INSIGHT INTO SETTING SUSTAINABLE WATER TARIFFS IN SOUTH AFRICA

Report to the
WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

BACKGROUND

The provision of good quality and enough water services has significant social, health and economic benefits, especially for poorer households. Providing such water services in the context of water scarcity, high poverty and high inequality, as is the case in South Africa, a difficult balancing task for the Water Service Authorities and Providers (WSAs and WSPs). Nonetheless, well-designed policy instruments, such as water tariff structures that incorporate the principles of fairness, equity, cost recovery, efficiency, sustainability and political feasibility, could go a long way towards providing good-quality water services in acceptable quantities, and equitably for all South Africans.

While the Department of Water and Sanitation (DWS) has in place guidelines for setting retail water and sanitation tariffs – such as recommendations for using Increasing Block Tariff (IBT) linked to a reference marginal cost or putting in place certain social goals such as ensuring ecological sustainability, meeting minimum water demand and ensuring equity in access to water – several gaps still exist in the guidelines. For example, the guidelines do not identify the appropriate reference value for marginal cost or minimum level of basic water demand.

AIMS AND OBJECTIVES

The primary aim and motivation for this study was to address some of the important gaps in the DWS guidelines related to the setting of water service retail tariffs and the overall design of the water service package. Specifically, the objectives of the study were:

1. To review, analyse and suggest important social goals and principles that could be considered when setting up water tariff structures and packages in South Africa.
2. To assess the rationale and need for a dual water service tariff structure in South Africa.
3. To assess alternative financing options for revenue sustainability in the water services sector in South Africa.
4. To assess the affordability of water services, especially among poorer households.
5. To estimate the revenue consequences of raising water tariffs in South Africa.

6. To analyse the long-run consequences of different transfer payments and revenue-raising arrangements within the water tariff structure.
7. To understand household water-saving behaviour and the use of water-saving technologies.

APPROACH

The above study objectives were achieved through a range of empirical approaches. Assessing the social goals, the rationale for the dual water tariff structure and the financing options for revenues sustainability was done through critical reviews of empirical and theoretical evidence. The evaluation of the affordability of water services, as well as the estimation of the consequences of raising water tariffs and the long-run consequences of the different transfer payment and revenue-raising options, were assessed using critical reviews and regression analysis models. Understanding household water consumption and saving behaviours was done using the choice experience methodology.

SUMMARY OF THE MAIN FINDINGS

The report identifies some important social goals to consider in setting water tariff structures. To adequately cover the cost of operations, maintenance and new investments, tariffs must be set at a level that appropriately reflects those costs. In addition, to account for efficiency, the tariffs must also consider environmental and other externality costs for the long-term sustainability of water resources. However, such tariffs will not be successful if we do not prioritise the social goals of equity in access as well as affordability, given the well-known political history and poverty of South Africa. Finally, the political and public acceptance of any schemes must be seriously considered, and any reforms must be monitored effectively to ensure success.

Furthermore, considering the rapidly growing population and scarce water resources, the report finds that there is merit in implementing a dual water tariff structure that reflects the costs of both providing fresh water and treating waste water. Such a dual water tariff structure would raise the necessary household awareness of and efficiency in the use of water resources.

The report shows further that as rates of water consumption continue to rise, it is crucial that water service providers diversify and innovate new sources of revenue in order to balance the water accounts. Potential new sources of revenue such as contracting out laboratory services or using already existing water infrastructure installations for advertisement services would go a long way towards complementing government transfer revenues and traditional operating revenues from water bills.

The empirical estimation of affordability indicates the need to re-evaluate the minimum basic water 'lifeline' provided to poor households in South African municipalities. The report shows that households earning R5,933.14 per month or less should be considered for receiving free basic water.

Ideally, a water block tariff should have fewer blocks – the literature suggests three. In our study we found that WSAs and WSPs should reduce their blocks to three. In such a scenario, the first block should reflect the lifeline block calculated in this study (i.e. the essential minimum consumption per household). The second block should reflect the average consumption, based on the marginal cost. The third block is a high block, set at a price designed to finance the full cost recovery.

Furthermore, based on both the trends and the demand elasticities in this study, our findings suggest that increases in water tariffs are more likely to result in a decline in revenue generated by the water sector. Therefore, if a policymaker's goal is to conserve water and reduce water consumption, increasing water tariffs would achieve this goal. However, if the aim is to raise revenue, significant increases in water tariffs are not the way to go.

The study also found that the incentive for water providers to collect revenue (and bad debts) is weakened by significant increases in transfers from national government in the form of grants. Low water tariffs also exacerbate the problem of low revenue collection. Finally, the study finds that South African households do not currently have water-efficient technologies installed on their properties, and that affordability and lack of knowledge about water-efficient technologies are the main reasons for not installing such technologies.

Results from the choice experiment show that households prefer technological devices for the kitchen, the shower and the garden, but have no interest in technological devices for the toilet. In addition, households were found to be willing to pay only very little in terms of water bills if they adopted water-efficient technologies.

RECOMMENDATIONS

Based on the findings of this study, we recommend the following:

1. The DWS, WSAs and WSPs must prioritise the setting of water tariffs to reflect the cost of operation, maintenance and capacity expansion, as well as environmental and other externality costs.
2. In achieving the above, the social goals of equity in access and affordability must be considered. The number of blocks matters; ideally, a progressive water tariff structure should contain three blocks.
3. The current 'lifeline' must be increased from 6 kl (6,000 litres) to 8.42 kl (8,420 litres) of water per household per month for households that earn less than R6000 per month.
4. Alternative non-traditional revenue-mobilisation activities must be promoted and encouraged among the WSPs, to improve water revenues.
5. Enough emphasis must be placed on wastewater pricing in a dual water-billing framework to enhance both the critical water use awareness required and promote efficiency in wastewater pricing.
6. WSPs must come up with innovative ways to reduce the mounting unpaid water bills and bad debts, to ensure revenue sustainability in the water sector.
7. There is a need to promote the use of water-saving technologies among the households, especially kitchen and shower technologies. Subsidising such technologies should be explored, given that poor households may not be able to afford installation costs.

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ABBREVIATIONS

2SLS	Two Stage Least Squares
AIC	Akaike Information Criterion
ASC	Alternative Specific Constant
AVC	Asymptotic Variance-Covariance
BIC	Bayesian Information Criterion
CE	Choice Experiments
CLM	Conditional Logit Model
CMA	Catchment Management Agency
CoGTA	Cooperative Governance and Traditional Affairs
CP	Competitive Price
CRS	Constant Returns to Scale
CV	Contingent Valuation
CVM	Contingent Valuation Method
DBT	Decreasing Block Tariffs
DEA	Data Envelopment Analysis
DMU	Decision-Making Unit
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation
EUWI-FWG	European Union Water Initiative – Finance Working Group
FBS	Free Basic Services
FBW	Free Basic Water
FDH	Free Disposable Hull
GDM	Gravity-Driven Membrane
GDP	Gross Domestic Product
GMM	Generalised Method of Moments
GMXL	Generalised Mixed Logit
IBT	Increasing Block Tariff
IIA	Independence of Irrelevant Alternatives
IID	Independent and Identically Distributed

KPI	Key Performance Indicator
KZN	KwaZulu-Natal
LCM	Latent Class Model
LL	Log Likelihood function
MC	Marginal Cost
MDGs	Millennium Development Goals
MFMA	Municipal Financial Management Act
MLM	Mixed Logit Model
MNL	Multinomial Logit
MP	Monopoly Price
MR	Marginal Revenue
MRS	Marginal Rate of Substitution
MSA	Municipal Systems Act
MWTP	Marginal Willingness to Pay
NIDS	National Income Dynamics Study
O&M	Operation and Maintenance
OLS	Ordinary Least Squares
PPC	Production Possibility Curve
PPF	Production Possibility Frontier
PPPs	Public-Private Partnerships
PPST	Payment Strategy Testing
RUM	Random Utility Model
SALGA	South African Local Government Association
SFA	Stochastic Frontier Analysis
VRS	Variable Returns to Scale
WRC	Water Research Commission
WSA	Water Services Authority
WSP	Water Services Provider
WTP	Willingness to Pay

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CHAPTER 1: INTRODUCTION

1.1 Introduction

South Africa is a naturally water-scarce country, with annual average rainfall estimated to be around 54% of the global average of 860 mm per annum. As water resources are stretched further, due to population growth and to dwindling reserves because of climate change, there is increasing pressure on the Water Service Authorities and Providers (WSAs and WSPs) to sustainably manage water resources and meet growing water demand. The Department of Water and Sanitation (DWS) has several guidelines for setting appropriate tariff structures and water packages aimed at ensuring good-quality water provision, equity in access, affordability, and long-term sustainability.

The DWS guidelines last revised in 2011 favour homogeneity in water service delivery package for both the rich and poor, recommend setting retail tariffs to recover the on-going capital and operating costs. The guidelines recommend that the portion of the tariffs related to usage should rise in incremental steps as household demand does – that is, an increasing block tariff (IBT) structure. A distinction tariff structure for potable water provision and wastewater management (sanitation) is also suggested, to promote water-use efficiency. The guidelines have in place certain social goals such as ensuring ecological sustainability, meeting minimum water demand, and ensuring equity in access to water for all South Africans.

However, several gaps have been identified in the DWS guidelines. For example, they do not identify the appropriate reference value for marginal cost or minimum level of basic water demand.

1.2 Aims and objectives

The primary aim and motivation for this study was to address some of the important gaps in the DWS guidelines related to the setting of water-service retail tariffs and the overall design of the water-service package. Specifically, the objectives of the study were:

1. To review, analyse and suggest important social goals and principles that could be considered when setting the water tariff structures and packages in South Africa.
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7. To understand household water-saving behaviour and the use of water-saving technologies.

1.3 Approach

The study objectives above were achieved through a range of empirical approaches. Assessing the social goals, the rationale for the dual water-tariff structure and financing options for revenue sustainability were done through critical reviews of empirical and theoretical evidence. The evaluation of the affordability of water services, the estimation of the consequences of raising water tariffs and the long-run consequences of the different transfer payment and revenue-raising options were assessed using critical reviews and regression analysis models. Understanding household water-consumption and -saving behaviours was done using the choice experience methodology.

1.4 Structure of the report

This report is structured as follows: Chapter 2 assesses the important social goals and principles that could be considered when setting water tariff structures and packages in South Africa. Chapter 3 reviews the rationale for a dual water service tariff structure in South Africa, while Chapter 4 reviews the alternative financing options for revenue sustainability in the water services sector in South Africa. Chapter 5 assesses the affordability of water services, especially among poor households, while Chapter 6 estimates the revenue consequences of raising water tariffs in South Africa. Chapter 7 analyses the long-run consequences of different transfer payments and revenue-raising arrangements within the water tariff structure. Finally, Chapter 8 investigates household water-saving behaviour and the use of water-saving technologies.

