greywater technology is simple to install and more affordable compared to an advanced system which costs a minimum of about

TZS2,760,000 (US\$1,200) depending on the irrigation area, number of bathrooms, and number of bedrooms among other factors. Given that Tanzania is a low-income country with per capita income of US\$1,080 which is lower than the sub-Saharan Africa's average per capita income of US\$1,604.3 (World Bank, 2024), it seemed intuitive to focus on simple greywater technology which is relatively cheap.

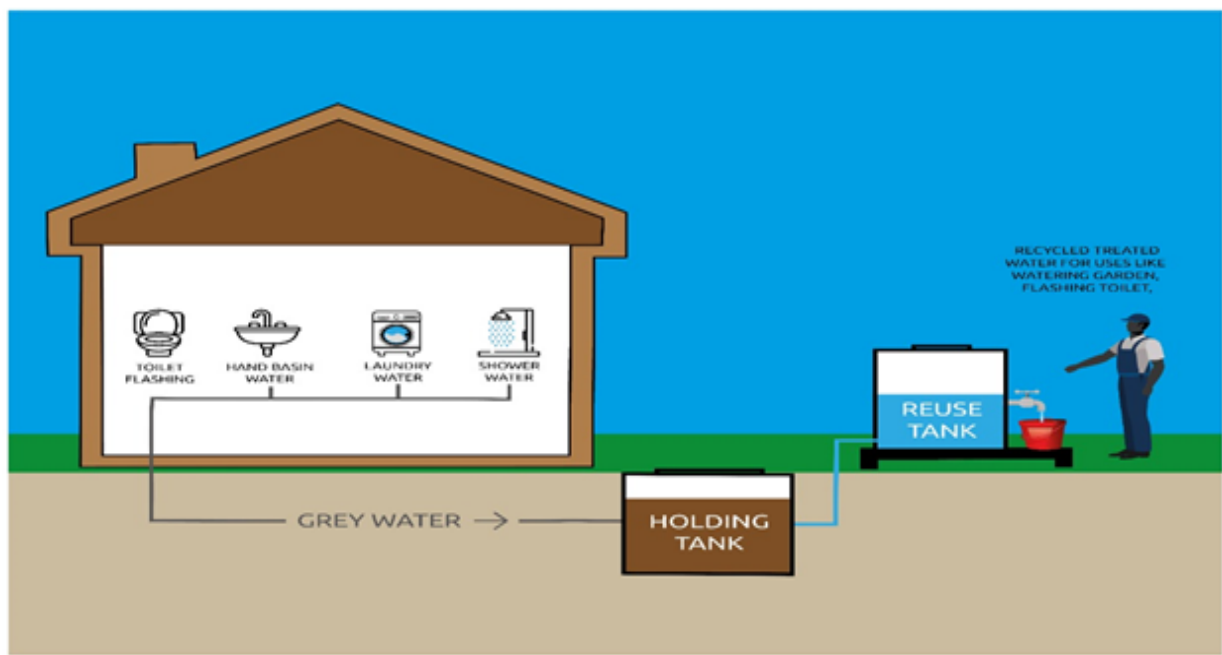


Figure 4.1: Description of Simple Greywater Technology

Source: Authors

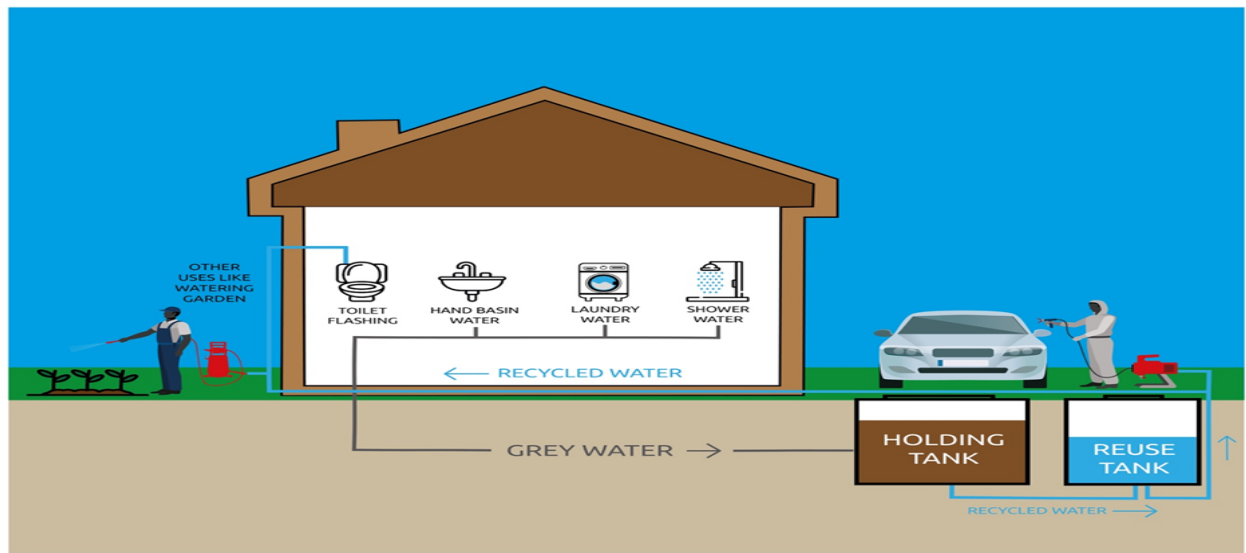


Figure 4.2: Description of Advanced Greywater Technology

Source: Authors

4.3 Review of the Literature

The Diffusion of Innovations theory underpins the adoption of water-saving technologies. According to the theory, the adoption of new technologies is influenced by the characteristics of the innovation itself, the communication channels used to promote it, and the social system in which it is introduced. In the case of water-saving technology, factors such as its relative advantage over traditional water usage methods, its compatibility with existing water systems, and the ease of use and accessibility of the technology may influence its adoption. Furthermore, Thiam et al. (2021) indicated that the analysis of technology diffusion frequently emphasises two primary factors as key catalysts for the adoption of more efficient and superior technologies: technology-push and demand-pull (Edler & Yeow, 2016; Ghisetti, 2017). According to the demand-pull perspective, technology diffusion primarily relies on the demand generated by consumers. On the other hand, producers innovate and develop technologies that

align with consumers' demands, thereby stimulating a technology push (Hötte, 2023). Below empirical literature review

4.3.1 Adoption of water-saving technologies

Advancements in household water technologies have led to significant reductions in water usage for various activities in recent years. These include the use of low-flow showerheads, kitchen faucet aerators, dual-flush toilets, high-efficiency washing machines, rainwater harvesting systems, and greywater systems. These technologies have contributed to water conservation and sustainability efforts for both urban and rural households (Aina et al., 2023; Bachrun et al., 2023; Chiturike et al., 2023; Farmer, 2019; Filali et al., 2022; Judeh et al., 2022; Sauri, 2020; Ternes, 2021; Zaied, 2018; Zhang et al., 2021).

Several studies have been conducted in different countries using different methods to understand household adoption of water-saving technologies and these studies can be grouped into studies conducted in rural areas (Ahiale et al., 2020; Bediako et al., 2018; Belachew et al., 2020; Chopra & Das, 2019; Jha et al., 2019; Lamm et al., 2017; Memon et al., 2020; Oh et al., 2018; Pérez-Urdiales & García-Valiñas, 2016; Ramsey et al., 2017; Shahangian et al., 2021; Wordofa et al., 2020) and those conducted in urban areas (Bediako et al., 2018; Dieu-Hang et al., 2017; Gyapong-Korsah et al., 2023; Oteng-Peprah et al., 2020; Portman et al., 2022). These studies have used different types of explanatory variables to investigate factors that influence the decision to pay for or adopt different technologies including water-saving technologies, but they were largely conducted among rural households. Using a binary logit model, Jha et al. (2019) examined the adoption of water-saving technologies among 701 household farmers in Tanzania and established that in female-headed households, perception of rainfall instability influences the adoption negatively. In contrast, social networks and public funds, household

wealth, and food security influence the adaptation of water conservation technologies positively. A study by Wordofa et al. (2020) used the multinomial logit model in Ethiopia in the farmers' domain and found that education of the household head, farming experience, extension contact, size of the plot, and number of working members influence the adoption of new technology positively while distance of plot from dwelling influenced the adoption of water conservation technologies negatively. Similarly, Marie et al. (2020) using 121 farm households in Ethiopia with a multinomial logit model to investigate the determinants of farmers' households' adoption of climate change strategies pointed to gender, family size, age, training, information access, farming experience, market access, plot size, annual income from farming and perception of the household on climate change influence the adoption positively while household income influences the adoption negatively. Belachew et al. (2020) using a multivariate probit model with 150 households showed socioeconomic characteristics such as sex, age, household size, education, access to extension service, livestock size, farm size, access to credit services and training influence the adaptation either positively or negatively depending on the kind of technology being introduced in Ethiopia.

Ramsey et al. (2017) conducted a survey involving 248 households in India and used the Multivariate Analysis of Variance method, which revealed that higher incomes, longer water-supply durations, and a belief that droughts could be prevented are positively associated with a greater inclination towards adopting water-conservation behaviours and technology while education levels and water-saving technology awareness do not have any significant impact. According to the review study of existing literature by Oh et al. (2018) in Malaysia, households, particularly those lacking prior knowledge or experience with the technology, may be inclined to reject water-saving technologies due to the associated attributes and incurred costs. Similarly, Lamm et al. (2017) using a qualitative approach from 24 operators across the USA

showed that adoption rates are influenced negatively by perceived costs, the complexity of the technology and its compatibility with the workforce's skills, and the operators' belief that environmentally friendly cultivation enhances the value of their products while observation of new technology being used successfully by others influence the adoption positively. Memon et al. (2020) conducted a study in four southwestern districts of Pakistan, involving 283 groundwater users. The research employed descriptive analysis and OLS regression to show that the likelihood of adopting water-saving technologies diminishes when incentives such as subsidised system installation, reliable suppliers offering warranties on system service and spare parts, and farmer training are absent.

Literature on the factors affecting the adoption of water-saving technologies in urban households is still rising. Some of the studies on urban households include Bediako et al. (2018), Dieu-Hang et al. (2017), Gyapong-Korsah et al. (2023), Oteng-Peprah et al. (2020) and Portman et al. (2022). For instance, Oteng-Peprah et al. (2020) examined 521 households' willingness to adopt greywater technologies in the Central region of Ghana based on the modified theory of planned behaviours. Using a structural equation model, they established that personal norms and attitudes were the determinants of the adoption of water-saving technologies. The same country, Bediako et al. (2018) used a different approach by focusing on the attributes of water-saving technologies to examine how they can influence adoption among 321 households. They found that relative advantage influences the adoption positively and households prefer less complex and compatible technologies. Another study was conducted by Gyapong-Korsah et al. (2023) in the urban settlements of Kumasi, Ghana and the focus was on household greywater use. The authors established that about 20.1% of the respondents were using greywater and they adopted a logit model which showed that the use of greywater was influenced by age, type of the house, marital status and high-water users

positively while gender and lower income was associated with a higher willingness to reuse water. They further showed knowledge of greywater, cost of water and education had no impact.

In Israel, Portman et al. (2022) investigated the public perceptions and perspectives of water reuse and the factors affecting the adoption of technologies for water reuse using logistic regression. Interviews with water experts and a survey of 372 urban households were used to collect data for this study. As opposed to Gyapong-Korsah et al. (2023) who established that knowledge of greywater was not an important factor, Portman et al. (2022) found that knowledge of reuse practices was the most significant explanatory variable when greywater systems and water harvesting systems were used as the dependent variables. Another study was conducted among urban households in 11 Organisation for Economic Co-operation and Development (OECD) countries by Dieu-Hang et al. (2017) to understand household adoption of water-efficient and energy-efficient appliances. Three types of variables were examined as potential determinants: policy variables (pricing, labelling, informational and education campaigns), situational variables (income, education, house ownership, household size and age) and environmental values and psychological factors (e.g., environment concerns). They established that determinants of water-saving technologies differ with whether the technology is low volume/dual flush toilets, water flow restrictors or water tanks to collect rainwater. Despite that fact, policy variables affected the adoption of these technologies.

4.3.2 Preferences and WTP for greywater technologies

Water-saving technologies have gained significant attraction as potential measures to cope with climate change which affects both developed and developing nations. Empirical literature on

these technologies has been rising with studies investigating households' preference and WTP for those technologies and several studies have been conducted across the globe.

One strand of this literature has applied the choice experiment approach and built the analysis from the random utility theory (Aina et al., 2023; Amaris et al., 2020; Amaris et al., 2021; Tapsuwan et al., 2018; Thiam et al., 2021). There are few studies on the choice experiment, which have been conducted in countries with varying levels of development: some studies have been conducted in developed countries (Tapsuwan et al., 2018) while others in developing non-African countries (Amaris et al., 2020; Amaris et al., 2021) and others in developing African nations (Aina et al., 2023; Thiam et al., 2021). For instance, Tapsuwan et al. (2018) examined the WTP for rainwater tank features among 278 water users in Sydney, Australia. Their main results indicated that on average, households were willing to pay US\$2300 for a round polyethene tank with an average volume of 4400 litres and they were willing to pay US\$770 more for a slimline tank over a round tank.

Amaris et al. (2020) used mixed and multinomial logit models to examine the preferences of various socio-economic groups for greywater, which differed in colour and odour as well as different uses in Santiago, Chile. The study reported that the key factors influencing both acceptability and willingness to pay for greywater reuse include gender, age, education level, water expenditure and awareness of greywater reuse. However, the significance of these factors varied depending on the intended use of greywater. On average, people were willing to pay between 1.7% and 18.7% of their monthly water bill for high-quality greywater, applicable to all uses except drinking. For portable uses, households were willing to pay an amount equivalent to 18.3% of the water bill amount. Still in Chile, Amaris et al. (2021) analysed the variation in individual preferences for household water reuse across six indoor applications.

Utilising an LC model, with data from 510 households, they identified distinct differences between latent classes based on socio-economic factors and prior awareness of water-saving technologies.

In Cape Town, South Africa, Thiam et al. (2021) used a total of 465 households to determine the attribute levels and socio-economic characteristics that influence the adoption of water-saving equipment. Five attributes were identified in this study: costs, lifetime of the technology, smell, ease of use, and possibility of engendering diseases, and an LC model was used in data analysis. They found that technological attributes such as lifespan and ease of use, bad smell and the likelihood of generating waterborne diseases can influence a household's decision to adopt greywater technology. Further, they found on average, marginal willingness to pay in class 1 was 1087ZAR AND 735ZAR for bad smell and disease, in class 2 was 4531.507ZAR and 1681.66ZAR for lifetime and ease of use, in class 3 was 1255.21ZAR for diseases. In a follow-up study, Aina et al. (2023) used a choice experiment to determine household preferred attributes for water-efficient showerheads, greywater technology, rainwater collection and double flush toilets by focusing on seven attributes, namely, reliability of access, need for treatment, complexity, ease of maintenance, water quantity saved, lifespan and cost of technology. A CL model and an LC model were used in this study. Aina et al. (2023) indicated that the respondents prefer technologies that conserve large amounts of water, have a long lifespan, are cost-effective, and involve simple water treatment methods. However, the reliability and ease of maintenance of the technology did not significantly affect households' adoption decisions. On average, the marginal willingness to pay was 3,987ZAR (US\$268) for the technologies that need simple water treatment, 3,378ZAR(US\$227) for those that conserve large amounts of water, 16,632ZAR (US\$1,116) for water-efficient-showers, 14,260ZAR (US\$957) for dual flush toilets and 2,712ZAR (US\$182) for a less complex technology (Aina

et al., 2023). With the LC model, the preferences also differed across classes, which indicated the existence of heterogeneity among respondents.

Another strand of literature has taken a different approach to the above-reviewed studies as different methodology was used. These include Rasoulkhani et al. (2018) who investigates various demographic and household factors, social network influences, and external factors like water pricing and rebate policies to assess their impact on the uptake of household water conservation technologies. By applying Agent-Based modelling and using data from the City of Miami Beach, their findings revealed that income growth and water pricing strategies had a greater effect on the uptake of water-saving technologies compared to demographic or building characteristics. Moreover, Shahangian et al. (2021) applied structural equation modelling in Tehran, Iran with 820 households and found that positive attitudes, social outcome expectance, feeling a moral norm in performing a behaviour, individual perceptions of difficulty or ease about the engagement and perception of other people's behaviours influence the adoption of water efficiency behaviours.

A study by Chopra and Das (2019) applied a CVM to estimate WTP for wastewater treatment in New Delhi using 167 households. Among the factors that were considered to influence positively the WTP for wastewater treatment included household income, awareness level, respondents' knowledge and perceptions of pollution caused by sewage and number of toilets as a proxy of water usage while age and gender influenced willingness to pay negatively. The average WTP values vary between Rs.100 to Rs.200. Ahiale et al. (2020) used a similar approach with 305 households in Northern Ghana and found that farmers' and households' characteristics, and socioeconomic and institutional variables influenced willingness to accept water conservation technologies. More specifically, gender, enough farm labour, wealth status,

education, the severity of erosion, soil fertility and previous participation in conservation influence the adoption of conservation technologies positively while the number of household members working on the farm, farm size, income and location influence the adoption negatively. Respondents are willing to accept GH¢922.08/hectare (US\$652.56) and GH¢714.92/hectare (US\$505.95) for stone bunds and soil bunds technologies respectively.

The above literature review has identified several studies on the adoption of water-saving technologies in different countries and the preferred attributes of these technologies. Studies on the factors affecting the adoption of water-saving technologies produced different results and have mostly been conducted in rural areas. A few of these studies have been conducted in urban areas where households are exposed to water rationing practices by water authorities with the potential of greywater technologies being able to complement existing water supply. It has also been shown in the above review that the literature on the preference and WTP for water-saving technologies in urban areas of developing countries, including Tanzania, is limited. More specifically, there are very few studies that have assessed the preferred attributes of water-saving technologies, particularly greywater technology. There is a notable gap in understanding the determinants of water-saving equipment adoption in urban areas and the investigation of its preferred attributes.

4.4 Study area description

The study is conducted in Dar es Salaam, Tanzania (see Figure 4.3 for a map of Dar es Salaam). Dar es Salaam is a city on the east coast of Tanzania, which covers a total land area of about $1,393km^2$ of the total area size for Tanzania land is $881,300km^2$ (Tanzania Bureau of Statistics, 2012). According to the Tanzania Bureau of Statistics (2022) Dar es Salaam is the largest region by population with about 5.38 million people in the 2022 census and comprises

five districts, namely, Kinondoni, Ilala, Kigamboni, Ubungo and Temeke districts with each district being a municipal boundary. The total population is about 0.98 million in Kinondoni district, 1.65 million in Ilala, 1.35 million in Temeke, 0.32 million in Kigamboni and 1.08 million in Ubungo District. Dar es Salaam is a hub of many economic activities including industrial activities and has the country's major seaport.

In Dar es Salaam, water is serviced by DAWASA under the supervision of EWURA. DAWASA supplies water to 23 water service regions within and around Dar es Salaam, which are shown in Figure 4.3c. There are a total of 332,489 domestic water connections in these regions at the time of the study and it is expected to increase owing to high levels of urbanisation and formalisation of informal settlements as well as population growth (EWURA, 2022). Further, DAWASA's water service regions had the highest average daily consumption level of $705,804m^3$ and a maximum daily production capacity of $386,569m^3$ in 2022/2023 (EWURA, 2023). This means the water authorities fail to meet the daily demand for water in the region.

Dar es Salaam, the largest city in Tanzania, is grappling with the effects of rapid urbanisation and population growth. The city's water infrastructure, which dates to colonial times, has seen minimal improvements, leading to ongoing challenges in providing adequate water services. Despite households having access to water on paper, the reality for many residents is contaminated, inadequate, unreliable, or expensive water (Smiley, 2013). This has resulted in poor or even non-existent access to water for a significant portion of the population.

Dar es Salaam relies on three surface water treatment plants, namely the Upper and Lower Ruvu plants located on the Ruvu River, and the Mtoni plant situated on the Kizinga River. Approximately 50% of the city's water demand is met through piped water sourced from these

treatment plants, while the remaining portion is supplied by groundwater. The unregulated proliferation of boreholes within the city has also been documented. However, inadequate monitoring of water quality and extraction persists, contributing to significant outbreaks of waterborne diseases, particularly during the rainy season. Furthermore, this situation has heightened concerns regarding the long-term water supply (Rugemalila & Gibbs, 2015).