CHAPTER 2: AN ANALYSIS OF THE ELEMENT OF SOCIAL GOALS IN WATER SERVICES TARIFF STRUCTURE

2.1 Introduction

It is argued that the global warming phenomenon will put more pressure on the availability of drinking water. The main challenge for society is to find a balance for the ever-growing demand for fresh water for various needs (Dikgang and Hosking, 2016). According to Banerjee et al. (2008), African water utilities[1] operate in a high-cost environment, with an average operations and maintenance cost of US$0.6/$m^3$, and higher costs for water utilities in middle-income countries such as South Africa and Namibia. These relatively high costs, together with the mandate to cover at least partial operations and maintenance costs, make tariff-setting in Africa more difficult than in other regions of the world.

The social and economic benefits of providing the right quality of water to poorer households are enormous. However, the costs associated with improved water quality are taking their toll on utilities (Banerjee et al., 2008). According to the World Health Organisation (WHO), 91 per cent of the world's population in 2015 had access to an improved drinking-water source, compared with 76 per cent in 1990. There was a marked improvement in access to improved sanitation from 54 per cent in 1990 to 68 per cent in 2015. By 2025, half of the world's population will be living in water-stressed areas. This is in addition to population growth, extreme weather events, water supply shortages, sanitation, and viable ecosystems.

Water is a scarce resource; hence, pricing is deemed to be an adequate tool of public policy that signals its scarcity to users. Dole and Bartlett (2004) argue that there is consensus that user charges have an impact on the performance of the public utility responsible for provision of the service, the well-being of the community, and the use of resources across the economy.

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[1] "Utilities (water, electricity and gas) are essential services that play a vital role in economic and social development. Quality utilities are prerequisite for effective poverty eradication. Governments are ultimately responsible for ensuring reliable universal access of service under accountable regulatory frameworks. Increased competition in the utilities sectors in recent years has entailed changes in regulatory frameworks and ownership structures of enterprises, in addition to business diversification." (ILO, 2015).

There is an extensive literature showing that a utility's management is enhanced the more it relies on user charges for funding purposes (see Bierhanzl and Downing, 1998; Bierhanzl, 1999). Most public utilities provide basic services such as water and sanitation; and thus, user charges affect people's use of these services, and the production of nearly all goods and services (Dole and Bartlett, 2004).

Although most utilities around the world are publicly owned, we acknowledge that some are privately owned. Nonetheless, one can expect some government intervention even in cases in which the private sector provides the service to ensure that the government does not charge monopoly prices. A profit-maximising monopoly determines its output at the level at which marginal cost (MC) equals the marginal revenue (MR) associated with the demand curve. It is for this reason that tariffs charged – even by privately-run utilities – are regulated.

Based on its impact on society and poor communities, the World Economic Forum has identified the global water crisis as the number one risk faced by the world (World Economic Forum, 2015). This awareness has led to a change in approach to water management, with the focus now being demand-side management of water from the traditional supply-side measures. The character of water as a scarce good and the need to efficiently price its consumption have gained increasing recognition (Arbues, Valiñas and Espiñeira, 2003).

Pricing water to accurately reflect the true costs of providing high-quality water and wastewater services to consumers is needed both to maintain infrastructure and to encourage conservation. In the past, this has led to water-pricing models that were based on full cost recovery, such that the underlying economic value of the water resources would be reflected in the price of the water.

User charges in the water sector are commonly referred to as water tariffs. The term is often used to refer to both potable water and wastewater tariffs. It is typically a price assigned to water supplied by a water utility to its customers via a piped network. Often, cost recovery is a common basis for setting potable and wastewater tariffs. This implies that these tariffs are not charged for the water itself, but to recover the costs associated with the provision of water, such as water treatment and the infrastructure associated with delivering the service.

The setting of tariffs below the levels required to recover costs is common in developing countries. However, this has resulted is the deterioration of water infrastructure, due to insufficient maintenance. The shortfall is often made up in the form of government subsidies, for both operations and new investments. In contrast, developed countries often set their tariffs at the level of cost recovery, or very close to cost recovery. Indeed, there are instances in which water utilities in developed countries generate a profit or surplus.

Most importantly, setting of tariffs goes beyond cost recovery, as a tariff is an instrument that can be used for a wide variety of goals. It is common for tariffs to have many goals. Appropriate water-tariff setting should embrace the concepts of fairness, equity, cost causation, efficiency, sustainability and political feasibility. It should be noted that conflicting goals are also common in water management scenarios. Dole and Bartlett (2004) argue that it is equally common for tariff-setting strategies to be vague and unsystematic.

The biggest challenge to setting a tariff on water is whether to price water by its average cost, based on the financial reason of cost recovery; or by its marginal cost, based on the economic reasoning of promoting an efficient use of the resource, which includes the environmental goal of water conservation. These constraints reflect a social concern over the fairness of water tariffs, but they are rarely revised to account for changing circumstances (Boland and Whittington, 1998).

Setting a tariff on water is challenging to most water utilities, as they must consider not only cost requirements but also the positive or negative social impact it will have on people. Disadvantaged communities and their ability to afford water prices must be critically evaluated to ensure the tariff is fair and efficient. Previous studies by Parshardes and Hajisprrou (2002) argue that water consumption is affected not only by income, but also by several other equally important factors, such as size and composition of household, type of residence, whether the household owns garden or electrical appliances that use water for cleaning purposes (e.g. a washing machine). This sometimes poses a problem when pricing water, as water utilities try to find a balance between equity, affordability and cost recovery.

2.2 Background

Ashton (2002) describes South Africa as a chronically water-stressed country, with between 500 m^3 and 1,000 m^3 of water available per person per year. Water availability was predicted by Turpie et al. (2008) to be the single greatest and most urgent development constraint facing South Africa. This is because water scarcity in developing countries is linked to the incidence of poverty and disease (Falkenmark, 1994; Ashton and Haasbroek, 2002).

As discussed earlier, water resource managers used to meet the rising water demands through supply-side solutions such as major inter-basin transfer and water-pumping schemes (Smakhtin et al., 2001). However, according to Turpie et al. (2008) these solutions are becoming less viable, due to the increasing costs associated with supply-side measures and the limited remaining exploitable water resource potential. The South African government through the Department of Water Affairs (DWA) has therefore turned to demand-side policies such as including a mandatory water resource management fee in the water tariff charged to consumers.

The public water sector in South Africa is organised at three different levels – national government, the water boards and the municipalities. The primary role of national government is to formulate and implement policies governing water resource management. The water boards (which are state-owned) primarily provide bulk water, offer some retail water services, and sometimes provide technical assistance to municipalities.

Although municipalities also own some of the bulk water-supply infrastructure, their main role is to provide retail water services. South Africa has 52 district municipalities and 231 local municipalities, which distribute water either directly or indirectly through municipally-owned enterprises or private companies. It is enshrined in the Municipal Structures Act and the Water Services Act of 1997 that it is the responsibility of the district municipalities to provide water services. However, the government may assign this responsibility to local municipalities.

In South Africa, water is valued as an economic resource (Water Services Act 108 of 1997). Significant costs are associated with making this resource available. Hence, methods should be devised to cover those costs. In pursuit of the objectives of water management, it is widely agreed that setting an appropriate price for a natural resource such as water can be an effective mechanism to achieve its efficient and productive use (DWA, 2013).

As contained in the Water Services Act (Act 108 of 1997), municipalities can use water tariffs as a cost-recovery tool. Although they need to recoup water provision costs, municipalities are obliged by the Free Basic Water Policy of 2002 to provide at least 25 litres per person per day of free basic water, within 200 metres of where the person resides and at a flow rate of at least 10 litres per minute (DWA, 2002). However, each municipality decides on whether free basic water is made available to everyone, or only to the poor. Water services tariffs are then levied for any subsequent water consumption above the free basic units.

As Le Blanc (2008), Muller (2008), Foster and Briceno-Garmendia (2010) and Hurtado (2012) observe, water scarcity, rapidly increasing water demand, insufficient tax revenues, environmental sustainability and water resources management, among others, provide a strong basis for tariff setting in the water sector. To secure the capital necessary for sustainable water-service provision and ecosystem stability, therefore, tariff setting must be accepted for at least two reasons:

- Water tariffs can generate revenues for recovering water-services costs, such as operation and expansion capital.
- Water tariffs may convey a signal to users about water scarcity, and can therefore encourage water conservation.

Around the world, different ways of setting tariffs have been employed; these vary across types of public services, and require detailed information on the utility and its customers. There are usually disagreements between water providers and policymakers on tariff design and objectives. Water tariffs can either be volumetric (water-metering) or flat rate (non-water-metering). Volumetric tariffs can be in the form of linear tariffs (proportional to consumption), increasing block tariffs (IBT, increasing with consumption) or decreasing block tariffs (DBT, decreasing with consumption).

Increasing Block Tariff structures (IBTs) are widely used in developing countries, in the belief that for poor households, they ensure basic access to water for consumption and sanitation. Other objectives include promoting economic efficiency, discouraging wasteful use, and desirable income transfers. In practice, IBTs have received mixed reviews, with shared connections to meters decreasing water conservation and increasing revenue instability and inequality, as what people pay is not related to the cost of supply.

In South Africa, the IBT structure is prescribed, by regulations under the Water Services Act (Act 108 of 1997), to address problems of unequal income distribution and to provide fair access to water (Bailey and Buckley, 2005). Municipalities in South Africa are required to use the IBT structure, but they do so with varying costs in similar blocks.

For example, in the 2013/4-year Cape Town provided between 0 and 6 m^3 of water per month free. The tariff for the block between 6 m^3 and 10.5 m^3 was R7.60 (R8.66 including VAT) per kilolitre; for the next block up to 20.0 m^3 it was R11.61 (R13.24 including VAT), while for the block from 20.0 m^3 to 35.0 m^3 it was R17.20 (R19.61 including VAT). The water tariff for the block between 35.5 m^3 and 50.0 m^3 was R21.24 (R24.22 including VAT). Any consumption exceeding 50.0 m^3 per month was billed at R28.02 (R31.95 including VAT) per kilolitre (Water Rhapsody, 2013).

Retail water-service tariffs also vary between user categories (residential, commercial, industrial or public buildings) and consumption (the higher the consumption, the higher the tariffs). Non-residential users of water are charged higher tariffs than residential users. Using Cape Town's 2013/14 rates as an example, domestic single residential water tariffs were R7.60 per kilolitre for water consumption in the range 6.0 m^3 to 10.5 m^3. Water tariffs for the same range for non-residential users, excluding VAT, were R12.51 for commercial and industrial users and R11.06 for schools (DWA, 2013).