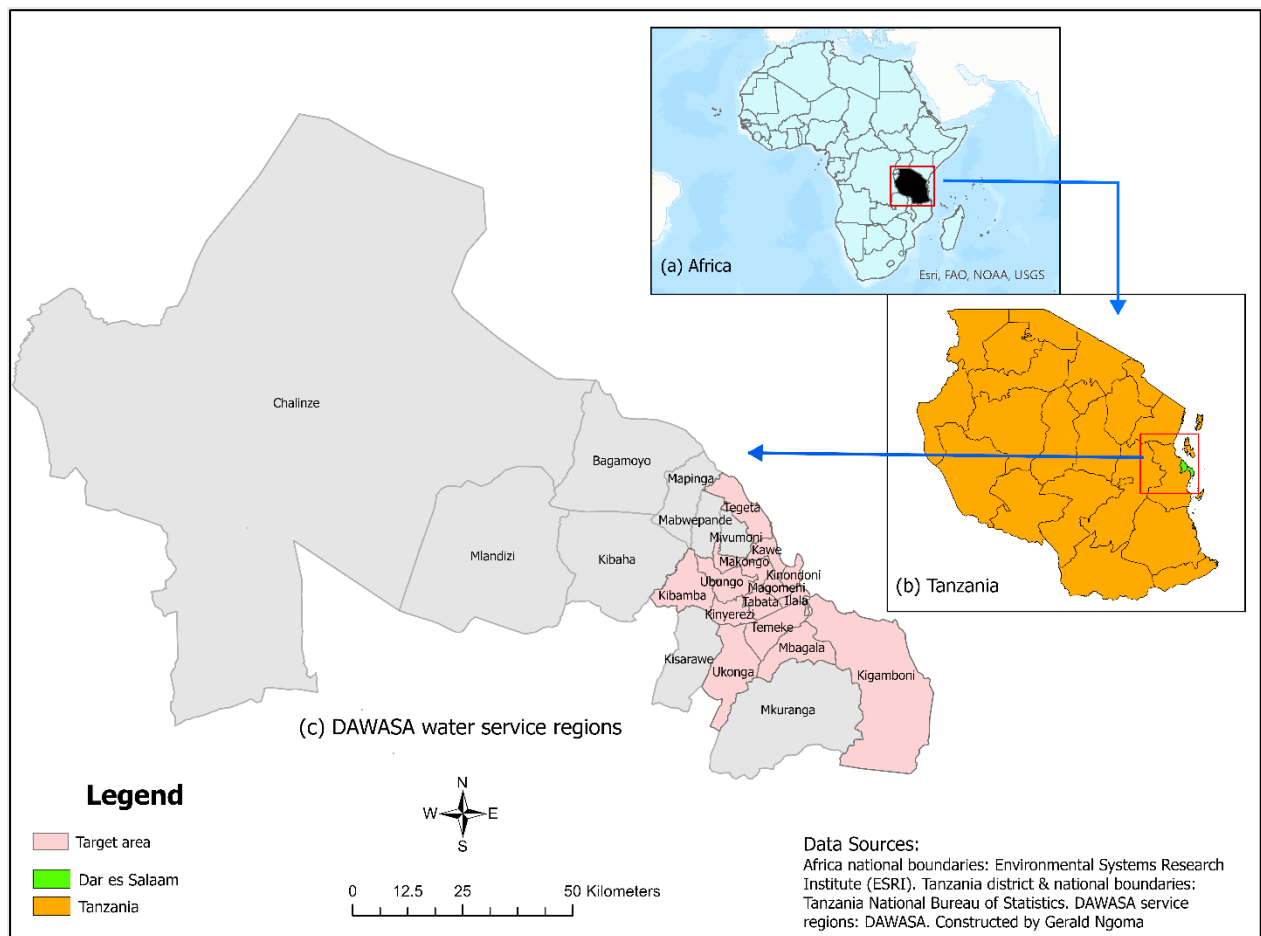


Figure 4.3: Map of Dar es Salaam Tanzania

4.5 Methodology

This methodology section outlines the methods used to investigate the adoption of water-saving technologies and a choice experiment examining preferences for greywater technologies. The

section first presents the methods for assessing adoption, followed by those for the choice experiment.

4.5.1 Adoption of water-saving technologies

An analysis of the factors affecting the adoption of water-saving technologies started with a binary logit model specified as follows:

$$p(\text{WaterTechAdopt}_i = 1) = \beta_0 + \beta_1 \text{gender}_i + \beta_2 \text{Age}_i + \beta_3 \text{Married}_i + \beta_4 \sum_{j=1}^{J-1} \text{Education}_{ij} + \beta_5 \log \text{Income}_i + \beta_6 \text{HHsize}_i + \beta_7 \text{SC}_i + \beta_8 \text{Garden}_i + \epsilon_i \quad (4.1)$$

where WaterTechAdopt_i is household ownership/possession of any water-saving technology, $p(\text{WaterTechAdopt}_i = 1)$ is the probability that a household has a water-saving technology and X is a vector of factors that can affect the adoption of water-saving technology. In this case, $\text{WaterTechAdopt}_i = 1$ if a household had water-saving technology and zero otherwise. In model (4.1), *gender* is the gender of the household head, *age* represents how old the household head is (in years), *married* is the marital status for the household head, *Education* represents categories of education variable, *logIncome* is the log of income of the household head, *HHsize* is household size, *SC* is social capital, the *garden* represents whether a household has a garden or not and ϵ_i is an error term with a logistic distribution. A description of these variables is provided in Table 4.1.

Table 4.1: Definition of variables

Variables	Type and definition	Expected sign
<i>Dependent variables</i>		
Water-saving technologies Adoption	Dummy = 1 if a household has adopted any water-saving technology including greywater technology; 0 otherwise. This is a dependent variable in the binary logit model	n/a

Water-saving technologies	Count = number of water-saving technologies adopted. This is a dependent variable in the Poisson model	n/a
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Independent variables

Gender	Dummy variable = 1 if the household head is male; 0 otherwise	-/+
Age	Continuous variable for household head age in years.	-/+
Married	Dummy variable = 1 if the household head is married; 0 otherwise	-/+
Awareness	Dummy variable = 1 if the respondent is aware of any water-saving technologies; 0 otherwise	+
Income	Continuous variable for household head income in Tanzania shillings.	+
Household size	Continuous variable for the number of people living in a household	+
Social capital	A dummy variable = 1 if the respondent is a member of a social group; 0 otherwise'	+
Garden	A dummy variable =1 if the household has a lawn or garden of flowers	+
Education:	Categorical	
No education	Dummy variable =1 if the household head has no education; 0 otherwise	Base
Primary	Dummy variable =1 if the household head has primary education; 0 otherwise	+
Secondary	Dummy variable =1 if the household head has secondary education; 0 otherwise	+
Certificate/ diploma	Dummy variable =1 if the household head has a certificate/diploma; 0 otherwise	+
University	Dummy variable =1 if the household head has a university education; 0 otherwise	+

A binary logit model only allows an examination of the factors affecting the likelihood of adopting water-saving technologies without considering the intensity of the adopted technologies. This means that it only considers whether a household has adopted water-saving technologies. Analysis was, therefore, strengthened by using a Poisson regression model,

which allows the modelling of the intensity of adoption. The dependent variable (y_i) is the total number of adopted technologies from the list: rainwater bucket, greywater bucket, rainwater tank, greywater tank, pond, borehole, buckets, and other water-saving technologies. Following Cameron and Trivedi (2013), the Poisson regression model that y_i given X_i is specified with density:

$$f(y_i|X_i) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!} \quad i = 1, 2, 3, \dots, n; y = 0, 1, 2, \dots, m \quad (4.2)$$

and a mean parameter

$$\lambda_i = e^{x_i' \beta} \quad (4.3)$$

where y_i is the number of adopted technologies by the household i , λ_i is the conditional mean which is equal to the variance of the Poisson distribution, n is total number of households and m is the total number of technologies available. The equality of the mean and variance parameters, which is referred as the equi-dispersion assumption in the Poisson distribution is regarded as a crucial assumption that should be satisfied in estimated models. Following Cameron and Trivedi (2022), the equi-dispersion assumption is tested using the Deviance and Pearson goodness of fit methods and uses robust standard errors as a possible solution for the existence of dispersion.

4.5.2 The Choice Experiment Approach

The study applied a discrete choice experiment approach to elicit preference and WTP for greywater technologies. This approach is grounded in Lancaster's theory (Lancaster, 1966) and the random utility theory (McFadden, 1974; Hanley et al.1998). According to Lancaster's theory, individuals derive utility from a good's attributes rather than the good itself. As

McFadden (1974b), suggests individuals select the option that offers the highest utility from the available alternatives. The fundamental premise of this approach is that individuals make rational decisions by selecting an option that offers the greatest utility. Consequently, the likelihood of choosing a particular option increases if it provides the highest utility compared to other alternatives. The method can accommodate many attributes compared to the contingent valuation method and binary dependent variable models which can be used.

In line with standard practice in stated preference literature (Johnston et al., 2017; Lancsar et al., 2017; Mariel et al., 2021), the choice experiment study followed the following steps in implementing the experiment: (i) determining choice attributes and their levels, (ii) designing choice cards and experimental design, (iii) questionnaire design, and survey implementation and (iv) econometric analysis.

(i) Determination of attributes and attribute levels

Literature review and personal interviews with participants from local public authorities and DAWASA were conducted to obtain attributes and their levels that households may consider when adopting grey water-saving technologies. The attributes obtained were discussed in FGDs whereby each group had 10 to 12 members from different households. FGDs helped to confirm and identify attributes that may influence households to adopt greywater technologies. A pilot test was conducted to refine and confirm the list of attributes and their levels to be used in the choice experiment. Through this procedure, five attributes, namely, lifetime, ease of access, the possibility of contamination, smell and costs were selected (see Table 4.2).

Lifetime, which is the durability of greywater technology after installation, is an attribute that can influence a household's adoption of greywater technology. When the lifetime of technology is perceived to be long, households are likely to select the given technology

compared to when the lifetime is perceived to be short. The lifetime of greywater technology had three levels namely 5, 10 and 15 years. Ease of use as a second attribute, captures the ease of acquisition of the maintenance skills and intensity of training needed to service the technology during and after installation (Aina et al., 2021). Greywater saving technology that is easy to use is the one that does not require training nor technical knowledge for installation and maintenance while a technology that is not easy to use requires training and technical knowledge for installation and maintenance. Therefore, ease of use had two levels: training required, and no training required.

The third attribute is the possibility of contamination which is crucial for driving household acceptability and willingness to adopt the technology (Amaris et al., 2020). Households are more concerned about their health, and they are likely to select a technology with a low chance of waterborne diseases. This attribute is also supported by Oteng-Pepurah et al. (2018) who showed household perception to adopt the technology depends on the quality of water produced and the level of treatment by the given treatment system. The study considered three levels for contamination, and these are low, medium, and high. To minimise potential subjectivity in respondents' interpretation of the contamination levels, Swahili phrases were used alongside the English terms during the experiment. This approach ensured clearer understanding and cultural relevance. For low contamination, the phrase *“hatari ya uchafuzi na kuenea kwa magonjwa ya maji ni ndogo”* and for medium contamination, the phrase *“hatari ya uchafuzi na kuenea kwa magonjwa ya maji ni ya wastani”* was used. For high contamination, the phrase *“hatari ya uchafuzi na kuenea kwa magonjwa ya maji ni kubwa”* was used.

Smell is the fourth attribute used in the experiment and is described as the odour released by water after treatment. Smell has three levels which are low, medium, and high. Water with a

high smell was defined as water with a strong odour that can be detected from a relatively shorter distance and is referred to as ‘*Harufu kali*’ in Swahili. The study characterises medium smell as a noticeable odour, that can also be described as earthy. Medium smell is known in Swahili as ‘*Harufu ya Kati*’. Water with a low smell was defined as that with little or faint detectable odour and is referred to as ‘*Hakuna harufu*’ or ‘*Harufu ndogo*’ in Swahili. The Swahili expressions for low, medium and high smell were used during the experiment to aid the differentiation of the three levels of smell by respondents.

Technology costs have been shown by other studies to be a driving force for adoption (Thiam et al 2020; Aina et al, 2021; Amaris et al., 2020; Lai et al., 2022). The adoptions could be limited when the cost of purchase and installation is high. According to demand theory, households’ adoption rates is expected to be higher when costs are lower. In this study, costs were presented to respondents in local currency, TZS since the study was conducted in Tanzania. Costs had five levels: TZS117,000; TZS234,000; TZS350,000; TZS699,600; TZS1,170,000. These costs are comparable to other water-saving technologies such as double flush toilets which costs between TZS150,000 UP TO TZS1,000,000, shower head, which ranges from TZS20,000 and rainwater collection technology which ranges from TZS500,000 TO TZS5,000,000.

Table 4.2: Attribute descriptions and levels used in the experiment

Attributes	Description	Levels
Lifetime	It indicates the durability of the technology after installation	5, 10, 15 years
Ease of use	Indicates the knowledge and technical ability needed to install and maintain the technology	No Training is required; No training or technical knowledge is needed for the installation & maintenance of the technology.

		Training required: Training and technical knowledge are needed for the installation & maintenance of the technology
Contamination	This shows the likelihood in which the water source can be contaminated by bacteria like cholera, Escherichia coli, and rodents and cause water-borne diseases	High: this technology can likely be contaminated and result in waterborne diseases. Medium: Moderate chance of waterborne disease Low: There is a low possibility of contamination hence a low chance of waterborne diseases.
Smell	The smell released by the water after treatment	High: Water with a strong odour and can be detected from a relatively shorter distance. Medium: Water with a noticeable odour. The smell might be described as earthy. Low: Water with a low smell has little to no detectable odour. The smell is faint.
Costs	It includes the cost of purchasing technology, installation, maintenance, and treatment to make water clean	TZS117,000; TZS234,000; TZS350,000; TZS699,600; TZS1,170,000

(ii) Design of choice cards and experimental design

In this stage, attribute levels were combined to form alternative scenarios and respondents were asked to choose their preferred option from a choice card. As presented in Table 4.2, three attributes had three levels, one attribute had two levels, and one had five levels. The choice experiment design had a total of 270 possible choice cards ($3^3 \times 2^1 \times 5^1$) for a complete factorial design. A complete factorial design with 270 cards was impractical and had the risk of imposing a cognitive burden on the respondents, which could have made respondents tired since the choice sets could be too many (Johnston et al., 2017). To reduce the number of choice

alternatives and reduce the response burden, an orthogonal fractional factorial design where a subset of the choice combinations is used, was adopted in NGENE software. The orthogonal design produced 16 choice cards, each representing a task for the respondent. A pilot test was conducted, which showed that 16 choice cards/tasks were too many for respondents to evaluate as it was inducing boredom and tiredness and could be reducing respondent motivation in participating truthfully. To circumvent these issues, the study adopted a blocked design in which 16 choices were blocked into 4 blocks and each respondent was randomly allocated to only one block. This means each respondent faced a set of four choice cards/tasks in the allocated block.

Choice cards were presented to respondents in an unlabeled experiment with two alternatives (Option A and Option B) and a status quo. An example of a choice card used in the main survey is shown in Figure 4.4. Each of the alternatives in Option A and Option B involved a different combination of attribute levels for the greywater technologies proposed to respondents. This means each alternative of options A and B in a particular task represented a unique and specific greywater technology characterised by the given set of attributes. The status quo is the option of not choosing any new proposed grey water technology and no costs were incurred, meaning respondents are happy with the current situation.

Attributes	Option A	Option B	Status quo
Lifetime 	5 years	10 years	Same as now
Ease of use 	No training required	Training required	Same as now
Contamination 	High	Low	Same as now
Smell 	High	Low	Same as now
Cost (TZS) 	\$50	\$500	Zero
Which option would you prefer?			

Figure 4.4: Sample choice card used in the main survey

Source: Authors

(iii) Questionnaire design and survey implementation

The study used a structured research questionnaire designed following literature guidance, FGDs and expert interviews. The questionnaire (see Appendix A) is designed to collect information on respondents' characteristics such as age, gender, education, income and expenditure of respondents, water usage and water-saving technologies. Following the design

of the research questionnaire, a pilot survey was conducted on 50 households in September 2022 to test respondents' understanding of attributes and their levels and other questions included in the questionnaire. These households were the same as those used in the FGDs and pilot surveys of the choice experiment presented in Chapter 2. The FGDs for both experiments were conducted on the same day, with respondents given a one-hour break between sessions. During the pilot surveys, a five-minute break was provided between the two experiments. It is worth noting, however, that the experts consulted for the current chapter differed from those engaged in the water supply improvement experiment.

In line with standard practices, the questionnaire included auxiliary questions to help engage respondents, evaluate their understanding of questions, evaluate the validity of the questionnaire, evaluate respondents' perceptions of the survey instrument, and identify respondents' attitudes, opinions, behaviours and experiences (Johnston et al., 2017). Most of these auxiliary questions were primarily used to check the validity of the main valuation questions and to inform data cleaning processes. The survey was conducted face-to-face using CAPI through Open Data Kit software. Ethical clearance was approved by UCT and UDSM (see Appendix B).

Data for this study was on 962 connected households using a probability proportional to size sampling approach in 16 DAWASA water service regions¹⁸ presented in Figure 4.3c. The study targeted high-water users in Dar es Salaam city and thus excluded non-piped, remote, and coastal water service regions. High-water users were targeted as they were more likely to

¹⁸ The water service regions in which data were collected are Ilala, Kawe, Kibamba, Kigamboni, Kinondoni, Kinyerezi, Mabwepande, Magomeni, Makongo, Mbagala, Mivumoni, Tabata, Tegeta, Temeke, Ubungo and Ukonga.

produce more greywater. The 962 households included in this analysis are the same as those who participated in the choice experiment on water supply improvement discussed in Chapter 2. These households took part in both experiments sequentially. This design choice was made with careful consideration of potential carryover effects, such as learning and fatigue, which can influence responses in stated preference studies (Boxebeld, 2024; Carlsson et al., 2012).

Learning effects may occur when respondents become more familiar with the experimental format and develop a clearer understanding of their preferences as they progress through the choice tasks (Boxebeld, 2024). In contrast, fatigue effects can emerge when respondents lose concentration or become cognitively exhausted after completing multiple tasks, potentially compromising the reliability of later responses (Johnston et al., 2017). To mitigate these risks, about 50% of respondents were randomly assigned to begin with either the choice experiment on water supply improvement or the experiment on greywater technology (focus of this chapter). In addition, a short activity was introduced between the two experiments, and respondents were given a five-minute break to reduce the likelihood of carryover effects and allow for cognitive reset. Also, the experimental set-up was disclosed in advance with respondents participating in instructional choice sets before the actual experiment. In the analysis, an alternative specific constant (ASC) was included as recommended in the literature (Boxebeld, 2024). For completeness, a test of the ordering effects was conducted before the estimation of preferences and WTP. This was important for determining whether the sequence in which respondents completed the experiments influenced their choices, and whether it was necessary to control for the order of experiments in the subsequent analysis (see Section 4.6.3 for more details).

(iv) Econometric framework

The analysis of the preferences and WTP for greywater technology was conducted based on the Random Utility Theory (McFadden, 1974) and utility theory by Lancaster (1966). According to this theory, an individual $n = 1, \dots, N$ will prefer a choice $j = 1, \dots, C$ that offers higher utility than an alternative $k \in C$, $\forall j \neq k$ at occasion $t = 1, \dots, T$, that is, $U_{njt} > U_{nkt}$. The utility (U_{nj}) derived from a choice j by an individual n is expressed as an addition function of a systematic part and a random part:

$$U_{njt} = \beta'X_{njt} + \varepsilon_{njt} \quad (4.4)$$

where X_{njt} is vector of observed attributes, β is a vector of utility weights, and ε_{njt} is the random part assumed to be independently and identically distributed (i.i.d) and follow type 1 extreme value distribution. The vector of attributes, β , determines the desirability of the greywater technology attributes by respondents. In choice experiment studies, it has become common to first estimate the preferences using a conditional logit (CL) model. Following the literature, the study first estimated a CL model by assuming that β is homogeneous across all respondents such that the choice probability of respondent n choosing alternative j is specified as:

$$P(j|X_{nt}) = \exp(\beta'X_{njt}) / \sum_{j=1}^C \exp(\beta'X_{nkt}) \quad (4.5)$$

However, a CL model is restrictive due to the assumption of the IIA, which means that choice probabilities between two alternatives in a choice set is not affected by the other alternatives in the choice set. Alternatively, the ratio of choice probabilities for alternatives j and k depends only on the attributes of j and k and the existence of another alternative does not alter the

relative probabilities. This cannot hold in many cases hence its restrictive. The assumption of IIA is tested using the Hausman and McFadden (1984) test. Another limitation of the CL model is that tastes and preferences for observed attributes are homogenous across all references, which may not be the case. Given these limitations, a Random Parameter Logit (RPL) model (Train, 2009) was considered within the random utility framework presented above. An RPL model is flexible as it enables an examination of unobserved preferences heterogeneity and is specified as follows:

$$U_{njt} = \beta'X_{njt} + \eta'X_{njt} + \varepsilon_{njt} \quad (4.6)$$

where η is a vector of random coefficients, which are assumed to follow a normal distribution with zero mean and variance estimated in the model. The RPL was estimated considering random and fixed ASC with the model that has lowest AIC and BIC values being selected for further analysis. The performance of an RPL to model respondent's preference was compared with the CL model, Generalised Multinomial Logit (G-MNL) and a 2-class Latent Class Model (LCM).