In conclusion, it should be noted that a water-service tariff structure is not only the key element in raising revenue to offset the costs incurred in provision. It is also a key element in allocating the water services provided, and it influences a wide range of choices and decisions – many of which are closely linked to local and regional economic development. South African water tariffs are not set endogenously through the interaction of demand and supply, thus automatically considering a whole range of market influences, but within a constitutionally mandated monopoly market setting.

As a result, the setting of water-service tariffs now happens largely at the discretion of the municipalities. It requires some negotiation, but also permits a wide range of options – for example, choosing a water-service provider (or composite of firms that will supply), choosing what water-service packages will be offered, and choosing the revenue-raising mechanisms that will be employed to recover costs. It is also a discretion that can benefit by more informed guidance.

2.3 Problem statement

The quest to balance the provision of affordable water services and the need to recoup the costs associated with water treatment, storage, transportation and treatment creates some complexity for municipalities. Determining a reasonable tariff structure that will be accepted across the board is a monumentally difficult task. This is due to income inequalities and other discrepancies within the South African dual economy. Even though municipalities offer monthly free basic units of water, as outlined in the Water Services Act (Act 108, 1997), such generosity is received with mixed feelings. This is evident in the increasing number of water-provision protests, in which poor South Africans accuse the authorities of neglecting their right to adequate water for dignified lives.

Poor households must register as 'indigent' for them to qualify for free basic water. However, there are also complexities in determining how many 'basic' units are enough for assorted households. There are also challenges when it is up to municipalities to determine who is poor and qualifies for free basic water. According to Mosdell and Leatt (2005), out of the 32 million people who received free basic water in 2005, almost half (about 15 million) were not poor. Most of the poor in rural areas who receive limited amounts of free water through standpipes do not benefit fully from the programme; and those without access to publicly provided water do not benefit at all. Calfucoy et al. (2009) state that the free basic water policy is therefore arguably more successful in wealthier municipalities, where revenue from wealthy households subsidises water provision to poor households.

South African municipalities generally struggle to maintain water infrastructure, due to insufficient revenue collection because of low tariffs. Together with the absence of guaranteed protected revenue for maintaining assets, this usually results in the deterioration of municipality-run water infrastructure. A new set of guidelines should therefore be devised for setting optimal tariffs that are both lucrative to municipalities, and economically affordable for all South Africans.

2.4 Purpose and objectives of the study

The need to address government laws together with the desire to recover water-provision costs makes an ideal opportunity for researchers to help in devising an optimal tariff structure. This study is relevant because it will draft a new set of guidelines to be adopted by municipalities when setting water-services tariffs. It will be a source of information to the DWA, SALGA, WSPs, WSAs, municipalities and other stakeholders.

The study will also serve as a source of information for researchers, since the results will inform debates on the issue of tariff setting for municipal water services. Most importantly, the study will contribute to alleviating the water services conflicts that have seen South Africans protesting for adequate and affordable water supply. The study will also suggest alternative revenue-raising instruments for South African municipalities. This is because most municipalities, especially poor municipalities, struggle to raise enough funds to maintain water-service infrastructure, usually relying on the government for bailouts. Recommendations in this study will also be useful for other developing and emerging economies that struggle to balance the need to provide affordably adequate water services and raising enough income to cover water-provision costs.

2.5. Theoretical Literature

2.5.1 The pure theory of local expenditure (Tiebout Model)

Developed by Charles Tiebout (1956), the pure theory of local expenditure (Tiebout model) asserted that if there were a large enough number of local government jurisdictions, and each of these local governments offered a different mix of local public goods and taxes, individuals would reveal their true preferences for public goods by choosing a local government jurisdiction in which to live (Tiebout, 1956).

The Tiebout model suggests that citizens – who have different tastes and are mobile – choose to live in the local government jurisdiction that produces the mix of tax and public-good outputs that corresponds most closely with their preferences. Their choice of location therefore reveals their preference for public goods. The greater the number of communities and the greater the variation in taxes and public services offered, the closer consumers will be to satisfying their preferences. Tiebout described a theoretical solution for the problem of preference revelation, a phenomenon that inhibits the achievement of allocative efficiency (Black, et al., 2005).

In the Tiebout model, it is assumed that all individuals are fully mobile, and have full information and many jurisdictions to choose from; that there are no geographical employment restrictions exist, no spill-overs across jurisdictions, and no economies of scale in the production of public goods. The Tiebout model demonstrates that a decentralised fiscal system can be welfare-increasing, compared to a centralised system that imposes a standardised public good/tax mix on people irrespective of their varying tastes. In principle, fiscal decentralisation can contribute to more efficient provision of local public goods and services by aligning expenditure more closely with local priorities (Black et al., 2005).

The Tiebout model is directly applicable to this study, in the sense that it looks at the provision of public goods and at how citizens make choices. However, it should be noted that the Tiebout model is based on several restrictive assumptions. For example, if there is a limited number of communities, they may compete to attract outsiders. Although this behaviour may provide an incentive for the efficient production of public services, the mix and level of public services provided may not be Pareto-efficient.

Moreover, most of the assumptions underpinning the Tiebout model do not really exist in the real world. Although the Tiebout model has several weaknesses, it is applicable in South Africa, where power is decentralised. The devolution of power within different tiers of government in South Africa makes the Tiebout model even more applicable. Another reason this study considers the Tiebout model appropriate is because it explains the behaviour of local authorities as seen in the main area of analysis in this study.

2.5.2 The public choice theory

Buchanan and Tullock (1962) asserted that policymakers act to maximise personal welfare rather than social good. It states that policymakers are ordinary men who make most of their decisions in terms of what benefits them, rather than society. This means that when elected officials make policy decisions, their emphasis is on votes. The only appropriate loss that policymakers seek to achieve is:

$$L = b_1 VL \qquad b_1 > 0 \qquad (1)$$

where L is the social welfare loss, b_1 is the weight given to votes lost and VL is the vote loss. Policymakers are assumed to maximise votes gained, not social welfare. Economic goal variables enter the picture because the behaviour of the economy affects votes. Therefore, vote loss might be represented as:

$$VL = c_0 + c_1(U - U^*)^2 + c_2(P - P^*)^2 + c_3(y - y^*)^2 \quad (2)$$

where U is the level of employment, P is the inflation rate, y is the growth in real income, U^*, P^* and y^* represent the target levels of these variables respectively, and c_1, c_2 and c_3 represent the loss of votes resulting from the deviation of macroeconomic goals from target levels. The representation assumes that vote loss depends on the squared deviation from the target level, if a heavy weight is given to large deviations from desired target levels. The c_0 parameter represents all other influences on voter behaviour.

Actions by policymakers who aim to minimise vote loss differ from the actions of those who wish to minimise social loss. This is a result of the 'collective rationality' assumption, where vote loss because of 'economic concerns' is proportional to social welfare loss. The collective rationality assumption suggests that when economic and social variables affect voting behaviour, voters reward or punish incumbent politicians depending on their performance in minimising social welfare loss. In this case, the optimal strategy to minimise vote loss (equation 1) is to minimise social welfare loss (equation 2). In the absence of collective rationality, it is suggested in this theory that the behaviour of the vote-maximising policymaker deviates from social-welfare-maximising behaviour.

The public choice theory is applicable to this study because setting water service tariffs in South Africa is a political decision, made considering the consequences politicians and other policymakers would bear should their water-service policies make citizens worse off. Coming up with a new set of guidelines for water services in South Africa therefore requires a clear understanding of the country's politics.

Politicians automatically dismiss any set of guidelines that may cost them the electorate. However, it can be noted in criticism that although the model has proved useful in explaining an important element of politics, not all individuals in the real-world act in accordance with the behavioural assumptions made. The hypothesis that voters are myopic is directly inconsistent and holds no water in the modern world. Voters today are so rational that they can distinguish between politicians who strive for personal gain and those who seek to maximise social welfare.

In conclusion, this section explained some theoretical literatures that underpin tariff setting. The Tiebout and Public Choice theories give insight into the motives and behaviour of policymakers who have the final say on the setting of water tariffs. An understanding of the behaviour and motives of policymakers, as explained by these theories, helps to determine the 'right' set of tariffs that will give satisfaction, both to the policymakers and to society. These theories are therefore relevant to the topic discussed in this study, because they give insight on what to consider when determining guidelines for tariff setting for municipal water services.

2.5.3 Department of Water Affairs Guidelines

In their capacity as the policy leader for Water Services Authorities and Providers (WSAs and WSPs) in South Africa, the DWA issues guidelines for financial and water services managers involved in setting retail water and sanitation tariffs for standardised piped water service packages; the most recent of which were issued in 2011 (DWA, 2011). These guidelines recommend an IBT structure for households, linked to an adjusted average cost – this being the average cost of supplying that portion of the water service targeted for revenue, after allowing for other income and expenditure flows (including transfers).

The guidelines recommend that initial water-service demand, termed 'basic demand', be satisfied at a tariff lower than the adjusted average cost reference value. But above a basic level of demand, the guidelines on the IBT become progressively more ambiguous. They recommend that water-service tariffs rise incrementally for households, peaking at a maximum equivalent to the marginal cost of supply; and that marginal cost also serves as a reference for the tariffs applied to commerce and other institutions.

2.5.4 Problems with the guidelines

First, the guidelines do not identify which marginal cost is being referred to. Their advocacy for the goal of efficiency implies that short-run marginal cost is the reference, but their advocacy for ecological sustainability suggests the extra cost of new water-supply schemes. A related confusion is how the cost-recovery goal could be achieved through marginal cost pricing – a challenge frequently referred to in the relevant economics literature (Varian, 2003).

When the capacity of the infrastructure is fully exploited, marginal cost and average cost tend to equate. For this reason, if only the highest tariff in an IBT structure is set equal to the marginal cost, it follows that full cost recovery through tariff revenue collection cannot be achieved (Varian, 2003). As would be expected, given the ambiguity in the guidelines to the IBT, how South African municipalities design their IBT structures has become highly arbitrary (Hosking and Jacoby, 2013).

Second, there are significant gaps in the DWA (2011) guidelines for water-service tariff setting. The guidelines lack analysis of the revenue consequences of raising tariffs under different municipal circumstances. The consequences of raising tariffs to raise revenue differ in the short and the long run – with more revenue likely to be raised from a tariff increase in the short run than in the long. Similarly, the revenue that can be expected to be raised by raising tariffs would be less, the greater the demand that has already been satisfied (because price elasticity should increase along the demand curve), and the more substitutes there are to the water services provided – for example, river or underground water supplies. This is explained by Dockel (1973) and), as well as Nahman and de Lange (2013).