The application of GMNL followed Fiebig et al. (2010) as it does not rely on the assumption of IIA or homogeneous preferences. The G-MNL attempts to account for preference heterogeneity and scale heterogeneity, and is specified as follows:

$$U_{njt} = \beta'_n X_{njt} + \varepsilon_{njt} \quad \Rightarrow \quad U_{njt} = \{\sigma_n \beta' + [\gamma + \sigma_n(1 - \gamma)]\eta_n\} X_{njt} + \varepsilon_{njt} \quad (4.7)$$

with $\beta'_n = \sigma_j \beta' + [\gamma + \sigma_n(1 - \gamma)]\eta_n$, $\gamma \in [0, 1]$ is scalar parameter, σ_n is the individual specific scale parameter of the error term, η_n is a $MVN(0, \Sigma)$ random vectors. To speed up

estimation, the study estimated a G-MNL type II (G-MNL-II)¹⁹ which fixes $\gamma = 0$ meaning $\beta'_n = \sigma_n(\beta' + \eta_n)$. According to Fiebig et al. (2010), σ_n which is the scale of the idiosyncratic error follows a log-normal distribution with mean 1 and standard deviation τ , that is, $\sigma_n \sim LN(1, \tau^2)$ and τ is the key parameter that captures scale heterogeneity. Hess and Rose (2012) pointed out the inability of this model in determining scale heterogeneity citing that it is difficult to separate the different types of heterogeneity. Hess and Train (2017) further argued that this scale parameter should not be interpreted as indicating scale preference since it captures all forms of correlation arising in the model. Hence, the G-MNL model is considered in this study for comparison purposes in capturing preference heterogeneity.

Similar to the RPL, the LCM is estimated in the RUM framework (equation 4.4) but considers that preference heterogeneity is discrete and that respondents with similar preferences can be categorised into different classes. Hence, it captures a different form of heterogeneity to the RPL model. Literature provides no clear preference

To account for the source of heterogeneity, the study introduced model interactions while considering the parsimony and convergence of the model. Hence, the study interacted with awareness of greywater technology with random attributes since individuals may prefer to adopt greywater technology depending on their exposure or awareness.

The study estimated a model with an ASC which took a value of 1 if the respondent chose the status quo and zero if Option A and Option B are chosen. The ASC allowed the study to examine if the respondents prefer to adopt greywater technology or not. The G-MNL model is

¹⁹ See Fiebig et al. (2010) for the types and nested models of the G-MNL.

estimated with cost as a fixed attribute while ASC and the other attributes were treated as random. For comparison purposes, a LC model with 2 classes is estimated with and without interaction terms and compared with the G-MNL model in terms of statistical significance and signs of coefficients.

Marginal WTP (mWTP) values for attributes of greywater technology were calculated from the G-MNL-II models and compared with those of the CL and LC models. They were calculated by dividing the coefficient of the attribute by the negative coefficient of the cost variable:

$$mWTP = -\left(\frac{\beta_x}{\beta_{cost}}\right) \quad (4.7)$$

where β_x is the coefficient of an attribute X other than cost and β_{cost} is the coefficient of the cost variable.

4.6 Results

4.6.1 Sample characteristics and perceptions on grey water-saving technology

A summary of descriptive statistics for respondents' characteristics is presented in Table 4.3. The sample is male dominated with 84% of the respondents being male and this may be due to the point that the study targeted household heads, who tend to be men in most cases. The average age for the sample is 46 years. Most of the respondents were married (86%) while 5% are single, 6% are widowed and 3% are divorced. Regarding the education level of the respondents, 41% had secondary education, 22% had university education, 21% had a certificate/diploma, 14% had primary education and 2% had no education. These statistics show that most of the respondents have secondary education or higher. For income, the study

established that the mean was TZS570,000 (~US\$250) per month, the minimum income was TZS50,000 (~US\$20) per month and the highest income was TZS2 million (~US\$870) per month. On average, the income reported above is close to the income for an individual in urban areas in Tanzania, which is reported to be TZS425,608 (~US\$199) (Medinaceli et al., 2024). Table 4.3 shows that the average household size for the sample is 5 people with a minimum of 1 and a maximum of 18. Twenty-four percent (24%) of the respondents cited that they have a garden of flowers or a lawn at their homes while 8% are members of social groups.

Table 4.3: Descriptive statistics of respondents

Characteristic	N	Mean	SD	Min	Max
Gender = 1 if male	962	0.84	0.37	0	1
Age (years)	962	46	10.20	25	90
Marital status					
Single = 1	962	0.05	0.22	0	1
Married = 1	962	0.86	0.35	0	1
Widowed = 1	962	0.06	0.23	0	1
Divorced = 1	962	0.03	0.18	0	1
Education					
No education = 1	962	0.02	0.14	0	1
Primary education = 1	962	0.14	0.35	0	1
Secondary education = 1	962	0.41	0.49	0	1
Certificate/Diploma = 1	962	0.21	0.41	0	1
University education = 1	962	0.22	0.41	0	1
Income (TZS million)	962	0.57	0.31	0.05	2
Household size	962	5	1.99	1	18
Garden = 1 if the household has a garden	962	0.24	0.42	0	1
Social capital = 1 if the household head is a member of a social group	962	0.08	0.26	0	1

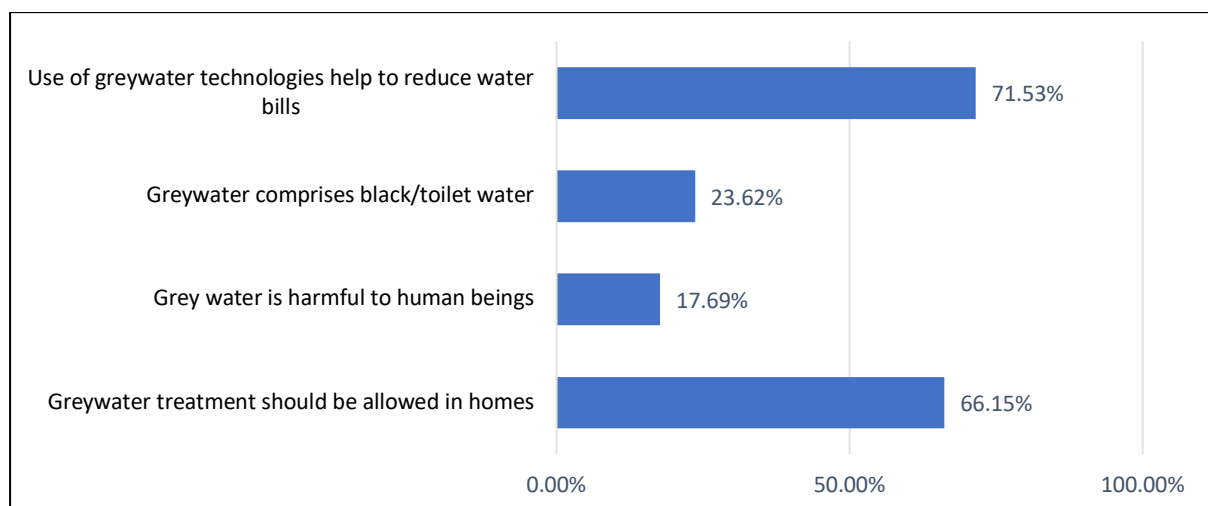
4.6.2 Adoption water-saving technologies

Table 4.4 presents descriptive statistics for the adoption of water-saving technologies with a particular focus on greywater technology.

Table 4.4: Adoption of water-saving technologies

Variable	N	Mean	SD	Min	Max
Household has water-saving technology = 1	962	0.40	0.49	0	1
Household re-use wastewater/greywater = 1	962	0.07	0.25	0	1
<i>Methods of re-using water (greywater)</i>					
Household use tank to collect greywater = 1	67	0.03	0.17	0	1
Household use bucket to collect greywater = 1	67	0.94	0.24	0	1
Household use well/pond to collect greywater = 1	67	0.03	0.17	0	1

As presented in Table 4.4, 40% of the respondents reported using water-saving technologies in their households. This figure includes all types of water-saving technologies, including greywater systems. Specifically, 7% of respondents indicated that they use greywater. Among these, 94% collect greywater using buckets, 3% use tanks, and the remaining 3% rely on wells or ponds. Households reported a variety of uses for greywater, including washing vehicles or motorcycles, gardening, and toilet flushing or cleaning. In addition, the study explored respondents' perceptions of greywater treatment, its composition, and its impact on household water bills. These findings are presented in Figure 4.5.

**Figure 4.5: Household perceptions for greywater technology**

Source: Authors

Figure 4.5 captures different respondents' perceptions on greywater technology for household purposes. It is shown that 71.53% of the respondents perceive that the use of greywater technology can help reduce their water bills implying that respondents believe in the usefulness of the technology. Close to a quarter (23.62%) of the respondents perceive that greywater comprises black/toilet water which shows that some respondents are misguided about what greywater is. In addition, 17.69% of the respondents believe that greywater is harmful to human beings while 66.15% believe that greywater treatment should be allowed in homes. These findings are generally inclined towards the usefulness of greywater technology for domestic use. Having a significant percentage of respondents perceiving greywater as black/toilet water and being harmful to human beings signifies the importance of appropriately designing greywater technology to increase its adoption. Therefore, a choice experiment is important to determine the preferred attributes of greywater technology that will be accepted for safe domestic use.

Following the analysis of the descriptive statistics for the adoption of water-saving technologies, the study proceeds to establish the factors affecting the adoption of water-saving technologies. The empirical results for the binary logit model on the factors affecting the adoption of water-saving technologies among urban households in Dar es Salaam are in Table 4.5. The model coefficients are shown in column (1) and the corresponding marginal effects are shown in column (2).

Table 4.5: Factors affecting the adoption of water-saving technology

VARIABLES	(1)	(2)	(3)	(4)
	Binary logit model		Poisson model	
	Coefficients	Marginal effects	Coefficients	Marginal effects

Gender	-0.25 (0.28)	-0.05 (0.06)	-0.27 (0.17)	-0.14 (0.09)
Age	0.02* (0.01)	0.004* (0.002)	0.01** (0.01)	0.01** (0.003)
Married	0.49* (0.29)	0.10* (0.05)	0.35** (0.17)	0.14** (0.06)
primary education	1.39** (0.54)	0.27*** (0.09)	0.46 (0.36)	0.25 (0.24)
Secondary	1.12** (0.56)	0.22** (0.10)	0.35 (0.38)	0.17 (0.20)
certificate/diploma	1.09** (0.54)	0.22** (0.10)	0.39 (0.37)	0.20 (0.22)
University	0.21 (0.57)	0.04 (0.12)	-0.05 (0.39)	-0.02 (0.17)
Awareness	0.84*** (0.25)	0.18*** (0.05)	0.37*** (0.13)	0.17*** (0.06)
Log(income)	1.37*** (0.23)	0.28*** (0.04)	0.78*** (0.14)	0.35*** (0.05)
household size	-0.15*** (0.05)	-0.03*** (0.01)	-0.07** (0.03)	-0.03** (0.01)
social capital	0.70** (0.28)	0.15** (0.06)	0.33*** (0.13)	0.17** (0.07)
Garden	-0.02 (0.24)	-0.003 (0.05)	-0.01 (0.12)	-0.002 (0.05)
Constant	-20.15*** (3.10)		-11.85*** (1.83)	

Observations	962	962
Pseudo R-squared	12.27%	6.16%
$\chi^2(12)$	81.77***	96.31***
HL statistic	6.94	-
Deviance gof statistic	-	749.38
Pearson gof statistic	-	789.59

*Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. HL = Hosmer-Lemeshow; gof = goodness-of-fit.*

As shown in Table 4.5, the Chi-square statistics for the logit model is $\chi^2(12) = 81.77$ with a p-value of 0.00, which means the null hypothesis of all the coefficients being jointly equal to zero is rejected at 1% level. It is also shown that the Pseudo R-Squared is 12.27% and Hosmer-Lemeshow Chi-square of 6.94, which is not statistically significant which implies the model

has a good fit. For the variables, age, primary education, secondary education, certificate/diploma, awareness, income, household size and social capital have statistically significant coefficients.

The Poisson regression model results in column (3) and column (4) has a $\chi^2(12) = 96.31$ and is statistically significant at 1% which supports the point that, jointly, all coefficients are statistically different from zero. Further, the Pseudo-Squared is low and equal to 6.16%. Goodness-of-fit was examined with the deviance and Pearson goodness-of-fit methods which also test the existence of overdispersion in the model. If the assumption of equi-dispersion is not satisfied, then the Poisson model will not be appropriate. The deviance goodness-of-fit statistic is 749.38 while the Pearson goodness-of-fit is 789.59; they are not statistically significant. This provides evidence of no existence of overdispersion and the appropriateness of using the Poisson model as a model of the conditional distribution for the study data²⁰ (Cameron & Trivedi, 2022).

For the logit model, the coefficient of age is positive and statistically significant at a 1% level which confirms that the likelihood of adopting water-saving technology increases with age. The results also show that having primary, secondary or certificate/diploma education is associated with a higher likelihood of adopting water-saving technologies than no education. The likelihood of adopting water-saving technology is higher for respondents with primary education by 27%, secondary education by 23% and certificate/diploma by 22%, on average.

²⁰ I attempted to compare the results for our model with the Negative Binomial model, but the results are the same in terms of statistical significance and coefficients with our Poisson model. Also, the dispersion parameter for the negative binomial model was very close to zero to indicate the absence of dispersion as established by our results for the Poisson model. In the negative binomial model, $var(y_i) = \lambda_i + \alpha\lambda_i^2$ with α being the dispersion parameter. If $\alpha = 0$, then $var(y_i) = \lambda_i$ which is the case of the for the Poisson model.

Furthermore, being aware of water-saving technologies is associated with a higher likelihood of adopting such technologies by 18% than not being aware of the technology, all things being the same. This result underpins the importance of exposure/awareness to water-saving technologies in adopting technology.

It is also shown in Table 4.5 that income for the logit model has a statistically significant coefficient at 1% and the marginal effect is 0.27. The marginal effect of income is interpreted as follows: an increase in income by 1% is associated with an increase in the likelihood of adopting water-saving technologies by 0.28% on average. For household size, the coefficient is negative and statistically significant at 1%, meaning an additional person added to the household results in a decrease in the probability of adopting water-saving technology by 3%. Social capital has a positive coefficient that is statistically significant at 1% implying that people with membership in social clubs or groups are more likely to adopt water-saving technologies than those without membership.

The Poisson regression results in columns (3) and (4) in Table 4.5 show that age, marital status, awareness, income, household size and social capital have statistically significant coefficients and marginal effects. For age, the coefficient means an additional year in age for a household head is associated with an increase in the number of water-saving technologies adopted by a household by 1% while the marginal effect means a 0.01 additional number of water-saving technologies. Further, the likelihood of using water-saving technologies is 35% higher for married respondents than for those who are not married and being aware of water-saving technologies is associated with using several water-saving technologies. Income is positively related to the number of technologies a household can adopt. The coefficient means a 1% increase in income is associated with an increase in the number of technologies adopted by

0.78% while an increase in household size by one person is associated with a decrease in the number of technologies by 7%. The semi-elasticity for social capital is 0.33 and the marginal effect is 0.17, which means that households whose heads are members of social groups are more likely to adopt more technologies than their counterparts.

4.6.3 Preference and WTP for greywater technologies

The study estimates choice models in preference space to examine respondents' preference and WTP for greywater technology attributes. This means the estimated coefficients of the models can be interpreted as the changes in the utility of respondents from the base level. The study first estimated CL for the full sample and tested whether conducting two experiments sequentially affected preferences and WTP. The results of this analysis are presented in Table 4.6

Table 4.6: Coefficients of CL models for testing IIA assumption and ordering effects

VARIABLES	CL model		CL model for order of experiment order		Heteroskedasticity CL model
			Greywater technology	Water supply improvement	
	(1)	(2)	(3)	(4)	(5)
Cost (millions)	-1.67*** (0.15)	-1.78*** (0.16)	-1.07*** (0.20)	-2.88*** (0.31)	-1.81*** (0.21)
Lifetime					
10 years	-0.02 (0.07)	0.01 (0.09)	-0.27** (0.13)	0.37*** (0.12)	0.01 (0.09)
15 years	0.47*** (0.07)	0.44*** (0.09)	0.47*** (0.13)	0.58*** (0.13)	0.45*** (0.10)
Ease	0.08 (0.05)	0.10* (0.06)	0.16* (0.09)	0.13 (0.08)	0.10* (0.06)
Contamination					
Medium	0.98*** (0.08)	0.90*** (0.10)	0.78*** (0.14)	0.98*** (0.16)	0.92*** (0.12)
Low	0.58*** (0.09)	0.54*** (0.11)	0.36** (0.15)	0.44** (0.17)	0.55*** (0.12)
Smell					
Medium	0.67*** (0.06)	0.64*** (0.08)	0.37*** (0.12)	0.94*** (0.11)	0.65*** (0.10)
Low	1.04*** (0.07)	0.99*** (0.08)	0.89*** (0.11)	1.15*** (0.12)	1.00*** (0.10)
ASC	-0.01	0.33**	0.56**	0.09	0.33**

Order	(0.14)	(0.17)	(0.24)	(0.25)	(0.17)
					-0.02
Interactions included	No	Yes	Yes	Yes	(0.10) Yes
Observations	11,544	11,544	5,892	5,652	11,544
No. of respondents	962	962	962	962	962
LL	-3737.89	-3604.11	-1789.25	-1770.82	-3604.06
AIC	7493.80	7242.23	3612.51	3575.64	7244.13
BIC	7559.98	7367.25	3726.09	3688.51	7376.50
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Interaction terms are for awareness and attributes					

The results for the CL model with and without interaction terms are shown in column (1)-(2) of Table 4.6. The CL with interaction terms has lower AIC and BIC values which implies that it is a better model than the one with no interaction terms. Further, a likelihood ratio test for the inclusion of interaction terms provides a chi-square value of 213.96 with a p-value of 0.00. This shows that the interaction terms are jointly different from zero hence supporting the conclusions from the AIC and BIC values. However, the coefficients of the two conditional logit models are similar in terms of sign and statistical significance.

For the CL model with interaction terms, the coefficient of cost is negative and statistically significant at 1% level. This is consistent with economic theory, which implies that consumer's utility decreases as cost rises. For this model, respondents' utility is likely to be higher for a greywater technology with either a 15-year lifespan, medium contamination, low contamination, low smell, or medium smell. The CL model was tested for the IIA using the Hausman and McFadden (1984) test and the results are shown in Table E.1 in the Appendix. At the 1% level, the study found no evidence that the IIA condition is met in the CL model. Therefore, models that relaxes the IIA assumption and account for preference heterogeneity were considered. As previously explained, the RPL model was the primary model used in the analysis, but it was compared with the GMNL and a LCM with 2-classes for robustness checks.

Before these models, the ordering effects between experiments on water supply improvement (presented in Chapter 2) and greywater technology (the focus of this paper) were analysed using a standard CL model and a heteroscedastic CL model. A Swait and Louviere (1993) test was conducted to assess whether differences in preferences between the two experimental groups - those who began with the greywater technology experiment and those who began with the water supply improvement experiment – are attributable to scale differences. This involved comparing the log-likelihood values of two separate standard CL models, one for each subgroup, with that of a heteroscedastic CL model in which the scale is allowed to vary by experimental order. The test is based on a likelihood ratio statistic calculated as $-2(LR_r - LL_{ur})$ where LR_r is the log-likelihood of the heteroscedastic model (the restricted model) and LL_{ur} is the sum of the log-likelihoods of the two separate CL models (the unrestricted model).

The results of this test are presented in columns (3) to (5) of Table 4.6. Column (3) reports the CL model estimates for respondents who began with the greywater technology experiment, while column (4) presents results for those who first undertook the water supply improvement experiment. Column (5) displays the estimates from the heteroscedastic CL model, which includes all respondents. The results in column (3) and column (4) are largely consistent in terms of the sign and statistical significance, except for the lifetime attribute. Respondents who began with the greywater technology experiment were less likely to prefer a system with a 10-year lifespan compared to one with a 5-year lifespan. In contrast, those who started with the water supply improvement experiment were more likely to prefer a greywater technology with a 10-year lifespan over one with 5 years.

The likelihood ratio test provides an LR statistic of 87.98 and an associated p-value of 0.00 meaning that the heteroscedastic CL model fits the data better than the standard CL models.

However, the coefficient of the order variable is not statistically significant suggesting that the error variance, which is interpreted as decision consistency does not differ significantly across respondents. This implies that while there is no evidence of decision inconsistency between the two groups, there are significant differences in preferences. The study, therefore, proceeds to estimating a RPL model which contains interaction terms to account for the sources of preferences heterogeneity not attributed to the order of experiments. Nevertheless, these findings are compared with those obtained from an RPL with interaction terms of the order variable and choice attributes for robustness checks.

The study considered various specifications of the RPL model. More specifically, RPL models were estimated both with and without interaction terms, and the ASC was tested as either fixed or random. Results for these models are presented in Table E.2 in the Appendix. Models including interaction terms exhibited lower AIC and BIC values compared to those without, indicating a better fit. Among these, the model with a random ASC yielded the lowest AIC (5250.30) and BIC (5426.79) values and was therefore selected for interpretation. The results of this preferred model, along with those from the GMNL and latent class models, are presented in Table 4.7. Further examination of the significance of adding an interaction term in the RPL was conducted using the likelihood ratio test which produced $\chi^2 = 24.89$ with $p = 0.00$. This means that the null hypothesis that the interaction terms are jointly equal to zero is rejected at 1% level.

Table 4.7: Results for RPL, GMNL and LC models

VARIABLES	RPL		G-MNL		LC model		
	Means	SD	Means	SD	Class 1	Class 2	Interactions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ASC	-5.42*** (0.88)	12.91** * (1.58)	-6.92*** (1.19)	15.77*** (2.01)	8.05*** (0.65)	-4.46*** (0.24)	
Lifetime							

		-				
10 years	0.08 (0.15)	0.79*** (0.21)	0.16 (0.24)	0.98*** (0.36)	-1.11** (0.52)	0.43*** (0.12)
15 years	-0.00 (0.16)	1.16*** (0.30)	-0.09 (0.26)	-1.49*** (0.47)	0.59** (0.29)	-0.03 (0.12)
Ease	-0.26** (0.13)	0.26 (0.39)	-0.42** (0.21)	0.63** (0.32)	0.15 (0.42)	-0.48*** (0.09)
Contamination						
		-				
Medium	1.41*** (0.17)	1.13*** (0.19)	2.36*** (0.37)	1.90*** (0.44)	4.06*** (0.43)	0.94*** (0.10)
		-				
Low	1.34*** (0.24)	1.65*** (0.27)	2.44*** (0.48)	2.21*** (0.50)	2.37*** (0.40)	0.91*** (0.16)
Smell						
Medium	0.58*** (0.14)	-0.02 (0.03)	0.92*** (0.18)	0.24 (0.26)	4.25*** (0.55)	-0.21* (0.13)
Low	0.86*** (0.18)	-0.14 (0.09)	1.30*** (0.26)	-0.14 (0.24)	4.17*** (0.46)	-0.28* (0.16)
	- 0.000003*		- 0.000006*		0.00000 6	- 000003*
Cost	** (0.00)		** (0.00)			** (0.25)
smellow_awareness	0.26 (0.28)		-0.05 (0.35)			1.05*** (0.21)
contmed_awareness	0.10 (0.21)		0.45 (0.37)			0.28* (0.15)
contlow_awareness	-0.77** (0.35)		-1.22** (0.55)			-0.45* (0.24)
lifetime10_awareness	0.05 (0.23)		0.42 (0.33)			0.08 (0.16)
lifetime15_awareness	0.44* (0.25)		0.86** (0.39)			0.63*** (0.18)
ease_awareness	0.07 (0.20)		-0.11 (0.32)			0.54*** (0.14)
ASC_awareness	-10.35*** (1.94)		-15.51*** (2.12)			
τ			0.99*** (0.09)			
Class share					0.28	0.72
Observations	11,544		11,545			11,547
No. of respondents	962		962			962
LL	-2561.45		-2547.89			-2598.13
AIC	5172.89		5204			5455.56
BIC	5356.74		5388			5455.57

*Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. LL; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.*

In the RPL model, the ASC and attributes (ease, medium and low contamination, medium and low smell, and cost) are statistically significant at a 1% level. For attributes with significant coefficients in the RPL model, results are similar to those of the CL model excluding ease which has an insignificant coefficient in the CL model. For further robustness check, the RPL model is compared with a GMNL model and a 2-class LC model whose results are in column (3)-column (7). Results for the RPL are similar to those of the GMNL model in terms of sign and statistical significance but they are different to those of LC model. For class 1, cost is not an attribute while it is important for class 2 with an expected negative sign. The results for RPL are robust to the results for class 2 in terms of expected signs and statistical significance. AIC and BIC show conflicting conclusions as the AIC shows that GMNL fits the data better while the BIC shows that the RPL model fits the data better. Overall, the RPL model performs well relative to the GMNL, CL, and the 2 latent class models.

In the RPL model, the cost attribute has a negative and statistically significant coefficient at 1% implying that respondents prefer greywater technology that costs less. This finding is consistent with the theory that consumers generally prefer a good or service that costs less given the budget constraint and unlimited wants. The attribute ease, which captures how easy it is to use technology and the need for user training, has a negative and statistically significant coefficient at a 1% level. This means that respondents were more likely to choose a greywater technology that requires some training for installation and maintenance to that technology which does not require training. It is shown in the table that the coefficients of the low and medium contamination are positive and statistically significant at a 1% level. This finding means that respondents are more likely to prefer greywater technology with lower and medium

contamination compared to high contamination. Further, the coefficient for low contamination is higher than that of medium contamination, showing that the intensity of preference increases as contamination decreases.

Concerning smell, the study found that greywater technologies that produce treated water with medium or low smell are less likely to be preferred to those that produce water with high smell. For smell, the coefficient for the attribute low smell is higher than that of the attribute medium smell indicating the increase in intensity of preference as treated water smell is reduced. For ASC, the coefficient is negative and statistically significant at the 1% level. This means that the status quo was less likely to be preferred to the alternatives. This finding implies that the respondents are more likely to adopt greywater technology than to remain with the status quo in which they do not have the technology.

4.5.4.1 Marginal WTP

The mWTP for the greywater attributes for models estimated with interaction terms are shown in Table 4.8.

Table 4.8: The mWTP for greywater attributes in TZS and US\$

Attributes	RPL	CL	G-MNL	LC	
				Class 1	Class 2
lifetime10	20807.50	-67,271.94***	26,740.7	1,960,000**	110,000***
	(9.05)	(US\$29)	(11.63)	(US\$852)	(US\$48)
lifetime15	563.25	146,102.9	-14,688.99	-1,040,000**	-10,000
	(0.24)	(US\$64)	(-6.39)	(US\$452)	(US\$4)
ease	-71453.18**	-36,920.8	68,238.77**	180,000	-180,000***
	(-31.07)	(US\$16)	(29.67)	(US\$78)	(US\$78)
cont_medium	386,364.4***	401,140.83***	384,671***	-7,160,000***	250,000***

	(167.98)	(US\$174)	(167.25)	(US\$3,113)	(US\$109)
cont_low	367867.20***	270,256.2	398,250.90***	-4,180,000***	240,000***
	(159.94)	(US\$118)	(173.15)	(US\$1,817)	(US\$104)
smell_medium	160011.70***	250,799.97***	150,578.20***	-7,490,000***	-60,000*
	(69.57)	(US\$109)	(65.47)	(US\$3,257)	(US\$26)
smell_low		445,829.38***	-	-7,350,000***	-70,000*
	236265.70***		211,421.70***		
	(102.72)	(US\$194)	-(91.92)	(US\$3,196)	(US\$30)

*** p<0.01, ** p<0.05, * p<0.1. US\$ amounts in parenthesis.

In Table 4.8, the results shown are for the RPL, G-MNL, CL and LC with interaction terms. The latent model's class 1 has the highest mWTP of all the models shown in Table 4.8. For RPL, respondents' WTP decreases by about TZS71,453.18 (US\$31.07) if the greywater technology does not require some training to install, use and maintain. Further, respondents were willing to pay at least TZS386,364.47 (US\$167.98) more for greywater technology that has medium contamination. The mWTP is TZS367,867.20 (US\$159.94) for greywater technology with low contamination. Compared to high smell, respondents were willing to pay at least TZS160,011.70 (US\$69.57) more for a greywater technology that produces medium smell and at least TZS236,265.70 (US\$86) for a technology that produces water with low smell. These mWTP estimates are similar to those obtained from the GMNL model, but generally lower than those from the CL model – except for the attributes 'ease of use' and 'low contamination'. They are also lower than the estimates from the latent class (LC) model, particularly for Class 1.

Analysis of greywater packages

The study further analyses WTP for different scenarios for greywater technology that can be introduced. Several packages comprising combinations of attributes have been in this

illustration and a RPL model has been used in the calculations. The results of the total mWTP for 8 greywater technologies or packages are presented in Table 4.9.

Table 4.9: WTP for greywater technology packages

Package	lifetime10	lifetime15	ease	Cont: medium	Cont: low	Smell: medium	Smell: low	WTP (TZS)	WTP (US\$)
1		X	X		X		X	676,149.33	293.98
2	X		X		X		X	696,393.58	302.78
3		X	X	X			X	694,646.53	302.02
4	X		X	X			X	714,890.78	310.82
5		X	X		X	X		599,895.33	260.82
6	X		X		X	X		620,139.58	269.63
7		X	X	X		X		618,392.53	268.87
8	X		X	X		X		638,636.78	277.67

Note: X means the attribute was included in that package

In this illustration, the WTP ranges between TZS599,895.33 (US\$260.82) and TZS714,890.78 (US\$310.82) which corresponds to the package (lifetime15, ease, low contamination, and medium smell) and the package (lifetime10, ease, medium contamination, low smell) packages, respectively. The WTP values are higher for packages that involve low smell and contamination, respondents are generally WTP more for technologies with medium contamination and medium smell. This corresponds to the preference results which show that technologies with low contamination and low smell are generally preferred. These WTP values are within the range of WTP amounts elicited through the auxiliary questions which showed a minimum of TZS200 (US\$0.09) and a maximum of TZS2 million (US\$870). For greywater technology packages the results of this study are lower than what was established by Aina et al. (2023) who showed that households were willing to pay ZAR5,713 (US\$383) for greywater technology. However, the WTP values are significantly lower than for other technologies as established by Aina et al. (2023): ZAR13,986 (US\$939) for rainwater technology, ZAR13,501 (US\$906) for double flush toilet and ZAR10,722 (US\$720) for water-efficient showerheads.

For the greywater attributes, mWTP for attributes in this study is higher than what Thiam et al. (2021) found.

4.7 Additional robustness analysis

In the previous analysis, the RPL model was compared with the CL, GMNL, and LC models as part of a robustness check, with the RPL model demonstrating strong performance. In this section, the focus is on comparing the RPL model estimated previously with an alternative RPL specification that accounts for potential ordering effects in the experimental design. While earlier diagnostics suggested that ordering effects were not present in the data, this analysis further investigates the issue by interacting each attribute with a binary variable indicating whether the respondent began with the greywater technology experiment (coded as 1) or the water supply improvement experiment (coded as 0). Columns (1) and (2) of Table 4.10 present the baseline model estimates, while Columns (3) and (4) display the mWTP results from the RPL model that accounts for experimental ordering. The mWTP estimates from the baseline model closely align with those from the model controlling for order effects, reinforcing earlier findings that ordering effects are minimal. In the RPL model that controls for order, WTP for a greywater technology with a 10-year lifespan was TZS284.72 (US\$0.12), and TZS472.74 (US\$0.21) for a 15-year lifespan. The attribute ease was associated with a negative WTP of -TZS31,310 (US\$13.61), indicating disutility. For moderate and low contamination levels, respondents were willing to pay TZS250,730.20 and TZS321,547.60, respectively. Similarly, the mWTP for moderate smell was TZS171,251.20 (US\$74.46), increasing to TZS251,608.80 (US\$109.40) for low smell levels.

Table 4.10: mWTP for sensitivity analysis

VARIABLES	mWTP (baseline estimates)		mWTP (Controlling for order)	
	TZS	US\$	TZS	US\$
	(1)	(2)	(3)	(4)
lifetime10	20,807.50	9.05	284,72	12.38
lifetime15	563.25	-0.24	472.74	0.21
Ease	-71,453.18	-31.07	-31,310.9	-13.61
cont_medium	386,364.4	167.98	250,730.2	109.01
cont_low	367,867.20	159.94	321,547.6	139.80
smell_medium	160,011.70	69.57	171,251.2	74.46
smell low	236,265.70	102.72	251,608.8	109.40

4.8 Heterogeneity analysis

Preferences and WTP were examined across various socio-demographic groups, including income level, municipality, gender, age, water consumption, and educational attainment. The WTP estimates are presented in Table 4.10, while the corresponding coefficient estimates are reported in Table E.4 in the Appendix. The sample was divided into low-income ($\leq$ median income) and high-income ($>$ median income) groups. The results indicate that individuals in the high-income group are generally willing to pay more for greywater technology attributes. In terms of geographical variation, respondents from Ilala and Temeke municipalities exhibit lower mWTP values compared to those from other municipalities.

Furthermore, preference and WTP for men and women are generally similar with both groups placing limited value on the lifespan of the technology. However, women exhibit a higher WTP for improved odour (smell) attributes than men. Age differences are also notable: older respondents (above 45 years) place value on all attributes, whereas younger individuals (below

45 years) primarily value attributes related to contamination and smell. Water consumption patterns reveal that low water users are willing to pay more than high water users, and they prioritise different attributes. Specifically, low water users place greater value on contamination and odour, while high water users emphasise lifespan and contamination. Educational attainment is another source of heterogeneity: individuals with higher education (certificate/diploma or university) demonstrate stronger preferences and higher WTP for all attributes, whereas those with lower levels of education place less value on most attributes.

Table 4.11: WTP in TZS

	Income		Municipality					Gender		Age		Water consumption		Education			
	Low	High	Kinondoni	Illala	Temeke	Ubungo	Kingamboni	male	female	less 45	more45	low	high user	Primary or less	secondary	Certificate/ diploma	University
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
lifetime10	103,855**	225,724***	-375,237	32782	415376	233961	240365	38588	22456	-47263	131134	30915	31583	78520	-2932	87494	26569
lifetime15	22,186	174,887***	-226,099	62651	440550	171390	136002	68937	17767	-15468	110705	40024	46039	-26759	116385	93765	25937
ease	16,564	176,805***	74,522	97464	103126	86454	-263154	-57484	133144	-41294	78237	116290	16874	113488	-11199	97545	194252
cont_medium	293,397***	537,288***	685,914	281650	251735	685015	458092	415402	307589	392227	390035	493234	294439	239668	246744	546693	599357
cont_low	7,566	617,790***	422,676	21136	28709	758806	777363	283131	226398	268414	260650	442454	137022	57891	65169	385067	642743
smell_medium	132,355***	250,668***	430,863	32592	4926	742576	80413	174288	212766	178924	183622	213245	162333	36146	221098	170814	269797
smell_low	249,158***	305,709***	569,733	68730	68822	1019880	247760	252701	361517	277218	242815	306280	230537	137745	318167	175872	301348

Table 4.12: WTP in TZS

	Income		Municipality					Gender		Age		Water consumption		Education			
	Low	High	Kinondoni	Illala	Temeke	Ubungo	Kingamboni	male	female	≤45	>45	low	high user	Primary or less	secondary	Certificate/ diploma	University
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
lifetime10	45	98	-163	14	181	102	105	17	10	-21	57	13	14	34	-1	38	12
lifetime15	10	76	-98	27	192	75	59	30	8	-7	48	17	20	-12	51	41	11
ease	7	-77	32	42	45	38	-114	-25	58	-18	34	51	7	-49	-5	42	84
cont_medium	128	234	298	122	109	298	199	181	134	171	170	214	128	104	107	238	261
cont_low	3	269	184	9	12	330	338	123	98	117	113	192	60	25	28	167	279
smell_medium	58	109	187	14	2	323	35	76	93	78	80	93	71	16	96	74	117
smell low	108	133	248	30	30	443	108	110	157	121	106	133	100	60	138	76	131

4.9 Discussion

The overarching objective of this chapter is to evaluate the adoption of water-saving technologies among urban households in Tanzania by examining their underlying preferences and willingness to pay for desirable attributes of such technologies. The findings supplement the literature on the adoption of water-saving technologies in developing countries. The proportion of households using water-saving technologies and those using greywater are established. Specifically, the percentage of people using water-saving technologies is established to be 40% and is in similar ranges to previous literature (Millock & Nauges, 2010; Ngcobo et al., 2023). A 7% rate of using greywater is established in the study and this rate is lower than what other studies established in other developing nations. Gyapong-Korsah et al. (2023) found the greywater use to be 20.1% while Dwumfour-Asare et al. (2017) found it to be 62% in Ghana. The lower rate of use of greywater established in this study can be due to perceptions of the technology and greywater itself. Users may perceive health risks, have mistrust of authorities responsible for lowering health risks and may find the idea of using greywater to be disgusting (Portman et al., 2022; Wade et al., 2021). Existing water systems and buildings as well as financial constraints can limit the adoption of greywater technologies. Perceptions of using wastewater are also established in the study as respondents perceive that greywater comprises black/toilet water (23.62%), greywater is harmful to human beings (17.69%) and should not be allowed in homes (33.85%). These findings are similar to the perceptions established by Ogunbode et al. (2023) in Nigeria who established that 21% prefer recycling water in their homes, 15.6% indicated that it is not hygienic, and 17.6% indicated that it could pose health challenges.

The findings on the factors affecting the adoption of water-saving technologies are generally similar for a binary logit model and a Poisson model. According to the binary logit model, the factors affecting the adoption of water-saving technology are education (i.e., primary education, secondary education, certificate/diploma), awareness, age, income, household size and social capital but education dummies did not have statistically significant coefficients in the Poisson model. Explicitly, having primary education, secondary education, or certificate/diploma is associated with a high likelihood of adoption of water-saving technologies. This could be due to the point that education exposes people to different technologies and improves peoples' knowledge of how the technology may work which is important for water-saving technology adoption. The importance of education in affecting the adoption of water-saving technology is in line with the results found by Portman et al. (2022) but is not consistent with Gyapong-Korsah et al. (2023). The study underpins also the importance of exposure/awareness to water-saving technologies in adopting the technology: being aware of water-saving technologies is associated with a high likelihood of adoption. This was also the case with the Poisson model, which shows that being aware of water-saving technologies is associated with adopting more technologies. This could be because awareness is associated with high knowledge and understanding of how technology works, its perceived benefits and how to access it, which promotes the adoption of technology.

Further findings of the study on the impact of income on the adoption and number of water-saving technologies are in line with previous studies (Gyapong-Korsah et al., 2023; Marie et al., 2020). The marginal effect of income as established in the logit model is very low, but it is positive to indicate that as income increases the likelihood of adoption also increases. The results also indicate that an increase in income is associated with an increase in the number of technologies that can be adopted, which is intuitive since more income increases the

affordability of several technologies. When the household head has a low income, then it will be spent on competing needs such that in general, and thus only few or no technologies can be adopted. As per this study, age is positively related to the likelihood of adopting water-saving technologies and hence, the older the household head is, the more technologies a household is likely to adopt. These results imply the accumulation of experience and exposure to technologies as people grow old such that they will adopt more technologies (Dieu-*Hang et al.*, 2017). This is true for Dar es Salaam, since most elders are likely to have more income than young ones hence likely to adopt the technology. The result on social capital is also intuitive: people who are members of social groups are more likely to adopt water-saving technology than their counterparts, which is consistent with the findings of *Jha et al.* (2019). Social groups provide some forms of financial support like credit which improves the financial position of borrowers to acquire and maintain the technology (*Carmen et al.*, 2022; *Cofré-Bravo et al.*, 2019). Also, social groups enable the exchange of knowledge, ideas and implementation strategies which improve the likelihood of adopting the technology.