More guidance and insight are therefore required, in the guidelines for tariff setting for municipal water services provided, on the scale of transfer payments and tariff-raising scope that would be tolerable without inducing adverse long-run development consequences. There are transfer payments through the Equitable Grant facility, implicitly through the IBT structure (where tariffs are set that exceed adjusted average cost) and to cover bad debt. These last two mechanisms for transfer payments can contribute to increasing the local water-service tariff, potentially reducing the relative economic attraction of the relevant locality to mobile, affluent households and businesses – inducing exit and discouraging entry.

Third, water-service tariff setting is quite complex in a country with policies that promote the provision of free basic water.

2.5.5 Setting Tariffs to Satisfy Multiple Goals

Economic theory suggests that prices based on the marginal utility concept will allocate water resources efficiently, and thereby encourage production and consumption decisions that are sustainable over time. While there is a trade-off between efficiency and equitability, which must be balanced by policymakers, it has been found that utility pricing promotes overall efficiency for society, i.e. sustainable water uses in both production and consumption (Rogers et al., 2001). The utility pricing option is further supported because it creates opportunity for the use of excess water resources elsewhere, and because it allocates the costs of production or consumption to the users who are responsible for them (Haneman, 2001).

Specifically, analysts prefer pricing based on marginal costs, where prices reflect the "incremental costs of producing an additional increment of good" (Haneman, 2001). To this end, it is argued that prices based on long-term marginal costs will drive long-term efficiency in water resource use. However, most theory rejects the use of water subsidies, because they distort true prices in the provision of water services and do not reflect the true costs of resource use to society (Rogers et al., 2001; Stallworth, 2007; Haneman, 2001; CCME, 2015; Olmstead and Stavins, 2007).

Unfortunately, the pricing theories put forward rest heavily on competitive market assumptions (Foster and Briceno-Garmendia, 2010), while the water sector and water services in general operate in monopolistic settings. For example, water utilities in many countries (including South Africa) operate on an administered (regulated) price basis and are highly monopolistic. Most importantly, however, water has no substitute, and cannot be freely replaced the way most goods can, in competitive markets (Hofmeyr, 2012).

The pricing of water and wastewater services is clearly unique, because of the salient features of water. More precisely: water occurs naturally, it is central to life, and it has no substitutes whatsoever. Consequently, the UN general assembly has declared access to safe drinking water and sanitation a human right (United Nations, 2010), while the South African government has declared the same access a constitutional right (South African Bill of Rights: Section 24 and 27).

In fact, the Millennium Development Goals (MDGs) include targets to "halve by 2015 the proportion of people without sustainable access to safe drinking water and improved sanitation"

(United Nations, 2015). At the same time, water and wastewater services are also economic goods that must be priced according to the economic market system (Haneman, 2001). The efficient and equitable pricing of water therefore requires the balancing of its social and economic aspects to deliver sustainable water and wastewater services.

Obviously, this is easier said than done. For example: subsidising water for low-income groups and the poor ensures that they enjoy their human right to water. However, with low levels of cost recovery from water users, there will be insufficient revenues for the efficient and equitable operation of water services; the result of which may be instability in general water-service provision (Cardone and Fonseca, 2004).

Water tariffs create different expectations for consumers and suppliers, and they are usually conflicting. Consumers want high-quality water to cover their most basic needs, at affordable and stable prices. Suppliers use tariffs as an important management tool for cost recovery, stable revenue over time, and lower administrative costs. A tariff design should be easy to explain, result in minimum administrative cost, and be easy to implement. According to Boland (1997), the 'best' tariff design for a community and situation is one that strikes the most desirable balance among the objectives that are important to that community.

These are ***six*** main goals that should be taken into consideration when setting tariffs:

a) Cost recovery. In delivering water services, authorities and utilities must meet financial obligations as they arise. The main sources of finance for water services are tax revenue and collection from meter readings (EPA, 2007). The finances are required to cover the costs of operations and maintenance as well as new investments on the water supply and management system, including water capture, treatment, storage, and transportation to customers, wastewater collection and treatment, and billing and collection of payments (EPA, 2007;

From the perspective of financial sustainability, an optimally operating utility is one that can cover the full cost of services. Specifically, tariffs faced by water consumers should at least return revenue equal to the cost of supply (Dole and Bartlett, 2004). The downside of tariffs based on cost recovery is that it is usually difficult to collect revenue from poor households, which leads to suppliers or water providers recovering less revenue. This leads to unstable revenue and cash flow difficulties for the utilities, thereby affecting the maintenance of ageing infrastructure in both developing and developed countries. The result of this is shortages in the water supply and increased public health risk.

b) Economic efficiency. This requires that prices signal to consumers the operational, environmental and wastewater cost – the cost of supplying an extra additional cubic litre of water to consumers. The cost of providing additional water is usually higher than the cost of supplying existing water, as the cheapest sources tend to be developed first. Past studies have recommended that the marginal cost of pricing water is the most appropriate price. As such, the price system is seen as the best tool for guaranteeing the optimal allocation of resources among different economic sectors (Dalhuisen and Nijkamp, 2009).

Accordingly, an optimal allocation of resources implies that the full cost of service provision – i.e. the operational, maintenance, capital and environmental costs (incorporating all costs to society) – has been fully accounted for (OECD, 1998; Perman et al., 1996; Hanemann, 1998). Several variations of economic efficiency exist, including allocative efficiency, which implies that water must reach all sectors of the economy at a price equal to marginal costs; and production efficiency, which suggests that maximum water supply must be supplied at the lowest possible cost. Specifically, the supply must be without interruption or wastage in the system (Dalhuisen and Nijkamp, 2009).

Economic efficiency also includes social efficiency, which suggests that the cost of water supply must include internal and external costs. Social efficiency therefore includes the cost of water service provision as measured from the perspective of both the utility and society (Dalhuisen and Nijkamp, 2009). Efficient tariff prices satisfy social welfare goals because they satisfy both consumer surplus and producer surplus. In terms of social efficiency, therefore, the price of water service provision must equal the marginal social costs of service provision (Dole and Bartlett, 2004).

Essentially, a resource is used efficiently if the benefit for society from consuming the last or marginal unit of the resource is the same as the cost of obtaining it, including the opportunity cost of foregoing alternative uses (A World Bank study done on different water-pricing tariffs in South Asia suggests that an efficient tariff would create incentives that ensure that for a given water-supply cost, users will obtain the largest possible aggregate benefits.

c) Equity. Equity in the tariff system requires that every individual should have access to at least sufficient water to attain a sustainable and dignified livelihood (CCME, 2015). Equity looks at the distribution of capital, goods and access to services throughout an economy and is often measured using tools such as the Gini index, through which low levels of equity are associated with poor access to basic services. The equity principle is advocated for in various legislative instruments – for example, the United Nations (UN) MDGs and the South African Constitution, to the extent that subsidies are provided pursuant to it. In this regard, water is a basic need for life for both humans and ecosystems; and a good (public or economic), scarce and volatile in availability, without substitutes, and involving risk for political, economic and ecosystem stability – the pricing of which rests on the pillar of equitability, i.e. distributive justice.

Distributive justice is based on measures of standards of living and standards of living inequalities in an economy – i.e. the Gini coefficients; which show that there are wealth, income and price differentials in society that create different affordability levels and different requirements for service levels on various goods and services (Dole and Bartlett: 2004). Among other things, these measures also reflect standards of life regarded as minimum for dignified living, and from which measures of daily water requirements – i.e. basic water-service levels – can be obtained. In this regard, distributive justice or access to water for all requires that members of society who are not able to afford services at financial sustainability or economic efficiency prices should be subsidised; i.e. their bill should be paid by the government, up to the basic level of water service.

To this end, South Africa provides a free basic water allowance based on an increasing block system, in terms of which the first block is free at 25 litres per person/per day or 8 people x 25 litres per household/per day. However, the satisfaction of the free basic level of water service and the quality levels thereof in South Africa are widely debated (Helena, 2011), probably because the updated measures for such standards and the required infrastructure are limited. Simultaneously, the equity goal requires that the costs of service should be borne by those consuming the service.

Two indicators that are widely employed by analysts to measure the equity goal in a tariff system are level of disposable income and unemployment rate in the target community. Since low-income groups consume water in subsistence compared to high-income groups, a balanced income distribution contributes to the fulfilment of the equity principal, while a more employed community requires less government subsidy in their water services.

Water services should be accessible to and affordable for all people, especially low-income groups. This usually means that minimum free basic water is provided to the poorest households, and there is some form of cross-subsidisation from those who can afford to pay – mainly businesses and other users of water. In this context, it is not the average tariff level that matters, but the way in which costs are allocated across different groups through tariff structures (Vilcara and Karina, 2009).

d) Affordability and feasibility. In both developed and developing countries, water is regarded as a basic need that everyone should have access to, regardless of whether they can afford it or not. This has led to recommendations that prices be kept low and water provided at minimal cost. This has led to a shortage in revenue for most utilities and a backlog in infrastructure maintenance, leading to government water subsidies to cover shortfalls and developmental assistance from international organisations. Affordability leads to several trade-offs between other objectives; and it is usually not cost effective to provide poor household water through private connections as they can be expensive, which is not efficient and does not discourage wastage or excessive use of water.

e) Political and public acceptance. The tariff that a water utility adopts must be publicly acceptable, to avoid issues of implementation and high administrative costs. It must be simple and transparent, so as to be understood by all water users. This will lead to more collaboration between governments and water utilities, which may lead to more water subsidies and assistance when it comes to connecting meters for consumers who are not easily accessible.

f) Resource conservation. A water tariff should encourage water conservation or impose a financial penalty for wasteful use of water services. Countries such as Singapore (PUB, 2014) take water conservation very seriously, such that their water bill has four main components: the water tariff, a water conservation tax, a sanitary appliance fee and a waterborne fee. The water conservation tax was introduced in 1991; it is levied as a percentage of total water consumption, to signal to users that water is precious from the first drop. It is pegged to a rate such that the total price of drinking water (water tariff plus water conservation tax) is equivalent to the cost of producing the next drop of drinkable water from the next available source (i.e. from desalination and NEWater – high-grade reclaimed water produced from treated used water that is purified further using advanced membrane technologies, which makes the water ultra-clean and safe to drink).

Water agencies must re-valuate their tariff design to see if it still meets its desired outcomes. This process is often complex; in addition to the water agency itself, it could involve outside consulting firms, lending institutions, political leaders, various stakeholders from the user population, and sometimes local and/or national legislatures (Boland and Whittington, 1998). As water becomes scarce and supply costs increase, re-valuation of the tariff becomes essential.