The choice experiment approach shows results on the preferred attributes of greywater technology. In line with theory and empirical literature, the study finds that an increase in the costs of technology is associated with a reduction in utility indicating that respondents prefer less-cost technologies. This finding is consistent with *Thiam et al.* (2021) who established that respondents in South Africa prefer a greywater technology that costs less. The study also finds that respondents preferred greywater technology that requires some training in the installation, use and maintenance compared to a technology that does not require training. This finding contradicts the finding of *Aina et al.* (2023) who established that respondents preferred water-saving technologies that are easy to use, install and maintain, meaning that training is not required. For this study, the preference for technologies that require training could be a result

of respondents' lack of trust in greywater technologies since they involve the use of recycled water. Respondents' trust could be in technologies that are well-installed and maintained given the risks associated with using recycled wastewater; and thus, well-installed technology could give them more health and safety assurance. Recycled water may create diseases and may be contaminated, and this could affect the perception of respondents hence the need to be trained on how to safely and healthy use and maintain them.

Furthermore, households preferred greywater technology that minimises contamination of water with bacteria like cholera, *Escherichia coli*, and rodents, which can cause water-borne diseases. This result is sensible given that high contamination can be associated with high health risks to people. The findings on this attribute are consistent with the findings of Thiam et al. (2021) who showed that respondents preferred water-saving technologies that do not have the possibility of engendering diseases when contacted. The smell was found to be another important attribute for a preferred greywater technology. In particular, a preferred greywater technology should produce water with low/no smell, which is consistent with what Thiam et al. (2021) and Aina et al. (2023) found. The study further shows that the intensity of preference for smell increases as we move from medium smell to low smell. A higher preference and utility for greywater technology that produces water with low smell could be because water with no or low smell could be viewed as being synonymous with cleanliness and purity, and this provides better psychological comfort to users and is linked to little/no potential health risks. Also, users can find the greywater technology which produces water with odour or bad smell to be disgusting (Wade et al., 2021).

Overall, respondents had positive willingness to pay for smell and contamination indicating high value placed on the negative externalities associated with the use of greywater within their

homestead. This finding is consistent with the key studies on greywater technology adoption in developing countries, which also established that respondents express disutility in smell and diseases associated with the technology.

Overall, respondents demonstrated positive willingness to pay for improvements in smell and contamination attributes, indicating a strong aversion to the negative externalities associated with greywater use within the household. This finding underscores the high value placed on health and hygiene-related aspects of the technology. It aligns with previous studies on greywater adoption in developing countries (Portman et al., 2022; Thiam et al., 2021), which similarly found that users expressed disutility due to concerns about odour and potential health risks linked to the use of recycled water.

Respondents were willing to pay between TZS599,895.33 (US\$260.82) and TZS714,890.78 (US\$310.82) to acquire and maintain a greywater technology with different attributes of lifetime, ease, contamination, and smell. Although these amounts exceed the average monthly income of a household head (TZS570,000 or ~US\$250), they represent approximately 9% to 11% of the average annual income. Prices of the technology respondents are willing to pay for are reasonable given that part of the cost would be a one-time payment, and some are contributed to maintenance throughout the technology's lifespan, which could be 15 years. In Dar es Salaam, simple greywater technologies cost between TZS1,500,00 (\$500) to TZS2,300,00 (\$1,000) which corresponds to about 17% to 33% of annual income, respectively. It is also important to note that the costs of acquiring technologies are about 2-3 times higher than the respondent's willingness to pay. The relatively low mWTP compared to the market cost of greywater technologies may be attributed to the generally low-income levels among respondents, as well as negative perceptions associated with the use of recycled water.

Considering respondents' WTP amounts, there is a significant cost gap which can hinder the adoption of greywater technologies by some households especially low-income households. This implies the need for financing mechanisms such as credit schemes by the private sector and government subsidies to promote adoption. Given that approximately 89% of individuals in Tanzania have access to financial services, and 36% reported access to credit, there is an opportunity to leverage financial mechanisms to facilitate the adoption of greywater technologies (FinScope, 2024).

4.10 Conclusion and Policy Implications

This study investigated the adoption of water-saving technologies by households in Dar es Salaam, Tanzania. A focused examination of a particular type of water-saving technology, greywater technology, is undertaken by examining peoples' preferences and WTP for such a technology. The study utilized the diffusion of innovation theories and empirical studies on water-saving technologies in determining the factors affecting the adoption of water-saving technologies in urban areas. Using data from 962 respondents from Dar es Salaam and by adopting a binary logit model, the study shows that the factors that affect adoption are education, age, gender, income, household size and water-saving technology awareness. It is established that females and aged heads and those who are aware of water-saving technology have a higher likelihood of adopting water-saving technology. Also, even people with primary, secondary and certificate/diploma education were more likely to adopt water-saving technologies. Using a Poisson regression, the study showed that households are likely to adopt more water-saving technologies as they become exposed to them and as income and age increase. However, they are likely to adopt more water-saving technologies as household size decreases.

A choice experiment is undertaken to complement the analysis of water-saving technologies by assessing the preference and WTP for greywater technology attributes. A choice experiment is consequently designed and implemented with the guidance of standard literature such as Johnston et al. (2017) and choice experiment studies on water-saving technologies such as Thiam et al. (2021) and Aina et al. (2023). This literature guided the design of the experiment including the selection of attributes and their levels, the design of choice cards and choice sets, questionnaire design and data analysis. Five attributes are used in this experiment, and these are lifetime of the technology, contamination of water, smell, ease of use and cost. All these attributes had three levels except for ease of use, which had 2 levels, and costs which were treated as continuous. A CL model is then adopted for the estimation but due to its failure to cater for preference heterogeneity and the failure of the Independence of Irrelevance Alternatives to hold, an RPL model that captures preference heterogeneity is ultimately adopted. A 2-class LC model and GMNL-II were also used as a benchmark model. The RPL model performed well against the CL, GMNL and LC models in terms of statistical significance and sign of coefficients.

Based on the RPL, the study found that ease, which captured whether training was needed or not, contamination, smell and cost are the important attributes of the greywater technology that can be introduced in Dar es Salaam. More specifically, preference is higher for greywater technology that requires some training to install, use and maintain as well as for a technology with medium and low contamination compared to high contamination. In addition, greywater technology with medium and low smell is preferred to technology with high smell. Regarding costs, the study established that utility decreased with the costs of technology. The ASC shows that respondents prefer adopting greywater technology relative to the status quo of no adoption at all.

The results of this study have important policy implications for the adoption of water-saving technologies in Dar es Salaam, Tanzania. The study established that people generally prefer adopting water-saving technologies, and they should be promoted in Tanzania and developing countries beyond. While the promotion of water-saving technology is important in Dar es Salaam given the scarcity of water, it is important to consider the factors influencing its adoption of which income is one. Less advanced greywater technologies cost about 2-3 times more than the willingness to pay amounts, which is about 17% to 33% of the average annual income for the household head. Policies should be implemented to promote the adoption of water-saving technologies for low-income people, and this is very important since Tanzania is a developing country. With greywater technologies being provided by the private sector and market costs being high, credit schemes by banks, microfinance institutions, or other organisations like saving groups should be considered to financially support households to purchase greywater technology. Given that approximately 89% of individuals in Tanzania have access to formal and informal financial services, and 36% report access to credit, there is an opportunity to leverage financial mechanisms to facilitate the adoption of greywater technologies (FinScope, 2024). Expanding access to credit specifically targeted at supporting the purchase and installation of such technologies could enhance uptake, particularly among lower-income households.

Also, arrangements like fix and supply on instalments by the private sector should be used by to promote the adoption of these technologies. Other policies include subsidising the acquisition of technology and lowering taxes on water-saving technologies to enhance their adoption. This could also work since people prefer less costly technologies. The effect of subsidising and tax reduction on greywater technology is to increase disposable income and lower purchasing costs which may increase adoption among low-income people.

With adoption being lower among people with no education compared to those with primary, secondary and certificate/diploma education, policies should be developed and targeted at those with no education. Also, people who are aware of the existence of water-saving technology are more likely to adopt the technology than those without. These findings show the importance of awareness and education to promote the adoption of water-saving technologies in Dar es Salaam. Hence, awareness and campaigning programs should be implemented to educate and make people aware of the existing water scarcity situation and the possibility of using water-saving technologies as a solution. In doing so, it is important to target social groups to influence peoples' perceptions towards the use of water-saving technologies. This also implies that people who are not members of social groups can also be targeted differently to promote the adoption of water-saving technologies.

Overall, the choice experiment results have important implications for the introduction of greywater technology especially on the preferred attributes. The study recommends the introduction of greywater technology that can produce treated water that has low smell, low contamination and requires some training on use, installation, and maintenance. Again, the greywater technology should not be expensive and there must exist some financial support through subsidies to stimulate mass uptake. The use of financial support is critical since mWTP for the greywater attributes is quite high relative to the income levels of the average household. Although the study specifically targeted high-water users, given their greater potential for water savings, the findings are also relevant to low water users, who may face more significant income constraints. For this group, the adoption of greywater technologies can contribute both to water conservation and to household financial savings. However, given their financial limitations, the promotion of greywater technologies among low water users should carefully consider issues of affordability and access.

The study examined factors influencing the adoption of water-saving technologies and looked at the preference and willingness of households to pay for specific water-saving technologies (greywater technologies) in Dar es Salaam, Tanzania. This focus on households residing in Dar es Salaam imposed limitations on the generalisability of study findings to other areas or cities in Tanzania since households in other areas may experience different socioeconomic features as those experienced by households in Dar es Salaam. Also, on preference and willingness to pay, the target was on greywater technologies only so future research can investigate other types of technologies. In addition, further studies can practically use intervention methods, where they introduce the greywater technologies to some households and later, we can see whether that can influence other households to adopt the technology.

Several limitations were faced by the study. Firstly, the study examined the factors affecting the adoption of water-saving technologies and could not focus on greywater technology. This is because of the few cases of households using greywater technology in the study's sample. This factor limited an in-depth investigation of the factors affecting the adoption of greywater technology using advanced methods such as regression analysis. Secondly, the study investigated preferred attributes and willingness to pay for greywater technology but focused on a few attributes of the technology (ease of use, contamination, smell and cost). There are some attributes that could have been introduced to comprehensively understand households' preferences for greywater technology. Few attributes were included in the choice experiment to reduce participants' fatigue and motivation to participate. Further research can examine factors affecting the adoption of greywater technology by conducting a large survey for Tanzania or other countries to encounter many cases of households to using greywater technologies. In addition, future research should consider including additional attributes for

greywater technologies considering the Tanzanian context to better understand household's preferences and willingness to pay.

Chapter 5: General conclusion

5.1 Summary of findings

This thesis addresses water scarcity in developing countries focusing on a case study of households in Dar es Salaam, Tanzania. The thesis raises three objectives which are as follows:

- (i) To investigate the households' preferences and WTP for reliable water supply in Dar es Salaam, Tanzania.
- (ii) To investigate the impact of an information campaign on domestic water-saving behavior among households in Dar es Salaam, Tanzania.
- (iii) To investigate the adoption, preferences and WTP for water-saving technologies among households in Dar es Salaam, Tanzania

The thesis employs a choice experiment method to investigate households' preferences and WTP for reliable water supply in Dar es Salaam, Tanzania. It examines different attributes related to water service, such as frequency, time of service, quality of water, water pressure, and costs. The assumption of preference homogeneity is tested and found to be invalid, indicating heterogeneity in preferences among respondents. To account for this, a RPL model is employed and a sample of 962 households is used. The study finds that respondents prefer high-quality tap water that is drinkable with or without treatment, higher water pressure (takes 2 minutes or less to fill a 20-litre bucket), and water services provided in the morning, (06:00-11:59) afternoon (06:00-11:59), or night (18:00-05:59). The study further shows that respondents' utility decreased with an increase in price of water used.

Regarding WTP, the study showed that respondents are willing to pay a minimum of TZS367.99/m³ (US\$0.16/m³), TZS721.74 (US\$0.31/m³) and TZS481.92 (US\$0.21/m³) more for water supplied either in the afternoon, night or morning, respectively, compared to water supplied for 24 hours. Furthermore, respondents are willing to pay additional amounts of at least TZS1383.77 (US\$0.60/m³) for tap water with high pressure and TZS1128.11/m³ (US\$0.49/m³) for tap water with standard pressure. Regarding quality, respondents are willing to pay an additional amount of TZS250.07 (US\$0.11/m³) for water which is drinkable after treatment (boiling) and TZS187.99/m³ (US\$0.08/m³) for tap water that is drinkable without treatment compared to water that is not drinkable without any treatment. This preference is attributed to a lack of trust in the water authority's ability to provide clean water, as well as the use of outdated infrastructure that increases the risk of contamination, prompting people to further treat water before consuming it.

Further, the study adopts an RCT to investigate the impact of an information campaign on domestic water-saving behaviour among households in Dar es Salaam, Tanzania. In the study, targeted households (treated group) receive monthly water consumption reports comparing their consumption to their neighbourhood's median. These reports were sent over six-month period. Utilising a DiD estimator, the study reveals that the information campaign impacted water consumption levels as the targeted group reduced water consumption by 1.49m³ (7.65%) compared to the control group during the intervention period. Additionally, in the first five months following the intervention, the treatment group reduced their water consumption by an average of 1.62m³ (8.18%) to 2.30m³ (11.18%). Overall, these findings suggest that the SCMs successfully motivated households to save water.

Lastly, the study investigates the adoption as well as preferences and WTP for water-saving technologies among households in Dar es Salaam, Tanzania. The study used data from 962 households and employed Poisson and binary logit models to analyse the factors influencing the adoption of water-saving technologies. Further, a choice experiment is conducted to examine the preferred attributes of greywater technologies (ease of use, contamination, smell, and costs) and the corresponding WTP. The study finds that 40% of households are using water-saving technologies and 7% are re-using wastewater. Of those re-using wastewater, 3% are using tanks, 94% are using buckets and 3% are using a well or pond. Binary and Poisson logit models reveal that age, education, income, membership in social groups and awareness of water-saving technologies are the factors affecting the adoption of water-saving technologies. Specifically, households with older, married, higher-income, more educated, respondents who were members of social groups and aware of water-saving technologies are more likely to adopt these technologies. Also, as shown by the Poisson model, these households are more likely to adopt a greater number of water-saving technologies.

The CL, generalised logit and latent class models are used to analyse the choice experiment data. These models reveal that households prefer greywater technologies with longer lifespans, less contamination and reduced odour, though the high cost of acquisition and maintenance caused disutility. Respondents are willing to pay a minimum of TZS90,283 (US\$39) for a greywater technology which is easy to use and install. Further, respondents are willing to pay at least TZS389,320 (US\$169) more for greywater technology with medium contamination and TZS424,912 (US\$185) for greywater technology with low contamination. Compared to high smell, respondents are willing to pay at least TZS137,230 (US\$60) and TZS189,146 (US\$82) more for a greywater technology that produces medium and low smell, respectively. Overall, a comparison of different attributes for a greywater technology shows a WTP ranging from

TZS414,511.8 (US\$180.22) to TZS573,947 (US\$249.54), which represents about 6% to 8% of the average annual income for a household head. In Dar es Salaam, the cost of simple greywater technologies ranges from TZS1,500,00 (\$500) to \$2,300,00 (\$1,000), equivalent to about 17% to 33% of annual income, respectively. These costs of acquiring greywater technologies are established to be 2-12 times higher than the respondent's willingness to pay.

5.2 Policy implications

The findings established in this thesis have important implications for policymaking. Foremost, the thesis highlighted that the quality and pressure of tap water matter to respondents. Therefore, the water authority can aim to supply water with high water pressure that reaches all households including those located in hilly areas, while ensuring it is of high quality to avoid health risks. These improvements will require significant investments by the water authority in infrastructure and quality, which may be challenging given the authority's limited funding. Therefore, they can accompany these water supply improvements with increases in the price of water as respondents are willing to pay for better services. These increases should be introduced in stages to help consumers adjust and to prevent them from turning to unsafe alternatives, such as open water sources.

Although households are generally willing to pay for water supply improvement, some are low-income earners, whose income may not be sufficient to meet their needs. Given that water is a necessity that everyone should access at a high quality, subsidies can be implemented, and significant government investments can be made to enhance water infrastructure, accommodate high water pressure, and improve water quality. Subsidies can be offered, and significant government investments can be made to improve water infrastructure to accommodate high water pressure and to enhance the quality of water. Hence, findings of this

thesis underscore the importance of the investment drive Tanzania undertook to raise US\$15.02 billion for the development of water infrastructure, enhancing water access and institutional development and development of water resource management through the Water Investment Programme (2023-2030). This form of subsidy will ensure that poor people, who are not able to use boreholes or buy water for basic use like cooking and drinking, are not forced to abandon tap water for unsafe and unimproved sources. This way ensures that the country stays on track to meet sustainable development goals related to improve access to water. Overall, these policy implications suggest the need for policymakers to review the water supply situation and pricing while considering the need to balance production and consumption.

The thesis further found compelling evidence of the effectiveness of information campaigns in promoting water conservation behaviour among urban households. A policy implication derived from this finding is for the DAWASA to adopt information campaigns to promote water conservation in Dar es Salaam. Information campaigns are less costly, easier to implement and less likely to face public and political resistance compared to alternative demand management instruments such as tariffs. Further, using information campaigns by DAWASA and other water supply authorities reduces the negative distributional effects of water demand management instruments, such as tariffs, which disproportionately impact the poor.

Additionally, the study findings imply that promoting water-saving technologies among households can result in water-savings. While the promotion of water-saving technology is important given the water scarcity, it is important to consider the factors influencing its adoption of which income is one. The Thesis' findings point to the need to promote the adoption of water-saving technologies for low-income people and this is very important since

Tanzania is a developing country. These policies include subsidising the acquisition of technology and lowering taxes on water-saving technologies to enhance their adoption. This could also work since people prefer less costly technologies. The effect of subsidising and tax reduction on greywater technology is to increase disposable income and lower purchasing costs which may increase adoption among low-income people.

Awareness and campaigning programs could be implemented to educate and make people aware of the existing water scarcity situation and the potential benefits of using water-saving technologies. In doing so, it is important to target social groups to influence peoples' perceptions against the use of water-saving technologies. The thesis also recommends the introduction of greywater technologies with treated water that has low odour, and minimal contamination, and that require some training for use, installation, and maintenance. Again, the greywater technology should be affordable and financial support through subsidies can be provided. The use of financial support is even critical since mWTP for the greywater attributes is quite high considering income levels.

Overall, the findings from this thesis point to the following implications:

- a) Investment in water supply infrastructure to enhance water quality and pressure, as households are willing to pay more for better services.
- b) Scaling up programs providing monthly consumption reports to encourage water conservation, leading to significant reductions in usage.
- c) Investment in educational initiatives to promote water conservation techniques and the benefits of responsible water use.

- d) Providing subsidies or incentives for smart metering technology to enable real-time monitoring of water consumption.
- e) Offering subsidies, tax incentives, or low-interest loans to reduce the financial barriers for households adopting water-saving technologies.
- f) Encouraging safe greywater reuse by providing guidelines and incentives, particularly in new residential developments.

5.3 Limitations of the thesis and areas for further research

The thesis faced several limitations. One limitation of the thesis is on the site, for this case Dar es Salaam, Tanzania. The focus on Dar es Salaam imposes a limitation in the direct generalisability of findings to other cities in Tanzania since the results apply only to the site where it was conducted. Different cities in Tanzania face different water supply scenarios hence different status quo as viewed by water users. In analysing the impact of information provision in nudging households to save water, the study focused on intervention for only six months and analysed post-impact for only five months following the intervention. The study tested only social comparison information, and it did not consider other types of messages or campaigns that can be used to nudge households to save water. In addition, there are few studies examining the impact of social comparisons on households' water-saving behaviours in African countries.

Also, the thesis examined the factors affecting the adoption of water-saving technologies and could not focus on greywater technology. This is because of the few cases of households using greywater technology in the study's sample. This factor limited an in-depth investigation of the

factors affecting the adoption of greywater technology using advanced methods such as regression analysis. Also, the thesis investigated preferred attributes and willingness to pay for greywater technology but focused on a few attributes of the technology (lifetime, ease of use, contamination, smell and cost). There are some attributes that could have been introduced to comprehensively understand households' preferences for greywater technology. Few attributes were included in the choice experiment to reduce participants' fatigue and motivation to participate.

Further research could be conducted in other areas using the choice experiment to elicit preferences and WTP for water supply and greywater technologies or apply methods that enable the generalisability of this study findings to other cities. Further, future studies can focus on rural areas to understand their preferences and willingness to pay for greywater technologies and what features of technology they prefer. Studies can also conduct cost and benefit analysis of water supply improvements in the case of Dar es Salaam, Tanzania, to provide useful insights on investment possibilities. Additional attributes of water supply improvements can be tested. Further research could be done in other African countries using longer intervention periods (e.g. 12 months) and exploring the heterogeneity of treatment effect for important factors such as income as well as assessing the effectiveness of different types of social messages such as tips and recognition messages in promoting water conservation.

Other studies could also evaluate whether the impact of sending information wanes out over time, that is whether households tend to revert to their original water usage habits after the study period ends. In addition, further studies could investigate the unintended impacts of these kinds of interventions and investigate other types of nudges. Research could also examine factors affecting the adoption of greywater technology by conducting a large survey for

Tanzania or other countries to encounter many cases of households to using greywater technologies. In addition, future research should consider including additional attributes for greywater technologies considering the Tanzanian context to better understand household's preferences and willingness to pay.

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Appendices

Appendix A: Questionnaire



Water Project

QUESTIONNAIRE



INTRODUCTION

Good morning/afternoon/evening. My name is **XXXX**, and I am part of a research team from the University of Dar es Salaam collecting data in Dar es Salaam on water consumption. The data collection is part of Ph.D. studies for miss Julieth Julius Tibanywana, a student at the University of Cape Town and also an assistant lecturer at the University of Dar es Salaam. The project's main objective is to examine what affects the water supply and demand in Dar es Salaam. A small sample of households has been selected in your community to participate in the study and your household is one of them. The information we are collecting is **confidential** and will only be used for this study identifying information will not be shared publicly. I kindly request your assistance in completing this questionnaire. The interview is voluntary and it will take approximately 40 minutes of your time. Your input will contribute to helping the Local authorities develop improved water policies.

Respondent eligibility; Household head/spouse/adult aged 18 years and above

Are you willing to participate?

- 0. No
- 1. Yes

Date:

Enumerator name:

SECTION A: SOCIAL DEMOGRAPHICS

		Code
A1	Household ID (record the one from the list)	
A2	District 1.Kinondoni 2.Ilala 3.Temeke 4.Ubungo 5.Kigamboni	
A3	Ward	
A4	Street	
A5	Are you the household head? 1. Yes (skip to A4) 2.No	
A6	What is The respondent's relationship with the household head? 1. Spouse	

				2. Children 3. Son-in-law daughter-in-law 4. Grandchild 5. Brother/Sister 6. Not related 7. Other relatives 99. Others, Specify	
A7	What is the Marital status of the respondent? 1 = Single, 2 = Married, 3 = Widow, 4 = Divorced 99. Other, specify		A15	How many rooms including kitchen and sitting room are in the house?	
A8	What is the Highest Education level of the respondent **? 0 = None, 1. Some primary 2 = Primary 3 = Some Secondary 4 = Secondary 5 = Certificate 6 = Diploma, 7 = University degree 99. Other, specify		A16	What is the Size of the property/land (m ²)	
A9	What is the Gender of the respondent? 0 = Female 1 = Male		A17	Number of years the household has lived in the area	
A10	What is the Age of the respondent (years)?		A18	What is the floor of the house? 1. Earth/sand 2. Tiles 3. Cement/concrete 4. Carpet 5. Dung 99. others, specify	
A11	Education level of the spouse 0 = None, 1= Some primary 2 = Primary 3 = Some Secondary 4 = Secondary 5 = Certificate		A19	The roof of the house 1. Grass/mad/leaves 2. Concrete 3. Iron sheets 4. Tiles 99. Others, Specify	

	6 = Diploma, 7 = University degree 99. Other, specify				
A12	Number of Adults in the household		A20	Construction materials of the house 1. brick & cement 2. Burnt brick 3. Mud 4. Iron sheet 5. Timber 99. Others, Specify	
A12-1	Number of children in the Household				
A12-2	Total Household size				
A13	Type of settlement 1. surveyed 2. unsurvey		A21	Which sanitary facility are you using? 1. Flush toilet 2. Traditional pit toilet 3. Ventilated improved pit latrine 4. No facility (bush, field) 99. Others, specify	
A14	Residence/house status 1. Owned SKIP to A15 2. Rented		A22	Do you share the sanitary facility (toilet) with other households? 0. No 1. Yes	
A14-1	If rented what is the monthly rent?				

SECTION B: HOUSEHOLD INCOME & EXPENDITURE

		Code
B1	What is the Main occupation of the household head 1. Agriculture 2. Employed by the government/parastatal 3. Employed by private sector/NGO'S 4. Self-employment 5. Casual works 6. Unpaid work (business & regular including housewife) 7. Disabled 8. Job seeker 99. Others, Specify	
B2	Household head's income per month (salary + part-time activities)	

B3	Is the spouse employed? 0 = No (skip to B6) , 1 = Yes	
B4	What is the main occupation of the spouse 1. Agriculture 2. Employed by the government/parastatal 3. Employed by private sector/NGO'S 4. Self-employment 5. Casual works 6. Unpaid work (business & regular including housewife) 7. Disabled 8. Job seeker 99. Others, Specify	
B5	Spouse's income per month (salary + part-time activities)	
B6	How many other members of the household bring income? (State number)	
B7	Total household income (state number) from other members	
B8	Total Household Income =B2+B5+B7	

B9	On average, how much do you spend on the following items per month?	
	a) Water	
	b) Food	
	c) Education	
	d) Health	
	e) Groceries	
	f) Electricity	
	g) Other energy sources (Gas, charcoal,fuel etc)	
	h) Other, specify	
	i) Total household expenditure	
B10	Does the household own a swimming pool? 0 = No, 1 = Yes	
B10-1	How big is your swimming pool in liters?	
B11	Do the households have flowers/gardens/trees?	
B11-1	How big is the garden (acres)	
B12	Does the household have a lawn?	
B12-1	What is the size of the lawn?	
B13	Do the households have the following	
	1=Yes, 0=No	If yes, how many
	Radio	
	Television	
	Non-mobile telephone	
	Computer	
	Refrigerator	
	Battery/Generator for power	
	Motorcycle	

Bicycle		
Iron		
Cows		
Goats		
Chickens		
Sheep		
Horses		
Car		

SECTION C: ACCESS TO WATER

C1	What is the main source of water for domestic use 1. Piped from authority 2. Tube well, borehole 3. Protected dug well 4. Unprotected dug well 6. Protected spring 7. Rainwater collection 8. Tanker truck 9. Cart with small tank/drum 10. Water kiosk 11. Bottled water 12. Surface water (river, streams) 99. others	
C1-1	Drinking	
C1-2	Cooking	
C1-3	Bathing	
C1-4	Washing	
C2	How much water do you use for household use per day? Liters (If bucket, enumerator translate into liters)	
C3	In the last month, has there been any time when your household did not have sufficient quantities of water when needed? 1. Yes, at least once 2. No, always sufficient	
C4	What was the (main) reason you could not access sufficient quantities of water when needed? 1. Water not available from the source 2. Water was expensive 3. Others, specify	
C5	How many hours per day is this water supplied on average? (hours/day)	
C6	Is water from the authority always available from the pipe in the?	

		1=Yes, 0=No	If yes, how many days
	last one week		
	last one month		
	last one year		
C7	Do you believe the city will completely run out of water one day in the future? 0 = No, 1 = Yes		
C7-1	If yes, why		
C8	What is the main cause of water unavailability for some days? 1. Old infrastructure 2. Fix leakages 3. Repair & Maintenance of pipes) 4. Poor management and inefficient administration 5. Natural factors (climatic change) 6. I don't know		
C8-1	How did the household cope with water unavailability? 1. Use storage water from a tank 2. Use storage water from buckets 3. Use storage water from well 4. Buy water 5. Use water from boreholes 99. Others, specify		
C8-2	What are the impacts of water unavailability on households? 1. Wastage of time 2. Loss of Revenue (eg in Groceries) 3. Lack of hygiene (no bathing etc)		
C8-3	Which period do you receive water currently? 1. Morning (06:00-11:59) 2. Afternoon (12:00-17:59) 3. Night (18:00-05:59) 4. Twenty-four hours		
C9	Do you take any steps to save water? 1. Yes 2. No		
C9-1	If yes, What exactly do you do? 1. Recycle/re-use water 2. Closing taps while brushing teeth 3. Closing taps while washing dishes 4. Closing taps while taking showers and using soap 5. Collect rainwater 99. Others, specify		
C10	Do you receive notification of water interruption?		
C10-1	If yes, from who		
C11	How do you describe the quality of water you are currently using for domestic purposes		

	1. Low : Not drinkable without treatment 2. Medium: Drinkable with treatment/boiling 3. High: Drinkable without treatment/boiling	
C12	Is the water meter shared? 0=No, 1=Yes	
C12-1	If yes, how many households share	
C12-2	How many people are in those households in total?	
C13	Do you share the piped water with others? 0=No, 1=Yes	
C13-1	How many?	
C14	Do you sell water? 0=No, 1=Yes	
C14-1	On average, how much water do you sell per day? In liters	
C14-2	What is the price of water you are selling (per 20-liter bucket)	
C15	How is the water bill paid? 1. Household alone 2. Shared with others	
C16	Do you know the price of water per unit (1000 liters) from the authority? 0.No 1. Yes	
C16-1	If yes, how much	
C16-2	What is your Perception of water price 2. High 2. Fair 3. Low	
C17	The maximum price you can pay for a unit of water	
C18	Do you know one unit is how many liters? 0.No 1. Yes	
C18-1	State the number of liters	
C19	What is your water consumption perception when compared to other neighborhoods with the same characteristics as yours? 1. High users 2. Medium users 3. Lower users	
C20	Are you a member of any social group within the community? Yes No	
C20-1	Which group are you a member of	
C21	Provide the water meter number	

C22	What is the current pressure of authority water from the tap? 1.High pressure: takes 2 minutes or less to fill a 20-litre bucket 2.Standard pressure: takes 2-4 minutes to fill a 20-litre bucket 3.Low pressure: takes more than 4 minutes to fill 1 20-litre bucket	
-----	--	--

SECTION D: WATER SUPPLY RELIABILITY

Access to quality and portable water is one of the priorities of the Tanzanian government towards the achievement of the United Nations Agenda 2030 Sustainable Development Goals specifically goal 6. The government is therefore working on a framework for ensuring household access to clean and safe water.

As you might know, there is unreliability of water in many parts of Tanzania, including Dar es Salaam. The current water unreliability is mainly a result of the aged and poor physical infrastructure of the water distribution, lack of regular maintenance of the systems, and limited capacity for water production coupled with the rising population.

To address the water interruption problem, DAWASA (Water Authority) in Dar es Salaam is considering investments to upgrade and replace the existing water distribution systems. These investments are expected to reduce the frequency and duration of water interruption observed in your household. Also, the quality of water is expected to improve. However, such investments are costly and would result in rising in water prices per unit. The government is therefore considering looking at ways of funding this intervention to ensure a regular supply of water. This would imply some of the cost is transferred to consumers to maintain the infrastructure and also compensate upstream farmers to put in place conservation measures.

The government, therefore, proposes a range of policy scenarios that would guarantee regular water service. **CHOICE EXPERIMENT SCENARIO**

In each question 1-5, we ask you to choose between alternative future options for water services provision. The water services and some future water service actions are described in the poster.

OPTIONS

OPTION C (STATUS QUO): is the same in each questions 1-5. This option described as no intervention. This option involves no new actions and no cost to you

OPTIONS A & B involves a combination of new water provision services. These actions are likely to affect the future water service provision. The attributes considered in the various policy options are presented by: Frequency of water availability in a week; Quality of water; Water pressure; Time of the service and costs.

Attribute description

Attribute	Description	Levels
Frequency	Number of days water is available in a week	2 days 4 days 7 days
Quality of water	Describes the condition of water for use	Drinkable without treatment/boiling Drinkable with treatment/boiling Not drinkable without treatment
Water pressure	Describe the force at which water flows from the tap	High pressure: takes 2 minutes or less to fill a 20-litre bucket) Standard speed: takes 2-4 minutes to fill a 20-litre bucket
Time of the service	This shows the time that households prefer to get the service	In the morning (06:00-11:59) In the afternoon (12:00-17:59) At night (18:00-05:59)
Additional cost of water per unit (TZS)	Additional costs per unit price of water	5;15;30;50;100

COSTS

Acting to ensure regular water supply would involve higher costs. The money to pay for the improved provision of water would come from all the people living around the community including your household is an additional charge on the water user fees charged. The additional cost per unit will depend on which new policy intervention you will choose. Part of the money collected will be given back to the community through the provision of social amenities such as schools, health facilities, and the construction of additional water sources other than the pipes to act as emergencies (based on community choice). This fund will be managed by elected committee members from the local communities and other state and non-state actors. An independent auditor will make sure the money is spent properly on the proposed interventions. Costs are (5,15,30,50,100)

SAMPLE CHOICE SET (sample poster)

Attributes	Option A	Option B	Status quo
Number of days water is available in a week 	4 days	2 days	Same as now
Quality of water 	Drinkable without treatment/boiling	Drinkable with treatment/boiling	Same as now
Water pressure 	Standard pressure	High pressure	Same as now
Time of the service 	Morning	Afternoon	Same as now
The additional cost of water per unit (TZS) 	50	15	Zero
Which option would you prefer?			

MAKING A CHOICE

I will now present to you four choice scenarios, each offering three options. Two of these options will vary based on different attributes of water service provision, which was explained above. The third option allows you to select “None of the options”(status quo). Please select only one of the three alternatives in each round that you believe is most appropriate for your household. There are no correct or incorrect answers “only your opinion counts”. As you make your decision, kindly take into account the following:

- The future scenarios predicted by water service providers;
- The additional cost that you will incur per unit of water consumed;
- Limited resources like income with unlimited expenses.

D1. Blocks	D2. Choice scenario	D3. Round	D4. Option picked (A, B, status quo)
1. Block 1	Block 1 choice scenario	1. Round 1	1. Option A
2. Block 2	1.	2. Round 2	2. Option B
3. Block 3	2.	3. Round 3	3. Option C (Status quo)
4. Block 4	3.	4. Round 4	
	4.		
	Block 2 choice scenario		
	1.		
	2.		
	3.		
	4.		
	Block 3 Choice scenario		
	1.		
	2.		
	3.		
	4.		
	Block 4 Choice scenario		
	1.		
	2.		
	3.		
	4.		

NB: ALL CHOICE SETS ARE ATTACHED: EACH HOUSEHOLD WILL BE RANDOMLY ASSIGNED IN ANY BLOCKS AND ANSWER FOUR CHOICE SETS.

FOLLOW UP QUESTIONS FOR THE CHOICES

D4. Which option would you prefer? **[this is for each of the 4 choice sets above]**

1. Option A
2. Option B
3. I prefer the current situation(Option C)

a. **If chose 3: ‘I prefer the current situation(Option C)’, why?** (multiple reasons are possible)

- 1 My current situation is better than the proposed alternatives
2. The costs of the alternatives proposed is high compared to the benefit of the improved water service
3. I cannot afford the additional expenses
4. I do not believe that water interruption will actually be reduced
5. I do not believe that the extra payment will be allocated to water supply improvement
6. DAWASA should cover the cost of improving the water supply
7. I prefer to take my own individual actions to mitigate water interruption
8. Others (specify)

D5. How confident are you of your answers of the choices you made for the above 4 choice sets? Please rate on a scale of 1-5, where 1 is not at all confident and 5 is very confident. You can also use any number between 1 and 5 to indicate where you fall on the scale, like 1, 2, 3, 4, 5.

D6. Please indicate to what extent you paid attention to each of the attributes listed below when making choices **in the above 4 choice sets** [1= always, 2= in some but not all, 3=not at all]

- 2.1 Number of days water is available in a week _____
- 2.2 Water pressure _____
- 2.3 Quality of water _____
- 2.4 Time of the service _____
- 2.5 Additional cost of water per unit (TZS) _____

D7. The project of improving quality of water supply will indeed be conducted in Tanzania in the next five years.

1. I definitely agree
2. I agree
3. I disagree
4. I definitely disagree
5. I do not know/Hard to say

D8. For the purpose of improving quality of water supply, the water price will indeed be changed in the next five years

1. I definitely agree
2. I agree
3. I disagree
4. I definitely disagree
5. I do not know/Hard to say

D9. To what extent do you believe that the decisions on the proposal from you and other survey participants will be taken into consideration by DAWASA?

1. Not taken into account at all
2. Not taken into account very much
3. taken into account somewhat
4. definitely taken into account
5. I do not know/Hard to say

D10. Please tell me how much you personally trust DAWASA.

1. Trust completely
2. Trust somewhat
3. Do not trust very much
4. Do not trust at all

D11. Please tell me how much you personally trust an employee/individual at DAWASA

1. Trust completely
2. Trust somewhat
3. Do not trust very much
4. Do not trust at all

SECTION E: GREY WATER TECHNOLOGIES

		Code
E1	Does the household have water-saving technology? 0 = No, 1 = Yes	
	If yes, which one (E4)	
	1=Yes, 0=No	If yes, how many
	Rainwater bucket	
	Grey water bucket	
	Rainwater tank	
	Grey water tank	
	Pond	
	Borehole	
	Buckets	
	Others, specify	
E2	Cost of water-saving technology that is used	
E3	The expected lifetime of water-saving technology	
E4	What is the extent of contamination for that technology used? 1. Low 2. Medium 3. High	
E5	What is the extent of smell produced by the technology? 1. Low 2. Medium 3. High 4. No smell	
E6	Describe the ease of use of your current water-saving technology 1. Ease (no training) 2. Training required	
E7	Does the household collect rainwater? 0 = No, 1 = Yes	
E7-1	For what purpose? 1 = Drinking, 2 = Vegetable garden, 3 = flowers, 4 = lawn, 5 = trees, 6 = toilet, 7 = Car wash, 8 = Cleaning the house, 9 = Swimming Pool, 10 = Other (_____)	
E7-2	What are the most common techniques used to harvest rainwater? 1 = Dish, 2 = Bucket, 3 = Tank, 4 = pond	
E8	Does the household reuse water? 0.No 1. Yes	
E8-1	If yes, for what purpose	
E8-2	How does the household collect the re-used water? 1.Buckets 2.Tank 3.Well 99. Others, specify	
E9	Have you ever heard about greywater technologies? 0 = No, 1 = Yes Enumerator Ask/explain more on grey water technologies Greywater comprises wastewater coming from baths, showers,kitchen sinks and washing clothes except for black/toilet water.	
E9	Should greywater treatment be allowed in homes? 0 = No, 1 = Yes	

E10	Do you think grey water is harmful to human beings? 0 = No, 1 = Yes	
E10-1	Why is it harmful?	
E11	Do you think greywater comprises black water? 0=No 1=Yes	
E12	Do you think the use of grey water technologies will help to reduce your water bills? 0 = No, 1 = Yes	
E13	Does the household have grey water (water treatment) technology? 0 = No skip next, 1 = Yes	
E13-1	Type of technologies used Portable water	0 = None portable, 1 =
E13-2	Market value/purchase price of technology (Tanzania shillings)	
E13-3	Year bought	
E14	Do you share treated water with neighbors/friends? 0 = No, 1 = Yes	
E15	Are you willing to pay for greywater? 0=No 1=Yes	
E16	What is the maximum amount you are willing to pay for simple grey water technologies (Using a bucket to collect grey water)	
E16-1	What is the maximum amount you are willing to pay for advanced grey water technologies? (The system is connected directly to the house)	

SECTION F: CHOICE EXPERIMENT _WATER-SAVING TECHNOLOGIES

Water-saving technologies are long-term solutions for water management, especially at the domestic level. Among the technologies is the use of the greywater systems. Greywater includes all wastewater produced in a household except toilet wastewater/black water. It can include wastewater from baths, showers, hand basins, washing clothes, dishwashers, etc. Some countries exclude wastewater from the kitchen given the high content of oil and particles.

Therefore, the government wishes to understand the preferences and willingness of households to adopt/pay for these technologies.

Currently, Dar es Salaam has experienced droughts. According to WHO, the recommended level of household water usage is between 50 and 100 liters per person per day. It is also recommended that households should install grey water technologies to lower the demand for freshwater hence reducing household water bills and also reducing wastewater into sewer systems which affects the environment. In addition, it reduces energy consumption such that with reduced freshwater demands for each household, there is reduced energy/electricity demand required to pump the water into the house, etc.