2.6 Discussion and summary

According to Stalker and Komives (2001), water systems in developing countries should provide water services that are safe, acceptable and affordable to users; and ensure an institutional and viable system that can re-coup costs. Whittington, Boland and Foster (2002) argue that these are often conflicting goals which have significant political and economic implications. The efforts that must be made to balance them are particularly challenging in developing countries and can result in the implementation of price structures that do not meet either goal, which may have an adverse impact on poor users.

The social goals of equity (access and affordability), efficiency and sustainability in water-tariff setting should include prioritising basic human needs and reducing inequality in access to water resources; therefore, any price structure should echo these goals. There is limited literature on the estimation effects of water price on household consumption behaviour, and on the imbalances between equity, efficiency and sustainability when estimating the affordability of residential water tariffs. It is important to ethically analyse the key principles underlying water-service tariff setting. These include **equity, efficiency, consumer welfare, income redistribution and sustainability** as elements of social goals in the water-services tariff structure.

Equity in the water sector recognises that every citizen must have access to water to redress any past discrimination; allocation of water must be equitable and fair, to promote social and economic development for all citizens. Therefore, equity has two important concepts – **access and affordability** – which must be taken into consideration for any water-tariff pricing. Access deals with the provision of an adequate supply of safe water to consumers, for them to meet their domestic and productive requirements. This also affects the sustainability of water resources in the country and the promotion of social and economic development; and at the same time, ensures that the environment is protected both now and in the future. Affordability has major implications for most low-income households in relation to the proportion of their budgets that must supplement increasing consumption of water.

In developing countries, there are still issues of access and of unsatisfactory water and sanitation services. The water and sanitation sector is heavily under-financed. With IBTs being the most commonly used tariff structure, its disadvantages have been overlooked, as people do not pay in relation to the cost of supply. This has led to the argument that an IBT must be supplemented by allowances for household size and composition I order to be equitable. In South Asia, there has been more emphasis on introducing subsidies with low administration costs.

It has been argued that in most African countries, the equity objectives of the IBT structure are not fulfilled, as the price paid by low-volume users is often actually higher than that paid by average or high-volume users. Moreover, it is not exclusively the poor who receive the subsidy on the lowest block under the current IBT structure, as many other users who are not poor do not exceed its upper limit. On the other hand, the minimum consumption charge is often burdensome for the poorest users. Many poor households – especially those in rural areas – are not even connected to the piped water network; therefore, they do not benefit from the subsidies. The indirect benefits reach those who have access to public stand posts (Banerjee et al., 2008).

In South Africa, IBTs have been received mixed reviews. Even though some of the big municipalities have been successful in implementing the systems, there are still shortages in cost recovery, which has led to inadequate investment in water infrastructure. Banerjee et al. (2008) found that most African utilities can achieve operating and maintenance cost recovery for the highest block tariffs, but not for first-block tariffs, which are designed to provide affordable water to low-volume users, who are often poor. For utilities whose operations depend on connecting more customers to the network, the inability of the poorer users to pay connection costs can be a major barrier to expansion. To create a more inclusive network and enable their utilities to grow, many African countries have begun to subsidise household connections.

Efficiency requires that water is used optimally and not wasted. For water distribution systems, efficiency is measured by comparing the water that is delivered to the final user with the water that is treated or lost in the distribution system (Garcia, 2014). The efficiency objective is very important to the sustainability of the water resource, in that it minimises supply costs.

An efficient tariff structure entails setting prices that signal the marginal benefits of water use to users. Therefore, prices should encompass not only financial cost, but also the externalities that the use of water imposes on the economy and environment. A well-crafted, efficient tariff guarantees the highest aggregate benefits for the marginal cost of supplying water (Whittington, Boland and Foster, 2000).

Consumer welfare is closely related to income distribution, especially in developing countries where tariffs are used for cross-subsidisation among consumers. The IBT is the most preferred structure, due to its ability to make provision for setting prices in the first block below cost for the poor households, while industrial water prices are set above cost to compensate.

Environmental conservation requires that a water tariff is designed to discourage waste. If one assumes that it is the large users of water who are the most likely to engage in 'excessive' or 'wasteful' use, then the IBT design confronts those users with higher prices, and thus discourages further use (Boland and Whittington, 1998).

The goals of efficiency, cost recovery, equity and affordability must be explicit when designing tariffs, and this can be done through the following steps:

- The utility must gather vast information about the different water users' current demands and future forecasts, and its own operating cost, revenue streams, investment plans and asset management. This will enable the utility to gather inputs from customers into their planning strategy for the design of the tariff.

- Review of the current design/structure – whether it is still achieving the objectives of cost recovery plus social equity, and whether there is a need to reform. This involves looking into the economic efficiency of setting prices equal to their relevant marginal costs. The utility or regulator must evaluate whether an equal tariff increase should be implemented across tariff categories, or if an overall rebalancing is needed between the different users (household and business). If tariffs do not meet the cost requirement, subsidies should cover the difference. Existing subsidies should be identified, and their targeting performance evaluated.
- Public and private participation – a successful tariff design is one that is not controversial, or which does not serve as a focus for public criticism of the water supply agency (Boland and Whittington, 1998). The tariff must also be simple to understand and politically acceptable, for better implementation. Public hearings and participation are crucial; often, regulators implement a tariff without proper inputs from the consumers.
- Implementation and monitoring – this is to identify the advantages and disadvantages of the proposed tariff, and how to best cross-subsidise the different users. Consistent monitoring is crucial to make the necessary adjustments over time, without a major overhaul of the whole value-chain system.

Designing tariff structures that are consistent with the objectives of the water sector (efficiency, economic sustainability, equity and affordability) can be difficult, and involves many trade-offs between equity, efficiency and sustainability. This is well documented in the literature (Mehta, 2006; Wegerich, 2007; Ingram et al., 2008; Araral, 2010; Achterhuis et al., 2010; Zwarteveen and Boelens, 2014). Policymakers therefore need to identify and prioritise the most important aspects of water tariff-design for the given country. According to the literature, however, using a combination of instruments concurrently leads to optimal outcomes. Indeed, with careful design a water tariff can meet both the cost-recovery and economic efficiency objectives, while a parallel subsidy programme could be used to address affordability. The next chapter discusses dual water-service billing for potable and wastewater as an alternative efficiency and conservation option for South Africa.

CHAPTER 3: ASSESSING THE RATIONALE FOR A DUAL WATER SERVICE TARIFF STRUCTURE

3.1 Introduction

Water services require the efficient management and development of naturally available water sources. To achieve this, storage facilities, treatment plants, piped networks and wastewater network removal and treatment plants are required. Water-supply systems must also meet certain minimum standards for public, commercial, industrial and agricultural activities. Of all the water services, the provision of potable water and wastewater treatment is perhaps the most important.

Pricing in the water sector is a politically sensitive issue in many parts of the world. As it is an industry often under government control, and with a vital public-health role, setting tariffs for water prices is often a compromise between all the social objectives. These social objectives include equity, efficiency, transparency, and potential conflicts with government environmental and social policy. Striking a balance between these various objectives comes at the expense of adopting water pricing that reflects the cost structure of supplying water services (Anstey, 2013).

A 'water tariff' is a price assigned to water supplied by either a public or a private utility, through a piped network, to water users. This term is also applied to wastewater tariffs. Household wastewater is derived from a few different sources. These include wastewater from toilets (black water), kitchens and showers (grey water), storm water (from rooftops) and pollution (chemical spills). Grey water is easier to purify than black water. In general, wastewater is water that emerges after fresh water is used by households and commercial and industrial users.

According to Cardone and Fonseca (2004), water and wastewater tariffs influence conditions of service and monthly bills for water users in various categories and classes. Regulatory bodies normally set tariffs for the appropriate catchment, purification and distribution of fresh water, and the subsequent collection, treatment and discharge of wastewater. Wastewater tariffs may be a fixed percentage of the water tariff, or they may be set separately.

Internationally, tariff-setting practices vary widely, and there is no consensus on which tariff structure best balances the objectives of utility, consumers and society (Whittington, 2002). It has been noted over time that water tariffs are often not high enough to cover the costs of the network and offer enough signals for the need for conversation to customers. This is also true for wastewater services. Rogers et al. (2001) argue that often, consumers are charged very little for the water and sanitation services they get. As a result, people are not aware of the real costs of providing water and sanitation services, due to the historically heavy subsidies from government. This is because water is a social good, and is considered to be a cheap and abundant resource. However, with rapid population growth and increased demand for safe, drinkable water, the availability of fresh water is decreasing dramatically in many regions of the world.

Rapid population growth, urbanisation, and economic growth in recent decades have increased the pressures on the urban infrastructure and natural resources such as sources of fresh water. These pressures are exacerbated by the extreme weather conditions around the world. Given these ever-increasing pressures, water tariffs are essential economic tools that if set at the appropriate levels could provide incentives to encourage sustainable water and sanitation behaviours. As the world's demand for water grows, fresh water and wastewater pricing becomes increasingly important. Because of water scarcity, countries around the world are reusing wastewater. This trend is likely to increase as more countries experience more severe fresh water shortages. Therefore, cost-reflective fresh water and wastewater pricing is vital for the viability of water utilities.

There are two types of water-tariff collection systems – combined (i.e. the water tariff includes a wastewater tariff) and separate (i.e. a dual water-service tariff structure). For most households, wastewater management cost is an external effect of fresh water demand. From the efficiency goal point of view, this cost should be incorporated into the potable tariff. From time to time, water and wastewater tariffs are revisited and adapted. This is the case in South Africa, where the Department of Water Affairs has issued revised guidelines for setting retail water and sanitation tariffs.

The rates for water and wastewater differ according to type of customer. A distinction is made between residential, commercial and industrial customers. Water charges vary widely across municipalities in South Africa. Most municipalities in South Africa have a two-tier water-billing system. A consumer is billed for the potable water that they consume or use, and also for the water they discharge into the sewer system (i.e. wastewater).

Increasing block tariffs are used to determine the consumption charge of portable water. As water use increases, the tariff shifts to the next block of consumption. The wastewater amount comprises two parts: a fixed charge and a variable charge. The former is fixed at a certain amount, depending on the value of the property. The discharged water is not metered; the assumption is that 75 per cent of potable water used by households is discharged into the sewer system, and that figure is used to derive the variable charge.

The South African Department of Water Affairs 2011 guidelines for retail water and sanitation tariffs suggest that decision-makers are in favour of the collection system. However, the rationale for a separate tariff for wastewater management is not adequately justified. To unravel arguments in favour of such a dual tariff system, the section below assesses what these tariffs entail, followed by a review of international practices around the world. Lastly, we assess whether there is any evidence to suggest that such a system is more beneficial.