Greywater can either be treated for household direct consumption (potable water) or external use such as toilet flushing, irrigation/gardening, swimming, bathing, and washing cars (non-portable water). Of course grey water treatment comes with a cost to the household, so we would like to know your willingness to pay for different greywater technologies that are available on the market.

The proposed greywater technologies are presented using CHOICE EXPERIMENT SCENARIO.

In each questions 1-5, we ask you to choose between alternative future options for water-saving technologies. The options are described in the poster.

OPTIONS

OPTION C (STATUS QUO): is the same in each questions 1-5. This option is described as no intervention. This option involves no new actions and no cost to you. If households decide not to install the greywater technology, then the situation will remain the same, that is the greywater will continue to be lost.

OPTIONS A & B involves a combination of proposed greywater technologies. The attributes considered for the greywater technologies are presented by: Lifetime of the technology; Ease of use; Possibility of contamination; Smell; and Costs.

Attribute description

Attributes	Description	Levels
Lifetime	It indicates the durability of the technology after installation	5 years; 10 years; 15 years
Ease of use	Indicates the knowledge and technical ability needed to install and maintain the technology	No Training: No training or technical knowledge is needed for the installation and maintenance of the technology Training: Training and technical knowledge are needed for the installation and maintenance of the technology
Contamination	This shows the likelihood in which the water source can be contaminated by bacteria like cholera, E.coli, and rodents and cause water-borne diseases	High: This technology can likely be contaminated and result in waterborne diseases. Medium: Moderate chance of waterborne diseases Low: There is a low possibility of contamination hence a low chance of waterborne diseases.

Smell	The smell released by the water after treatment	High: Water with a strong odour and can be detected from a relatively shorter distance. Medium: Water with a noticeable odour. The smell might be described as earthy. Low: Water with a low smell has little to no detectable odour. The smell is faint.
Costs	It includes the cost of purchasing technology, installation, maintenance, and treatment to make water clean	117,000 TZS 234,000 TZS 350,000 TZS 699,600 TZS 1,170,000 TZS

Sample choice set

Attributes	Option A	Option B	Status quo
Lifetime  shutterstock.com · 1960158127	5 years	10 years	Same as now
Ease of use 	No training	Training required	Same as now

Contamination 	High	Low	Same as now
Smell 	High	Low	Same as now
Cost (TZS) 	117,000	1,170,000	Zero
Which option would you prefer?			

If households decide to install the greywater technology, then the two possible options are presented. In option A, the lifetime of the technology to be adopted is expected to be short (less than 5 years) and no training is required for installation use or maintenance. However, the risk of contamination such as water-born disease and the smell is high. The costs of this technology on average are expected to be low around 117,000 Tanzania Shillings.

In option B, the lifetime of technology is expected to last long (more than 5 years) and training is required to install, use and maintain it. For this case, the risk of contamination and the smell is low. However, the cost of this technology is 1,170,000 Tanzania Shillings.

MAKING A CHOICE

I will now present to you four choice scenarios, each offering three options. Two of these options will vary based on different attributes of water service provision, which was explained above. The third option allows you to select “None of the options”(status quo). Please select only one of the three alternatives in each round that you believe is most appropriate for your

household. There are no correct or incorrect answers “only your opinion counts”. As you make your decision, kindly take into account the following:

- All attributes of the greywater technologies
- The costs you will incur
- Resources such as income are limited with unlimited wants.

Blocks	Choice scenario	Round	Option picked (A, B, status quo)
1. Block 1	Block 1 choice scenario	1. Round 1	
2. Block 2	1.	2. Round 2	1. Option A
3. Block 3	2.	3. Round 3	2. Option B
4. Block 4	3.	4. Round 4	3. Option C (Status quo)
	4.		
	Block 2 choice scenario		
	1.		
	2.		
	3.		
	4.		
	Block 3 Choice scenario		
	1.		
	2.		
	3.		
	4.		
	Block 4 Choice scenario		
	1.		
	2.		
	3.		
	4.		

NB: ALL CHOICE SETS ARE ATTACHED: EACH HOUSEHOLD WILL BE RANDOMLY ASSIGNED IN ANY BLOCKS AND ANSWER FOUR CHOICE SETS.

QN: WHAT ARE THE REASONS FOR YOUR CHOICE?

NB: The two choice experiments presented were conducted side by side with some households randomly allocated to start with the choice experiment for water supply improvements while others started with the choice experiment on greywater technology

SECTION G: ELECTRICITY QUESTIONS

G1	What is your main source of energy for cooking in the household? 1. Electricity 2. Bottled gas 3. Paraffin/Kerosene 4. Charcoal 5. Firewood 6. CRPO residuals, straws, Grass 7. Animal dung 8. No food cooked in the households. 99. Others, Specify	
G2	What is your main source of energy for lighting in the household? 1. Electricity 2. Solar 3. Gas 4. Paraffin-hurricane lamp 5. Paraffin-pressure lamp 6. Paraffin wick lamp 7. Firewood 8. Candles 99. Others, Specify	
G3	Do you use electricity from TANESCO? 0=No 1=Yes	
G4	Do you use electricity for water pumping? Or any water-related activities? Like warming the water.	
G5	Are you on post-paid or pre-paid electricity? 0.No 1.Yes	
G6	What is your current electricity consumption per month? In unit	
G7	Do you think saving water also saves electricity? 0.No 1. Yes	
G8	What actions do you take to reduce electricity consumption? 1. turning off lights when living in the room/house /sleeping, 2. turning off appliances when they are not in use, and 3. unplugging appliances when leaving the house/not in use	
G9	Do you do the following things? keep track of water use,	
G9-1	keep track of electricity use,	
G9-2	keep track of water & electricity use	
G10	Provide the electricity meter number/account number	

G11	Name of the respondent	
G12	Mobile number of respondent	
G13	Is the respondent replaced from the main list? 0.No 1.Yes	
G13-1	If yes, why	
G13	Household GPS Coordinates	

End of questionnaire

Appendix B: Ethical approval letters



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02 08 2022

Julieth Tibanywana
School of Economics
University of Cape Town
REF: REC 2022/08/002

**Domestic water consumption behavior in developing countries:
A case study of urban households in Tanzania**

We are pleased to inform you that your ethics application has been approved. Unless otherwise specified this ethical clearance is valid until 31-Dec-2023 .

Your clearance may be renewed upon application.

Please be aware that you need to notify the Ethics Committee immediately should any aspect of your study regarding the engagement with participants as approved in this application, change. This may include aspects such as changes to the research design, questionnaires, or choice of participants.

The ongoing ethical conduct throughout the duration of the study remains the responsibility of the principal investigator.

We wish you well for your research.

A handwritten signature in black ink, appearing to read 'Jacques Rousseau'.

2022.08.02
16:44:31 +02'00'

Jacques Rousseau
Commerce Research Ethics Chair
University of Cape Town
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"Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."

RE: REQUEST FOR RESEARCH CLEARANCE

1. The purpose of this letter is to introduce to you **Julieth J Tibanywana** who is a bonafide staff of the University of Dar es Salaam (UDSM) and who is at the moment required to conduct research.
2. In accordance with government circular letter Ref. No. MPEC/R/10/1 dated 4th July 1980, the Vice-Chancellor of the University of Dar es Salaam is empowered to issue research clearances to staff members and students of the University of Dar es Salaam on behalf of the government and the Tanzania Commission for Science and Technology (COSTECH). I am pleased to inform you that **Julieth J Tibanywana** has been granted a research clearance.
3. I therefore, kindly request you to grant any help that may enable the candidate(s) achieve the research objectives. Specifically we request your permission for the researcher to meet and talk to the leaders and other relevant stakeholders in your administrative area in connection with this research.
4. The title of the research is **"DOMESTIC WATER CONSUMPTION BEHAVIOUR IN DEVELOPING COUNTRIES: A CASE STUDY OF URBAN HOUSEHOLDS IN TANZANIA"**.
5. The period of the research is from **25 July, 2022 to 31 December, 2023** and the research will cover **Dar es salaam region**.
6. Should there be any restriction, you are kindly requested to advise us accordingly. In case you may require further information, please do not hesitate to contact us through the Directorate of Research and Publication, Tel. +255 22 2410500-8 Ext. 2084 or +255 22 2410727 and E-mail: research@udsm.ac.tz

Yours sincerely,



William A.L. Anangisye

VICE CHANCELLOR

Cranford Pratt Building, University of Dar es Salaam, P.O. Box 35091, Dar es Salaam.

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Appendix C

Table C.1: RPL model with no correlated terms

VARIABLES	Without Interaction terms		With interactions	
	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)
Cost	-0.0099*** (0.0015)		-0.0096*** (0.0015)	
Afternoon	1.6275*** (0.2998)	-0.2950** (0.1425)	0.8113 (0.5410)	0.0149 (0.1092)
Night	3.1761*** (0.3316)	2.0495*** (0.2288)	2.2274*** (0.5810)	1.8996*** (0.2359)
Morning	2.0033*** (0.3021)	1.3167*** (0.1921)	1.3518** (0.5636)	-1.3001*** (0.2253)
High pressure	2.5478*** (0.2864)	0.9088*** (0.1438)	2.7866*** (0.4704)	0.8480*** (0.1548)
Std. pressure	1.5259*** (0.2764)	-0.0601 (0.0913)	1.5567*** (0.4560)	-0.1061 (0.0943)
Drinkable with treatment	0.5090*** (0.1462)	1.2105*** (0.2027)	0.2379 (0.2607)	1.1544*** (0.1952)
Drinkable wo treatment	0.4381*** (0.1144)	1.6188*** (0.1549)	0.2826 (0.2415)	1.5946*** (0.1550)
Frequency	0.2170*** (0.0337)	0.6515*** (0.0530)	0.0306 (0.0711)	0.6286*** (0.0517)
Drinkable with treatment × Income			0.4124 (0.3885)	
Drinkable without treatment × Income			0.2669 (0.3777)	
Afternoon × Income			1.3822* (0.8066)	
Night × Income			1.5223* (0.8833)	
Morning × Income			1.1173 (0.8806)	

Frequency × Income		0.3280*** (0.1119)
High pressure × Income		-0.5809 (0.7525)
Std. pressure × Income		-0.2070 (0.7321)
Chi-square	313.93***	330.87***
LL	-3523.61	-3515.94
AIC	7081.22	7081.89
BIC	7206.236	7265.73
No of Respondents	962	962
No. of Observations	11,544	11,545

Table C.2: RPL model with correlated terms (with and without correlated terms)

	No Interaction terms (1)	Interaction terms included (2)
Cost	-0.0060** (0.0028)	-0.0066** (0.0028)
Afternoon	4.6439*** (1.4677)	2.4460** (1.2404)
Night	6.9857*** (1.4218)	4.7973*** (0.9649)
Morning	5.3390*** (1.4799)	3.2032*** (1.1343)
High pressure	8.0343*** (2.1789)	9.1976** (4.3347)
Std. pressure	6.5024*** (2.1191)	7.4983* (4.4464)
Drinkable with treatment	1.7811*** (0.4027)	1.6622** (0.7509)
Drinkable without treatment	1.3378*** (0.3781)	1.2495* (0.6817)
Frequency	0.2584** (0.1108)	0.0194 (0.2017)
Drinkable with treatment $\times$ Income		0.2286 (1.0141)
Drinkable without treatment $\times$ Income		0.1530 (0.8081)
Afternoon $\times$ Income		3.1731** (1.5440)
Night $\times$ Income		3.3182** (1.4190)
Morning $\times$ Income		3.0033** (1.4260)
Frequency $\times$ Income		0.4359 (0.2712)
High pressure $\times$ Income		-1.0759 (1.1143)
Standard pressure $\times$ Income		-0.8231 (1.0464)
/111	-4.2483*** (1.4287)	-4.2894*** (1.4785)
/121	-5.9612*** (1.3625)	-5.4833*** (1.2981)
/131	-3.4351*** (1.1567)	-3.1035** (1.3030)
/141	-1.6575 (1.5852)	-0.1417 (1.9912)
/151	-1.5046	0.0708

	(1.5633)	(2.1013)
/161	-2.3255***	-2.4510***
	(0.7211)	(0.4324)
/171	-1.1648**	-0.9843**
	(0.5358)	(0.3978)
/181	0.7955***	0.7826***
	(0.1200)	(0.1128)
/122	2.2456***	2.7240***
	(0.8028)	(0.6100)
/132	0.0510	0.2455
	(0.8860)	(0.4759)
/142	2.3224*	6.2417***
	(1.3092)	(1.4948)
/152	2.1106*	6.0794***
	(1.1499)	(1.5554)
/162	0.4992	0.4648
	(0.5086)	(0.3908)
/172	1.3707***	0.9199**
	(0.3484)	(0.4060)
/182	-0.0365	-0.1811
	(0.1846)	(0.1107)
/133	2.1303***	-2.1441***
	(0.4828)	(0.4594)
/143	3.9553***	-4.0470
	(1.2019)	(4.9344)
/153	3.6250***	-3.6484
	(1.4009)	(5.2045)
/163	-0.8370	0.6640
	(0.6674)	(0.8185)
/173	-0.4251	0.8347
	(0.5287)	(0.7381)
/183	-0.1340	0.2046*
	(0.2547)	(0.1173)
/144	6.6666***	4.7984
	(2.5130)	(3.1163)
/154	5.8823**	3.9852
	(2.3527)	(3.3368)
/164	-0.9618***	-0.7655**
	(0.3423)	(0.3703)
/174	-2.0040***	-1.5987***
	(0.4848)	(0.4944)
/184	0.0753	0.0440
	(0.1493)	(0.0818)
/155	1.1132***	-1.1213***
	(0.3060)	(0.2259)
/165	-2.5543***	2.1555
	(0.7204)	(1.4527)
/175	-2.4009***	2.2780*
	(0.7378)	(1.2191)

/185	0.1885*	-0.0650
	(0.1062)	(0.1149)
/166	-0.3913	1.4548
	(1.0765)	(1.1616)
/176	-0.3338	1.6015***
	(0.6824)	(0.5907)
/186	-0.0933	-0.2147
	(0.3135)	(0.1935)
/177	0.2237	-0.2147
	(0.6944)	(0.1935)
/187	-0.0119	-0.2056
	(0.5460)	(0.1580)
/188	-0.2455	0.0522
	(0.1894)	(0.2361)
Chi-square statistic	89.93	179.89***
LL	-3282.86	-3270.23
AIC	6655.712	6646.46
BIC	6986.64	7036.21
No. of Observations	11,544	11,544
No. of respondents	962	962

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors in parenthesis.

Table C.3: The mWTP for water supply improvement

Attribute	CL model		RPL model	
	Without interactions	with interactions	without interaction terms	with interaction terms
Afternoon	245.88*** (0.11)	-9.17 (-0.004)	778.16*** (0.34)	367.99** (0.16)
Night	528.05*** (0.23)	283.52* (0.12)	1170.56*** (0.51)	721.74*** (0.31)
Morning	360.64*** (0.16)	142.99 (0.06)	894.64*** (0.39)	481.92*** (0.21)
High pressure	438.05*** (0.19)	540.25*** (0.23)	1346.28*** (0.59)	1383.77** (0.60)
Standard pressure	207.97*** (0.09)	246.84** (0.11)	1089.57*** (0.47)	1128.11* (0.49)
Drinkable with treatment	22.5 (0.01)	-5.52 (0.002)	298.46* (0.13)	250.07** (0.11)
Drinkable without treatment	91.42*** (0.04)	82.64 (0.04)	224.17*** (0.10)	187.99* (0.08)
Frequency	47.88*** (0.02)	22.24 (0.01)	43.29** (0.02)	2.91 (0.001)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. US\$ in parenthesis. A rate of US\$1 = TZS2,300 which was prevailing at the time the experiment was conducted was used.

Appendix D

Appendix D.1: Power calculations

Power calculation with clusters was done to obtain the minimum required sample size. The study randomized intervention at the ward level to minimize spillover effects since urban households live in the same wards. According to Khandker et al. (2009), at least 30 clusters per group are needed. According to the local water authority, the study area comprised more than 100 wards in total. The study assumed a significance level and average water-saving effects of 5% and statistical power of 80% to assess the intervention's impact. With the average cluster size of 12, coefficient of variation of cluster size of 0.9, and intra-cluster correlation of 0.01, the total number of clusters required was 37 per group. With the researcher's discretion, the total number of clusters per arm was increased to 40 and the average cluster size to 20. Since the study had two arms then there was a total of 80 arms and eventually ended up with a total of 1600 households.

Appendix D.2: Results

Table D.1: balancing test for randomisation

Variable	Control Mean[SE]	Treatment Mean[SE]	p-value (1)-(2)
Sample	800	800	
Average monthly consumption	22944.583 [715.350]	24232.187 [808.011]	0.233
Median monthly consumption	11.137 [0.136]	10.918 [0.143]	0.266
Total billing	4.35e+05 [15654.164]	4.59e+05 [17182.104]	0.294
Average monthly billing	36240.949 [1304.514]	38272.968 [1431.842]	0.294
Total collection	-4.39e+05 [15373.567]	-4.60e+05 [16335.017]	0.332
Average monthly collection	-3.65e+04 [1281.131]	-3.84e+04 [1361.251]	0.332

Table D.2: Short-medium term results

Variables	(1) Feb	(2) Feb-Mar	(3) Feb-Mar	(4) Feb-Apr	(5) Feb-Apr	(6) Feb-May	(7) Feb-May	(8) Feb-Jun	(9) Feb-Jun	(10) Feb-Jul	(11) Feb-Jul
Treatment × post	-1.18 (1.43)	-1.34 (1.29)	-1.34 (1.29)	-1.51 (1.05)	-1.51 (1.05)	-1.55* (0.90)	-1.55* (0.90)	-1.39* (0.81)	-1.39* (0.81)	-1.49* (0.77)	-1.50* (0.77)
Post	-2.86*** (0.99)	-4.13*** (0.95)	-4.00*** (0.91)	-5.42*** (0.72)	-4.42*** (0.71)	-5.27*** (0.79)	-4.57*** (0.64)	-5.20*** (0.74)	-4.70*** (0.59)	-6.11*** (1.00)	-4.81*** (0.56)
Water bill (-1)	-0.17*** (0.05)	-0.06*** (0.02)	-0.06*** (0.02)	-0.02 (0.01)	-0.02 (0.01)	0.01 (0.01)	0.01 (0.01)	0.03** (0.01)	0.03** (0.01)	0.05*** (0.01)	0.05*** (0.01)
Month-by-year dummies	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Constant	29.41*** (1.58)	24.83*** (0.78)	25.25*** (0.74)	25.18*** (0.70)	24.39*** (0.51)	21.81*** (0.68)	22.84*** (0.45)	23.01*** (0.62)	22.36*** (0.42)	19.75*** (0.89)	21.30*** (0.43)
Observations	3,200	6,400	6,400	9,600	9,600	12,800	12,800	16,000	16,000	19,200	19,200
R-squared	0.15	0.04	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.05	0.05
No. of households	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600

The dependent variable is household water consumption per month in m³. *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at ward level in parenthesis.

Table D.3: Short-term medium results (normalised consumption as the dependent variable)

Variables	(1) Feb	(2) Feb-Mar	(3) Feb-Mar	(4) Feb-Apr	(5) Feb-Apr	(6) Feb-May	(7) Feb-May	(8) Feb-Jun	(9) Feb-Jun	(10) Feb-Jul	(11) Feb-Jul
Treatment × post	-5.70 (6.88)	-6.85 (6.59)	-6.85 (6.59)	-7.38 (5.11)	-7.37 (5.11)	-7.93* (4.60)	-7.93* (4.60)	-7.01* (4.07)	-7.01* (4.07)	-7.64* (3.92)	-7.65* (3.92)
Post	-13.83*** (4.79)	-21.13*** (4.87)	-20.43*** (4.66)	-26.40*** (3.53)	-21.55*** (3.46)	-26.93*** (4.06)	-23.36*** (3.25)	-26.13*** (3.70)	-23.64*** (2.96)	-31.23*** (5.14)	-24.58*** (2.86)
Water bill (-1)	-0.81*** (0.22)	-0.29*** (0.10)	-0.28*** (0.10)	-0.11 (0.07)	-0.10 (0.07)	0.06 (0.06)	0.06 (0.06)	0.14** (0.06)	0.14** (0.06)	0.25*** (0.06)	0.25*** (0.06)
Month-by-year dummies	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Constant	142.04*** (7.61)	126.96*** (3.98)	129.12*** (3.77)	122.67*** (3.43)	118.83*** (2.48)	111.53*** (3.47)	116.78*** (2.30)	115.69*** (3.13)	112.43*** (2.13)	100.98*** (4.54)	108.89*** (2.21)
Observations	3,200	6,400	6,400	9,600	9,600	12,800	12,800	16,000	16,000	19,200	19,200
R-squared	0.15	0.04	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.05	0.05
No. of households	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600

The dependent variable is the household's monthly water consumption normalised by the average control group consumption in the post-period and multiplied by 100. *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at ward level in parenthesis.