3.2 The economics of wastewater

The spread of public services and social infrastructure has been an essential component in reducing poverty and inequality, especially in developing countries (Junior et al., 2012). Municipalities around the world have a mandate to serve the public diligently. Collectively, they face similar challenges – those of treating growing volumes and organically loaded wastewater produced by ever-increasing growth in population and industry. This is usually coupled with environmental pressures to improve plant performance and improve the quality of water, either for direct discharge or for beneficial water reuse applications (Williamson, 2007).

Understanding the process of water treatment can help to shed light on the economics of wastewater treatment. According to the OECD (2009a), it is vital to differentiate those services that benefit direct users primarily (e.g. potable water supply and sewage) from those that provide benefits to a larger pool of beneficiaries that extends beyond direct users to positive externalities (e.g. wastewater treatment has positive externalities downstream). Another important distinction lies between private and public goods, which gives rise to four categories of goods along two dimensions, based on two main characteristics:

- the degree of rivalry in consumption. Rivalry suggests that the resource has a scarcity value, and that there is a non-negative marginal cost in providing to an additional customer; and

- the degree to which users can be excluded from accessing the good or enjoying its benefits. This can be measured by the transaction costs that must be incurred to exclude possible beneficiaries.

As people will not be willing to pay for a good or service from whose fruition they cannot be excluded, the competitive market will provide insufficient quantities of public goods. While externalities can come about because of private and public goods, public goods always produce positive externalities for all users that cannot be excluded from their benefits. For example, the fact that downstream dwellers benefit from upstream wastewater treatment is a case of positive externalities. The question that arises is whether wastewater treatment could be a public (or at least quasi-public) good. While users can be excluded from being connected to wastewater treatment, this does not necessarily prevent polluters in the area with wastewater treatment from benefiting. On this basis, we conclude that this service appears to have some public good component (OECD, 2009a).

According to the OECD (2009a), an additional category that is also relevant for some water services is that of 'merit goods', the consumption of which has a 'general interest' dimension. This is also linked with the dimension of externalities. The consumption of merit goods is often below the social optimum, for two possible reasons. The first is because private consumers do not account for the positive consumption externalities. Secondly, individuals are myopic and maximise short-term utility, not taking into consideration their private long-term benefits. Some elements of wastewater services have important consumption externalities providing a complex set of benefits at community, regional and even national levels. An example would be basic sanitation services and wastewater collection, for which willingness-to-pay levels tend to be lower than their societal value, as households are unable to fully consider the additional community benefits that their use of these services entails.

An increasing number of countries around the world are experiencing growing water stress. One of the main drivers behind water stress is pollution emanating from increasing amounts of wastewater, because of rapid urbanisation. This is exacerbated by the fact that not all wastewater is treated, and from the contamination of aquifers from various sources. The result is that such water pollution reduces the amount of fresh water that is safe to use. Radcliffe (2003) argues that the costs and pricing mechanisms for wastewater are not transparent, as the true cost of potable fresh water is not reflected in the current prices. The main reason for this discrepancy is costs that are unaccounted for, and that the environmental externalities are not costed and internalised.

These growing demands must be satisfied with an aging infrastructure and reduced budget. User-fee increments are viewed as political suicide. However, public expectations for performance and service improvements continue to escalate – despite the universal push towards reducing taxes, and therefore municipal budgets. Capital investment in new infrastructure is particularly difficult to finance, and municipalities often find themselves unable to raise the required capital to build or maintain the facilities. These economic dynamics are particularly manifested in the public utilities department, and are particularly acute around wastewater treatment (Williamson, 2007).

A significant number of wastewater managers are of the view that treatment begins at the headworks. The collection system is deemed simply a way to transport the wastewater to the treatment facility. The capital and operation and maintenance (O&M) costs linked to the collection system can be a substantial portion of the utilities department budget. There are many hours – if not days – of residence time in the collection system that are non-beneficial to the treatment process (Williamson, 2007).

Despite improvements in water and sanitation availability, the great majority of people in developing countries must deal with very low coverage of wastewater treatment plants. This has serious implications in terms of spreading diseases and reducing well-being, especially for the poor. The main reason for this low coverage is the high investment cost of wastewater treatment plants (Junior et al., 2012). Considering rapid urbanisation and budget constraints in developing countries, wastewater treatment deserves greater emphasis. It is difficult to see how this low coverage could be significantly increased in the future, unless new, unconventional strategies are developed, and affordable wastewater treatment options are used. In developed countries, effective wastewater management is well established.

In OECD countries, access to safe drinking water and sanitation has been ensured to a large extent, following significant investment over many decades. However, to rehabilitate the existing infrastructure so it conforms to stringent environmental and health regulations, and to maintain service quality over time, substantial investments are required. In contrast, the challenges in non-OECD countries are daunting (OECD, 2009).

According to economic theory, 'economic efficiency' means resources are allocated such that production of goods and services for society is maximised. The overarching lesson from the economics literature is that to achieve more efficiency (and increase social welfare), prices in every sector of the economy should reflect the underlying structure of costs. In principle, there are three important categories of costs that tariffs in the wastewater sector should seek to reflect to enhance economic efficiency, for a mix of theoretical and pragmatic reasons. They are: total costs, marginal costs, and costs of a customer class. Wastewater tariffs should reflect these costs for a wide variety of reasons, including (Anstey, 2013):

- Tariffs that do not accurately reflect total costs (including depreciation, operational expenditure and return) may cause water utilities to run into financial problems, call on government funds, or hinder private sector involvement, which could increase the efficiency of the sector.
- Tariffs that fail to reflect marginal costs result in users not making efficient use of water services. The absence of marginal cost signals in pricing leads to over- or under-provision in the service from a social perspective.
- Tariffs that do not account for the costs of a customer class result in 'cross-subsidies' from other users, which hinder efficient competition or cause inefficiency in the sector.

Anstey (2013) goes further, to argue that the starting point for cost reflectivity for many regulatory regimes is that total revenue generated from wastewater tariffs reflects the total costs of the service. This principle is commonly referred to as the 'user pays principle', or 'full cost recovery'. Pragmatism is cited among the reasons for setting tariffs that reflect total costs. Tariffs that ensure full cost recovery remove the need for a government subsidy and ensure the viability of wastewater operations. In the current backdrop of rising costs in the water sector and the dire economic environment that places pressure on government funds, ending a government subsidy could seem particularly attractive to decision-makers.

According to Anstey (2013), in principle, tariffs that cover total costs do not have to increase economic efficiency in the short term. For example, if the costs of providing additional wastewater services are negligible, since the costs of the necessary infrastructure have already been sunk, it might be efficient in the short term to charge a price for water services that does not recover total costs. Most importantly, in the long term, crafting tariffs that cover total costs will tend to increase efficiency where:

- such tariffs create a conducive environment for private-sector investment in the provision of wastewater services, by establishing a precedent that costs will be recovered; or where
- simple charges are a first step along the road toward implementing more efficient pricing signals.

Only a few countries achieve full cost recovery through tariffs alone, even when considering supply costs alone. Recovering the cost of providing water services is a stated objective of many water utilities around the world. Banerjee (2008) argues that this includes most African water utilities, who report that their potable water tariffs are set with the goal of cost recovery. Only Chad reports that their tariffs are designed without any specified cost-recovery mandate. In the case of wastewater, no country requires covering of any part of the investment cost. According to the Federation of Canadian Municipal and National Research Council (2006), the United States of America, Australia and New Zealand have already legislated the need for full cost recovery at the municipal level. For instance, the Ontario government passed the Sustainable Water and Sewage Systems Act (Bill 175), which calls upon municipalities to quantify the full costs of their potable water and sewage systems, and then prepare a cost recovery plan.

Rehberg's (2010) survey of European countries shows that the water and wastewater prices are at the same level, with the assumption that the quality and performance levels are similar. The Swedish Water and Wastewater Association (2015) reveals that almost 99 per cent of the costs of capital and running are covered through tariffs in Sweden. This implies that the water business in that country can be regarded as self-reliant.

An assessment of other European countries reveals that the high quality of supplied potable water and wastewater has adequate costs, which in Germany are borne directly – almost to the full extent – by consumers. In Germany, 99 per cent of portable water costs and 96 per cent of wastewater costs are borne directly by the consumers. Measured at the available income, German consumers are paying almost the same amount or less for potable water supplies and wastewater disposal as consumers in Austria, England/Wales, France and the Netherlands. The comparison shows that the amount of the subsidies varies widely in the countries examined. Moreover, an assessment of the quality of supply and disposal – measured by parameters such as drinking water quality, degree of connections and rehabilitation rates of networks – suggests that they are significant differences despite uniform European directives (Rehberg, 2010).

There is no evidence to suggest, in developing countries and particularly in Africa, that the revenue generated through water tariffs comes anywhere close to full cost recovery. The tariffs are not even enough to cover operations and maintenance costs. Similarly, the World Bank (2011) indicates that in India, tariffs generally fall far short of recovering costs. Even inasmuch as they try to achieve this, the common practice is one of operational cost recovery, with tariffs that do not take capital costs into consideration.

The cost of ‘institutional’ components, as proposed by Cardone and Foreca (2003), is generally also not covered through tariffs. Policymakers seem to have difficulty in designing tariffs for cost recovery. The reason for this is that water pricing represents much more than a source of finance, both for decision makers and in the perception of the public. One of the challenges faced by policymakers in their crafting and implementation is reconciling the different policy objectives and dealing with the public’s opposition to tariff increases. A clearer comprehension of the potential conflicts between policy objectives, and more effective communication with the public regarding these matters, would go a long way towards helping reduce opposition to reform (OECD, 2009).

3.3 Survey of tariff setting around the world

Typically, water users – especially those in urban areas – pay more attention to the quality of drinking water and less attention to wastewater. This implies that users are more likely to be willing to pay for improved safe drinking water than for wastewater services, irrespective of the costs associated with the provision of the services. This complicates the issue of who should pay, since the value associated with the respective services seems to be independent of the costs.

Typically, potable and wastewater bills generally comprise a once-off connection fee (for having access to the service), a recurrent fixed charge, a volumetric rate which is multiplied by the volume of water consumed (in cases where there is a metering system), and in some cases a minimum charge that is independent of consumption levels for each period. Most importantly, the recurrent elements may take on different forms and combinations.

A 2007/8 survey of OECD countries on potable and wastewater tariffs reveals that there has been a continual increase in real prices – at times substantial – for household service, both in OECD and non-OECD countries, which may signal an increased role for tariffs in cost recovery. Other trends from OECD countries that emerged include a continued decline in the use of decreasing block tariffs and flat fee systems for household tariffs, in favour of a two-part fixed charge and variable fee, with either a uniform or an increasing block volumetric component. There are also increased applications of taxes to water bills. Last but not least, continued attention to social concerns is addressed through new, innovative tariff structures or parallel income-support mechanisms (OECD, 2009).

According to OECD (2009), dual water-service charges (i.e. separate wastewater charges) are increasingly being introduced to recover wastewater management costs. An OECD 2008 survey shows that some regions of Belgium (such as Brussels), Denmark, France, South Korea, Portugal, Spain, Sweden, Switzerland and Scotland have adopted a dual water-service tariff structure. The survey also revealed that most countries used the same tariff structures for wastewater as for the supply of potable water, often combining a fixed and a variable element. This was found to be the case in the Czech Republic, Finland, France, Hungary, Italy, Spain, Sweden, Northern Ireland and Scotland.

However, their levels and block structure generally differ from those of drinking water tariffs. In most cases, the variable wastewater charge is applied to the volume of water used (or a percentage thereof, as in the case of Northern Ireland), or a percentage of the variable water charge (OECD, 2009).

It was also established from countries that responded to the 2008 OECD Survey that most countries levy separate charges for sewerage and sewerage treatments, although in most instances the basis for charging remains water consumption with differences only in the size of the volumetric rates. In some instances, for example in Belgium, Denmark, Sweden and Italy, customers receive a combined bill for potable drinking water, sewerage and sewerage treatment services. In contrast, countries such as Australia, Canada, Finland, France, Germany, Hungary, South Korea, the Netherlands, the United Kingdom, and the United States of America have adopted separate invoices, or separate information on one single bill (OECD, 2009).

3.4 Is a separate tariff system more beneficial?

The rationale for a dual tariff system for potable water and wastewater services are is twofold. The first reason is that each tariff sends a signal to consumers of the different costs and importance associated with each service. Consumers generally demand high-quality water and sanitation services. However, while they might be aware of the costs of providing high-quality potable water services, generally they are not aware that sanitation services have costs of their own and must be provided at an increasingly higher standard because of their associated health implications.

Secondly, each tariff provides consumers with an incentive to use water conservatively. In cases where they are aware that higher consumption results in higher charges, consumers may adjust their behaviour to lower their utility bills and thereby conserve water. To be more specific, if the collection system separates the potable water bill from the wastewater bill, consumers become aware of the costs of each service and are therefore able to influence their bills accordingly. However, the ability of consumers to influence their bills under a dual tariff structure depends largely on the way the wastewater bills are generated.

If, as is the case in South Africa for potable water, a two-part wastewater tariff is implemented comprising a fixed charge and a variable charge, such that the fixed charge is based on the value of the property and the variable charge assumes that 75 per cent of portable water used by households is discharged into the sewer system, there may not be an incentive to reduce wastewater – unless wastewater discharges are metered. Since the consumer’s wastewater bill is generated before they even discharge, in a way consumer are discouraged from investing in water-recycling technologies, reusing grey water or harvesting rainwater.

In this regard, it has been noted that metered services (charges based on volumes of disposal) provide a fairer means of distributing the costs of supply, encourage conservation, and measure the flow of wastewater as well as supplying information on consumption that can be used in the design of more efficient tariffs. Conversely, the disadvantage with basing tariffs on property values is that for each additional unit of water consumed at a price that is below the cost of providing the additional unit, the consumer's consumption has the effect of raising the bills of all other consumers, i.e. the consumer does not pay the full cost and so the shortfall is recovered from others. In addition, researchers in other countries have found that the property-based system does not help low income consumers efficiently, or provide incentives to save water, especially to consumers who live in high-value properties but consume very little water. Furthermore, poor households that were unmetered were found to be facing increasingly large bills – more than metered households – as the sizeable cross-subsidies in property-based systems are eroded (Walker, 2009).

Notwithstanding the benefits outlined, however, it is noted that metering requires a meter to be fitted to the customer's pipeline and then read periodically, which may involve additional costs compared to a non-volumetric system. However, this disadvantage may be offset when households who use more water pay more and when those who pollute more (through discharging wastewater) pay more. It is further noted that the assumption that 75 per cent of the potable water consumed by households is disposed of as wastewater holds true for most countries (Walker, 2009).

Consequently, the 75 per cent wastewater assumption used in South Africa is in line with these findings. However, the 75 per cent discharge of potable water as wastewater is not positively correlated with the discharge and treatment costs. Given the need to expand both potable and wastewater systems, and the fact that substantial capital is required, it is critical to introduce a dual system that recovers as much of the cost from consumers as possible. Such a system would make consumers aware of the costs incurred by each respective system, which should make them less resistant to increased charges.

3.5 Summary

Growing water scarcity due to global warming, rapid urbanisation and growing economies – particularly in developing countries – is focusing the minds of policymakers on the problem of water pricing. Most efforts have been directed at fresh (potable) water pricing, with less emphasis on wastewater pricing. However, in the current situation, where freshwater is becoming increasingly scarce and large volumes of wastewater are not treated (particularly in emerging and developing countries) and are polluting freshwater sources, the wastewater must be treated.

In a scenario where there are insufficient funds to maintain and expand both potable and wastewater infrastructure, it is becoming increasingly critical that pricing for both potable and wastewater reflects the full costs. Setting the tariffs of water and wastewater at the correct level and adopting the right water tariff collection system is vital to supporting sustainable water and wastewater services and enhancing efficient resource allocation and conservation.

As developing countries such as South Africa face increasing maintenance and expansion costs to sustain increasing household, commercial, and industrial demand for water services, it has become crucial to consider pricing water services under a dual water-service structure. Under such a system, wastewater would be billed separately and characterised by a two-part bill comprising a fixed charge and a variable component, as is generally the case with potable water billing.

CHAPTER 4: AN ASSESSMENT OF TWO ALTERNATIVE BALANCING OPTIONS FOR REVENUE COLLECTION

4.1 Introduction

The issue of the financial sustainability of water service providers such as municipalities is nothing new. How a water system prices its services is crucial, as it impacts on the long-term sustainable management of water resources. Both public water utilities and private water utilities pursue common financial and non-financial objectives. According to Hughes and Leurig (2013), these objectives are influenced by a wide variety of factors, which include among them the following:

- Financial requirements
- Public policy goals
- Ease of implementation
- Political constraints

This study focused on the financial factors. Setting the right price, one that reflects the true value of water, is clearly not an easy task. Nonetheless, it is crucial, for both the effectiveness and the integrity of the water pricing system. Hughes and Leurig (2013) argue that pricing is one of the primary instruments used by water-service utilities to balance their budgets. The most commonly promoted pricing methodology is the 'cost-of-service' approach, which basically aims to collect the revenues required to meet a utility's financial goals. Although most large utilities use this approach, the practice is far from universal, particularly among smaller utilities.

Pricing must be set to cover the cost of operations and capital programmes, but also to cover the costs of funding those improvements. Most large systems rely heavily on debt to fund capital programmes that exceed available funds on hand. For this reason, their ability to honour debt payments is a critical indicator for market participants. Debt services coverage is arguably the main driving financial indicator for utilities that rely heavily on capital markets for their operations and investments, and it plays a vital role in the quantitative analysis conducted by rating agencies. Furthermore, the pressure placed on utilities by investors to generate specific amounts of revenue dictated by loan agreements and bond covenants can be excessive. Therefore, a utility may be quite gratified to collect enough internally generated revenue to meet its basic cash expenditure requirements, without relying on external finance that usually has strenuous conditions attached (Hughes and Leurig, 2013).

Yet the South African water sector does not have a widely divergent balancing option for revenue collection to cover the costs of municipal provision of water services completely. While the water sector in South Africa does not have divergent pricing, or models competing to establish an altogether new pricing model, examples of innovation are surfacing, due to technological advances, shocks and business disruption trends such as droughts and continued increases in temperature, resulting in a higher rate of water evaporation. In almost all South African municipalities, water tariffs comprise a fixed charge (or service charge), which is paid independently of water consumption, and a variable component paid progressively, according to blocks of consumption – unit prices increase as consumption increases.

Despite the similar rate structure, there is (for example) tremendous variability in the way these structures apportion fixed costs, the proportions of revenue and customers that fit within each tier, and the pricing difference between tiers. As a result, the sector standards may give an analyst relatively few guidelines for evaluating the revenue implications of a rate structure. Most importantly, there are imbalances in the different circumstances between cost-recovery sources and options for water-service provision.

4.2 Financial sustainability and cost recovery in the water sector

From the perspective of financial sustainability, an optimally operating utility is one that can cover the full cost of services. Specifically, tariffs faced by water consumers should at least return revenue equal to the cost of supply (Dole and Bartlett, 2004). If the cost function faced by the supplier is perfectly known, then – for those services that can be accurately measured in volumetric terms (e.g. water, electricity, water-borne sewerage) – cost recovery is achieved by charging end-users the (full) short-run marginal cost of production, plus a portion of long-term operating and maintenance costs.

Financial sustainability in the water sector specifically refers to the adequacy of revenues for meeting operations and maintenance (O&M) costs and capital costs. O&M costs can be funded through (McPhail, Locussol and Perry, 2012):

- charges for water and related services (operating revenues); or
- government subsidies (non-operating revenues).

Capital costs can be financed from:

- cash surpluses generated from operations; and
- long-term debt and/or development grants.

There are almost no examples in developing countries of water-service providers whose operating revenues are significantly below O&M costs but are nevertheless able to develop and maintain their infrastructure and still supply reliable and efficient services. This is because the financial sustainability of water-service providers relies heavily on the predictability and stability of revenue. The most predictable and stable source of revenue in developing countries is the utilities' clients – provided, however, that they have access to the infrastructure and a service of acceptable quality. Government budgets, on the other hand, are subject to many restrictions, and external 'donor' programs are subject to an even wider range of constraints, and so cannot be considered predictable and stable sources of funding (McPhail, Locussol and Perry, 2012).

Given that a significant proportion of the population in a developing country does not have access to a piped water network, utilities in these regions have a great opportunity to improve their financial sustainability by increasing their customer base. This is critical to sustain the viability of the water sector in developing countries. To achieve this, water utilities should expand their piped water system, which requires significant capital injection and the implementation of cost-recovery pricing. Cost recovery for water utilities refers to the ability to cover total costs (financial, environmental and resource costs) from its revenues.

Environmental cost reflects the damage that water users impose on the environment and ecosystems, while resource cost reflects the value of forgone opportunities that other users suffer due to the depletion of the resource beyond its natural rate of recharge or recovery (WATECQ, 2003). Furthermore, the pricing should be incentive compatible. Despite the growing awareness of a need for cost reflective pricing, many utilities around the world are yet to fully implement this pricing regime.