Table D.4: Model results for the first five months after the intervention

VARIABLES	(1) After 1 month	(2) After 2 months	(3) After 2 months	(4) After 3 months	(5) After 3 months	(6) After 4 months	(7) After 4 months	(8) After 5 months	(9) After 5 months
Treatment × post	-1.10 (1.11)	-0.33 (1.38)	-0.34 (1.38)	-2.05** (1.03)	-2.06** (1.03)	-2.30** (1.03)	-2.29** (1.03)	-1.62* (0.85)	-1.62* (0.85)
Post	-0.13 (0.72)	-4.25** (1.64)	-2.51** (1.19)	0.68 (1.14)	-1.97 (1.28)	5.68*** (1.32)	0.40 (1.03)	-4.72*** (0.71)	-4.72*** (0.71)
Water bill (-1)	0.19*** (0.04)	0.17*** (0.03)	0.17*** (0.03)	-0.01 (0.06)	-0.01 (0.06)	0.04 (0.06)	0.04 (0.06)	0.06 (0.05)	0.06 (0.05)
Month-by-year dummies	No	Yes	No	Yes	No	Yes	No	Yes	No
Constant	13.67*** (1.39)	18.22*** (1.21)	16.33*** (1.07)	18.86*** (2.51)	21.66*** (2.48)	11.87*** (2.04)	17.62*** (2.37)	19.51*** (1.13)	19.51*** (1.13)
Observations	3,200	6,400	6,400	9,600	9,600	12,800	12,800	16,000	16,000
R-squared	0.16	0.04	0.04	0.01	0.01	0.03	0.01	0.03	0.03
No. of households	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600

The dependent variable is monthly water consumption (M³). *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at ward level in parenthesis.

Table D.5: Results for the post-intervention period

VARIABLES	(1) After 1 month	(2) After 2 months	(3) After 2 months	(4) After 3 months	(5) After 3 months	(6) After 4 months	(7) After 4 months	(8) After 5 months	(9) After 5 months
Treatment × post	-5.53 (5.54)	-1.61 (6.65)	-1.64 (6.65)	-9.88** (4.94)	-9.91** (4.96)	-11.18** (5.00)	-11.14** (4.99)	-8.18* (4.27)	-8.18* (4.27)
Post	-0.66 (3.63)	-20.49** (7.90)	-12.08** (5.72)	3.28 (5.48)	-9.50 (6.18)	27.59*** (6.39)	1.93 (5.02)	-23.80*** (3.61)	-23.80*** (3.61)
Water bill (-1)	0.97*** (0.20)	0.84*** (0.15)	0.84*** (0.15)	-0.06 (0.30)	-0.07 (0.30)	0.19 (0.30)	0.20 (0.30)	0.28 (0.27)	0.28 (0.27)
Month-by-year dummies	No	Yes	No	Yes	No	Yes	No	Yes	No
Constant	68.54*** (6.97)	87.83*** (5.84)	78.72*** (5.15)	90.78*** (12.07)	104.27*** (11.95)	57.68*** (9.91)	85.63*** (11.51)	98.47*** (5.70)	98.47*** (5.70)
Observations	3,200	6,400	6,400	9,600	9,600	12,800	12,800	16,000	16,000
R-squared	0.16	0.04	0.04	0.01	0.01	0.03	0.01	0.03	0.03
No. of households	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600

The dependent variable is the household's monthly water consumption normalised by average control group consumption in the post period and multiplied by 100. *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at ward level in parenthesis. Results are estimated with a fixed effects estimator.

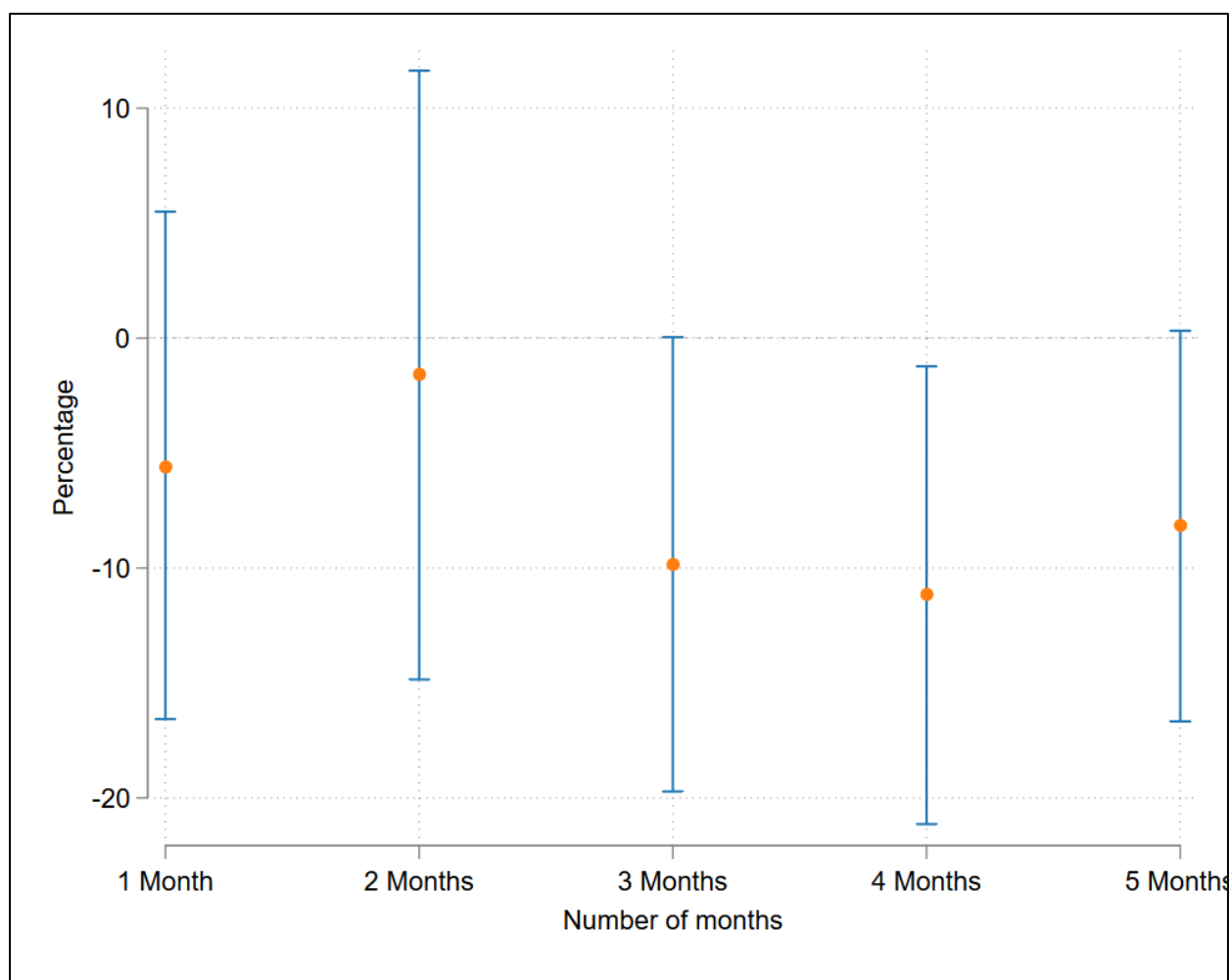


Figure D.1: Estimated percentage change in consumption for the treated group (w.r.t control group)

Source: Authors

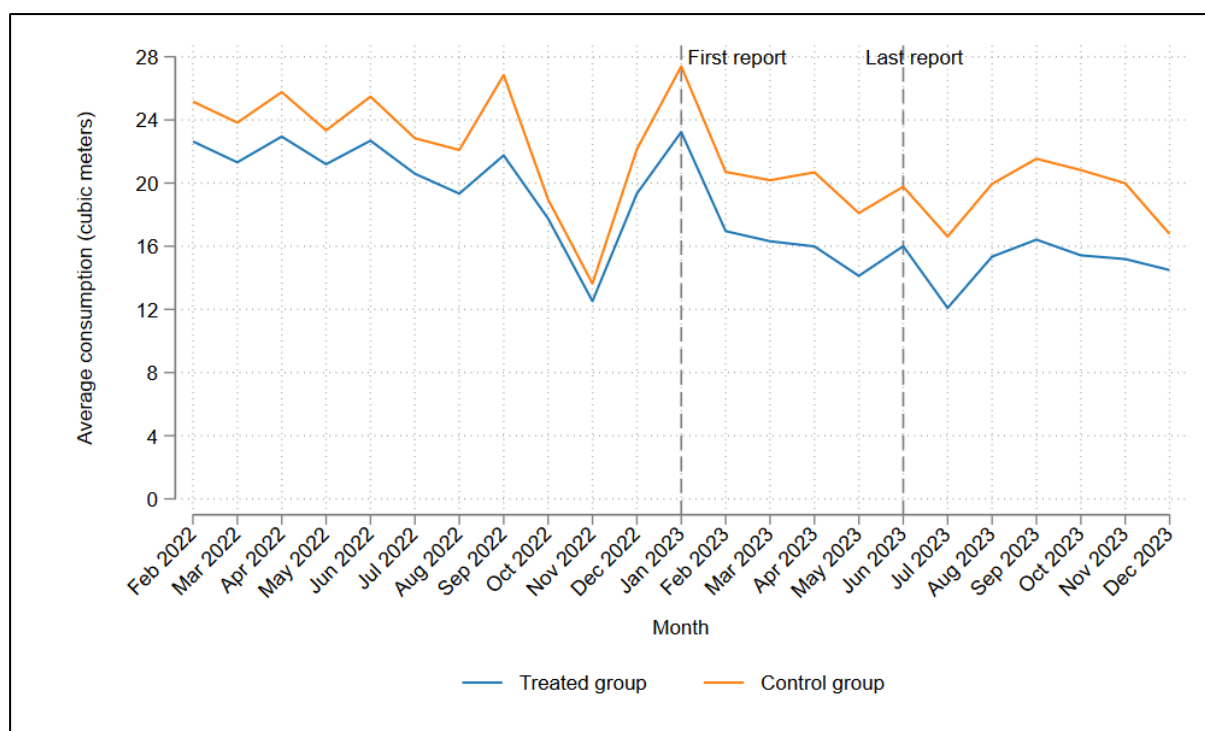


Figure D.2: Consumption patterns in the pre and post intervention for the treatment and control groups

Appendix E

Table E.1: Testing for IIA

Option excluded	χ^2	Degrees of freedom	P-value	Conclusion
Option A	238.60	9	0.00	Violated at 1%
Option B	524.54	9	0.00	Violated at 1%
Status quo	161.96	8	0.00	Violated at 1%

Table E.2: Results for CL, G-MNL and LC models with no interaction terms

VARIABLES	Fixed ASC				Random ASC	
	Without Interactions		With Interactions		Without interactions	
	Mean	SD	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Cost	-0.00*** (0.00)		-0.00*** (0.00)		-0.00*** (0.00)	
ASC	-0.95*** (0.28)		-1.16*** (0.28)		-9.46*** (1.37)	13.27*** (1.49)
Lifetime						
10 years	-0.00 (0.22)	2.48*** (0.40)	-0.19 (0.24)	2.62*** (0.39)	0.13 (0.12)	0.66*** (0.23)
15 years	1.28*** (0.26)	4.51*** (0.61)	0.40 (0.26)	4.20*** (0.54)	0.17 (0.13)	1.17*** (0.27)
Ease	0.01 (0.13)	1.95*** (0.23)	-0.10 (0.15)	1.88*** (0.22)	-0.25** (0.10)	-0.26 (0.48)
Contamination						
Medium	2.27*** (0.27)	4.69*** (0.58)	1.47*** (0.26)	4.53*** (0.57)	1.38*** (0.14)	0.93*** (0.24)
Low	1.13*** (0.26)	4.69*** (0.58)	0.78** (0.34)	4.15*** (0.47)	0.99*** (0.18)	1.57*** (0.28)
Smell						
Medium	1.05*** (0.13)	0.86*** (0.32)	0.98*** (0.15)	-0.72* (0.37)	0.64*** (0.11)	0.00 (0.03)
Low	1.82*** (0.22)	1.64*** (0.46)	1.62*** (0.21)	1.50*** (0.40)	0.92*** (0.15)	-0.05 (0.05)
smellmed_awareness			0.08 (0.23)			
smellow_awareness			0.32 (0.35)			
contmed_awareness			2.06*** (0.56)			
contlow_awareness			1.06* (0.56)			
lifetime10_awareness			0.46 (0.37)			
lifetime15_awareness			2.14*** (0.58)			
ease_awareness			0.12 (0.29)			
ASC_awareness			-1.63*** (0.52)			
Observations	11,544	11,544	11,544	11,544	11,544	11,544
No of respondents	962	962	962	962	962	962

LL	-3326.75	-3242.03	-2609.94
AIC	6685.50	6530.06	5253.87
BIC	6803.17	6699.20	5378.88

Table E.3: Results for CL, G-MNL and LC models with no interaction terms

VARIABLES	(1)	(2)		(3)	
	CL	G-MNL		Latent Class	
		Mean	SD	Class 1	Class 2
lifetime10	-0.02 (0.07)	0.29 (0.24)	0.42 (0.45)	-0.98** (0.50)	0.46*** (0.10)
lifetime15	0.47*** (0.07)	0.19 (0.22)	0.23 (0.35)	0.91*** (0.28)	0.21** (0.09)
Ease: base = training required	0.08 (0.05)	-0.30* (0.16)	-0.93*** (0.29)	0.15 (0.42)	-0.48*** (0.09)
contamination: base = high cont_medium	0.98*** (0.08)	3.02*** (0.46)	2.48*** (0.61)	4.34*** (0.41)	1.06*** (0.08)
cont_low	0.58*** (0.09)	2.45*** (0.44)	-2.93*** (0.51)	2.24*** (0.38)	0.75*** (0.13)
smell_medium	0.67*** (0.06)	1.16*** (0.20)	0.30 (0.24)	4.68*** (0.54)	0.14 (0.10)
smell_low	1.04*** (0.07)	1.89*** (0.33)	-0.05 (0.22)	4.57*** (0.45)	0.17 (0.13)
ASC	-0.01 (0.14)	-13.67*** (2.08)	19.38*** (2.78)	8.34*** (0.64)	-4.29*** (0.23)
Cost	-1.67*** (0.15)	-7.05*** (1.10)		0.51 (0.54)	-3.78*** (0.24)
τ		1.21*** (0.12)			
Class share				0.28	0.72
LL	-3737.89	-2589.90		-2642.18	
AIC	7493.80	5215.78		5322.37	
BIC	7559.98	5328.39		5462.09	
Observations	11,544	11,544		11,544	
Number of respondents	962	962		962	

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E.4: Coefficients of RPL

VARIABLES	Income		Municipality					Gender		Age	
	High	Low	Kinondoni	Illala	Temeke	Ubungo	Kingamboni	Male	Female	≤45	>45
Means	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
cost	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)
lifetime10	0.74*** (0.18)	-0.42** (0.20)	-2.40*** (0.93)	-0.15 (0.23)	1.97*** (0.51)	-0.58* (0.34)	0.77*** (0.29)	0.14 (0.14)	0.11 (0.48)	-0.20 (0.18)	0.43** (0.17)
lifetime15	0.58*** (0.17)	-0.09 (0.19)	-1.45* (0.80)	-0.29 (0.24)	2.09*** (0.53)	-0.43 (0.29)	0.44 (0.30)	0.25* (0.14)	-0.09 (0.36)	-0.07 (0.19)	0.37** (0.18)
ease	-0.58*** (0.16)	0.07 (0.16)	0.48 (0.57)	-0.45** (0.21)	-0.49* (0.29)	0.22 (0.38)	-0.84*** (0.28)	-0.20* (0.11)	-0.68 (0.52)	-0.18 (0.17)	-0.26* (0.14)
cont_medium	1.77*** (0.22)	1.18*** (0.20)	4.39*** (1.51)	1.30*** (0.27)	1.19*** (0.32)	1.71*** (0.37)	1.47*** (0.41)	1.48*** (0.16)	1.57** (0.63)	1.70*** (0.24)	1.29*** (0.19)
cont_low	2.03*** (0.29)	-0.03 (0.24)	2.71** (1.20)	0.10 (0.32)	-0.14 (0.40)	1.90*** (0.59)	2.49*** (0.54)	1.01*** (0.19)	1.16* (0.68)	1.16*** (0.28)	0.86*** (0.24)
smell_medium	0.83*** (0.15)	0.53*** (0.16)	2.76*** (0.57)	0.15 (0.19)	0.02 (0.25)	1.86*** (0.42)	0.80*** (0.26)	0.62*** (0.11)	1.09** (0.53)	0.78*** (0.16)	0.61*** (0.14)
smell_low	1.01*** (0.21)	1.00*** (0.22)	3.65*** (0.74)	0.32 (0.26)	0.33 (0.36)	2.55*** (0.53)	0.79** (0.34)	0.90*** (0.16)	1.85** (0.86)	1.20*** (0.23)	0.80*** (0.20)
SD											
ASC	-8.55*** (1.52)	-10.15*** (2.09)	-24.10* (12.42)	-22.68*** (4.96)	-15.02** (6.30)	-2.45* (1.33)	-3.41*** (0.73)	-9.49*** (1.21)	-11.98*** (4.06)	-10.99*** (2.06)	-8.41*** (1.55)
lifetime10	0.38 (0.49)	0.89*** (0.30)	0.02 (0.15)	-0.36 (0.37)	0.76* (0.39)	-0.43 (1.61)	-0.02 (0.08)	0.84*** (0.25)	-0.16 (1.25)	-0.03 (0.24)	-0.77** (0.32)
lifetime15	0.27 (0.29)	1.67*** (0.34)	-1.32* (0.80)	-0.84* (0.49)	0.21 (0.32)	0.80 (0.93)	0.74 (0.58)	1.28*** (0.25)	1.65 (1.36)	1.15*** (0.39)	1.32*** (0.39)
ease	0.65* (0.39)	-0.22 (0.35)	-4.22*** (1.48)	0.29 (0.37)	0.15 (0.40)	-1.47 (0.94)	0.43 (0.67)	-0.09 (0.12)	1.71* (0.88)	-0.10 (0.23)	0.70 (0.46)

cont_medium	-1.19*** (0.27)	-1.04*** (0.29)	2.33** (1.10)	-1.56*** (0.36)	0.06 (0.11)	-1.00** (0.39)	0.71 (0.78)	1.05*** (0.22)	-1.44 (0.95)	1.35*** (0.29)	-0.78* (0.40)
cont_low	1.85*** (0.40)	-1.31** (0.52)	-10.34** (4.67)	-1.76*** (0.61)	0.52 (0.55)	-2.15** (0.97)	0.64 (1.11)	1.58*** (0.29)	1.67* (1.01)	2.42*** (0.42)	1.25*** (0.47)
smell_medium	-0.01 (0.04)	-0.11 (0.10)	0.20 (0.27)	0.04 (0.09)	-0.52 (0.78)	-0.31 (0.65)	-0.01 (0.03)	-0.01 (0.03)	1.42 (0.99)	-0.03 (0.12)	-0.03 (0.06)
smell_low	-0.05 (0.09)	-0.03 (0.11)	-0.46 (0.41)	-0.01 (0.03)	0.84 (0.87)	-0.99 (1.11)	-0.11 (0.18)	-0.07 (0.07)	-0.95 (1.23)	0.07 (0.09)	-0.10 (0.10)
ASC	9.82*** (1.48)	17.56*** (3.02)	27.66** (13.46)	20.23*** (4.46)	55.75** (22.17)	9.85*** (1.97)	2.06*** (0.51)	12.60*** (1.49)	22.07*** (6.41)	16.78*** (2.77)	11.56*** (1.63)
Observations	5,508	6,036	2,112	3,516	2,628	1,860	1,428	9,648	1,896	5,616	5,928
LL	-1228	-1318	-436.8	-764.5	-429.9	-419.7	-329.1	-2201	-392.1	-1206	-1385