The cost structures faced by water providers are complex and involve many integrated production and supply processes. The supply of water to urban communities consists of a variety of complementary actions, from abstraction to delivery and billing. Jooste (2008) groups these activities into two broad concepts: 'direct' and 'indirect' provision. The direct provision of water services entails the physical provision of the water, including the activities of abstraction from the water source, purification, carriage, storage, delivery, billing and payment collection. In addition, it includes operations and maintenance (and capital improvements) to keep the supply system running. Direct primary costs incurred by utilities comprise infrastructural capital costs such as the building of dams, pipelines and delivery systems. The indirect costs comprise activities that support the physical delivery of water, such as legislation, policymaking, standard setting, regulation and monitoring. Taking the cost functions of local municipalities as given, questions of cost minimisation are not relevant to the investigation of cost-recovery solutions for public utilities for the purposes of this study.

This study therefore considers only the demand-side water-pricing options for revenue collection to recover the costs of providing water services. As already indicated, water-service providers must be able to recover both their operating and maintenance and infrastructure investment costs. According to McPhail et al. (2012), there are two main principles to be followed to ensure enough revenues for cost recovery:

- Revenue generated must be enough to cover the utility's 'cash needs', i.e. its O&M costs and the repayment of the principal and the interest on its loans. Revenues are therefore directly affected by the capital structure of the service provider – if all investments are financed by grants, cash needs are limited to O&M costs. This way of estimating revenues, based on cash accounting, is mostly consistent with the vision of service providers using cash-based budgets, such as government departments or water-user associations.
- Revenue generated must be enough for meeting 'utility costs', i.e. its O&M costs, the depreciation of its fixed assets and a return on assets adequate to service the debt and remunerate the equity invested. In such cases, revenues are not directly affected by the

capital structure, and translate the principle that investments must be recuperated with a profit to cover the financing costs, whether debt or equity. This approach of estimating revenues, based on accrual accounting, is consistent with the vision of water utilities managed as corporate entities, whether public or privately owned.

According to McPhail, Locussol and Perry, (2012), in practice, since cash costs are covered, the cash-needs approach can be considered financially sustainable in the short term. However, it perpetuates the water-service provider operation's reliance on debt and (if applicable) on development grants, as it does not permit building up cash reserves to safeguard the utilities operation against external shocks. Moreover, it translates into the need for steep tariff increases every time a lumpy investment is to be financed. One way to address this is to limit the share of debt financing, and to request the water-service operation to contribute to the financing of its capital expenditure programme from cash reserves.

To illustrate the dangers associated with the 'cash needs' approach, we refer to a study by Fall et al. (2009) that uses Cote d'lvoire as a case study. Up until the mid-1980s, rapid expansion of the water service sector of Cote d'Ivoire under the Department of the Central Government was funded exclusively by debt. The water tariff was reset every four years for meeting future O&M costs, i.e. the costs of the contract with the private operator, and for repaying sectorial loans. The National Water Fund, which was responsible for servicing the debt, was replenished by the difference between the tariff paid by the customers and the tariff that SODECI (the private operator) was permitted to retain on its collection from clients to cover the costs of its contracts. When the exchange rate to the US dollar (in which a large share of the debt was denominated) appreciated steeply against the domestic currency, and there was a slowdown of the economy resulting in lower sales to large industrial clients whose water bills were the main contributors to the National Water Fund, this was inadequately replenished and unable to service the debt. The water-service sector was hit by a major financial crisis, despite having been operated by an efficient and profitable private operator since the late 1950s.

The financial recovery programme, supported by a Bank-financed Water and Sanitation Adjustment Loan, was particularly based on (Fall et al., 2009):

- a restructuring of the sectorial debt still to be serviced by the National Water Fund;
- a relocation of the sector roles, with the operator becoming responsible for identifying and implementing the capital development programme; and
- revised sectorial financing regulations, with future capital spending being strictly limited to what could be funded from cash surpluses generated by operations.

Despite the latter constraint, the operator (SODECI) managed to significantly increase the size of its customer base from 200 000 to 550 000 from 1988 to 2006. This was achieved by focusing the capital development programme on extensions of distribution networks, and by subsidising the cost of the new connections provided to low-income households.

In contrast to the approach discussed above, the utility-cost approach aids in building up cash reserves, limiting dependency on debt, and protecting the water-service provider against unforeseen shocks. A few Bank water service projects have now included a return on fixed assets in operation clause in their financing agreements. Nonetheless, to be meaningful, this clause requires that fixed assets are sufficiently valued. If this does not hold, then they may have to be revalued; if fiscal regulations do not permit it, the revaluation would have to be carried out on a *pro forma* basis. This is partly why this type of covenant is seldom used. Moreover, depending on the rate of return sought, this approach may result in an accumulation of large cash reserves, giving the impression that the water-service operation is making extraordinary profits. The risk of the cash being diverted for purposes other than water-service provision is high, especially in cases of public water utilities (McPhail, Locussol and Perry, 2012).

McPhail, Locussol and Perry (2012) argue that another potential issue with this approach is the discrepancy between the average depreciation periods of water-service fixed assets (typically, 25 to 40 years), and the maturity of debt available in most developing countries for funding infrastructure investments. Under this model, depreciation of fixed assets may not be enough for repaying the loan principals and thereby meeting cash needs. This implies a ‘hybrid’ approach, in which revenues are estimated to be adequate to cover O&M costs, the debt service (principal and interest), the depreciation of equity-financed assets and a return on equity, allowing cash needs to be satisfied and cash reserves to be built (McPhail, Locussol and Perry, 2012).

What is the cost of poor collection? Income statements for water-service providers report billing, not collection, as operating income. There are two kinds of unpaid bills a utility must typically deal with (McPhail, Locussol and Perry, 2012):

- those that would never be recovered, no matter what, and for which a ‘provision for bad debt’ must be listed as an operating expense. In the water service operations where private and public clients are used to paying their water bills, even with some delay, the provision for bad debt can probably be limited to 1 to 3 per cent. In water operations, where certain types of clients are known to be recurrent defaulters – such as government agencies in most African countries – it may have to be much higher.
- those that would be recovered with some delays, and for which the utility must provide additional working capital for maintaining a positive cash position. Working capital variations are reflected in the cash-flow statement, not in the income statement.

For estimating revenues required for meeting cash needs, it is thus prudent to add the following to the utility’s O&M costs, debt repayment, and if applicable, cash contribution to the Capital Expenditure Programme:

- a ‘reasonable’ provision for bad debts; and
- the need for funding variations of the Working Capital Requirement (see Niger case, below).

4.3 When collection does not cover cash needs

When current collected revenues are inadequate to cover cash needs, the priority should be on agreeing a financial recovery plan for the revenue-earning entity to which the financing is extended. The plan could combine the following (McPhail, Locussol and Perry, 2012):

- reducing operating costs, especially in staff and energy costs;
- increasing sales revenues by adjusting tariffs and expanding the customer base;
- improving collection through targeted incentives;
- injecting additional equity by shareholders; and/or

- restructuring the balance sheet by writing off uncollectable arrears and forgiving, freezing or rescheduling existing debt.

A significant number of public-private partnerships (PPPs) have attempted to provide an answer to the points above (and have often succeeded) by outsourcing technical and commercial operations to private operators. When the quality of the service is still not good enough, but is improving gradually, two difficult political decisions must be taken into consideration when crafting a financial recovery plan, regarding (McPhail, Locussol and Perry, 2012):

- the pace of water-service tariff increments; and
- the enforcement of bill payment.

The ‘common sense’ approach – which entails waiting until the quality of the service has improved before charging cost-recovery tariffs, and disconnecting customers in arrears – often does not work. Therefore, enhancing the quality of the water service (e.g. increasing the number of hours per day during which water is available) always takes many years; and when it is finally felt that customers may be willing to accept paying cost-recovery tariffs, the magnitude of the increase needed often makes it politically impossible to implement.

Fall et al., (2009) looked at the case of Guinea (Conakry), where a transparent subsidy scheme was adopted to support regular tariff increases while improving the quality of the service. In the late 1980s, Guinea undertook an ambitious reform of its urban water-service sector, based on:

- outsourcing of the technical and commercial operations to a private operator (SEEG) within the framework of a 10-year afterimage (lease) contract with the public asset holding company SONEG; and
- a gradual move towards full recovery of O&M and capital costs from user fees.

The full cost of water estimated at around GF400/m^3 (equivalent to US$0.80/m^3) had to be compared to the GF60/m^3 customer tariff that was applicable before the mobilisation of SONEG and SEEG. The government agreed to increase the customer tariff immediately to GF150/m^{3,} a level adequate to cover SEEG’s operating expenses in local currency and make a limited cash contribution to SONEG's capital budget. Furthermore, the government also requested funds from the World Bank to fund 100 per cent of the foreign exchange component of SEEG's tariff for four years, and a gradually decreasing share of it for six more years, so that after ten years SEEG's tariff would be fully covered by collections from customers.

This support was to be paid based on the actual amount of collection of water bills by SEEG, so that the latter would obtain the tariff indicated in its bid for each cubic meter of water billed and collected (this is a good example of 'output-based' financing). The government finally agreed to service 100 per cent of SONEG's debt for two years, and then to gradually decrease its support so that the debt would become fully serviced by SONEG after six years. This move towards cost recovery was bold but was nevertheless implemented even more rapidly than initially anticipated. After seven years, revenues from customers were enough to cover O&M, depreciation and financing costs, and to contribute to cash for SONEG's Capital Expenditure Programme.

4.4 Governance structure for water-service provision

Governance for water and sanitation services is generally defined by the Global Water Partnership as the "range of political, social, economic and administrative systems that are in place to craft and manage water resources, and the delivery of water services, at different levels of society" (Garcia and Quesada, 2011).

The governance framework of a country's water sector (understood here as the administrative levels of policy and the legal framework regulating utility ownership) plays a vital role for the important issues discussed in this report, i.e. water pricing and cost recovery. While in theory, similarities exist in the legislation and tenets of water governance, the individual characteristics of each administrative model may combine to yield different outcomes. For example, while a country may establish a decentralised administrative structure for its water to provide (inter alia) quicker responses and adaptation to local conditions and needs, this choice does not necessarily guarantee that priorities are dependent on the success of national and international objectives (e.g. compliance with the WFD) – particularly when the effects may not be welcomed by the local population. Similarly, it can be expected that boards of directors in private enterprises will have different interests and drivers to the decision-makers in public water utilities. Therefore, focus may be skewed either towards the recovery of costs and profit maximisation, or in favour of socio-political matters (EEA Technical Report, 2013).

Administrative levels of decision-making in the water-provision sector are generally homogeneous in many parts of the world. In most cases, they follow a framework in which policy made at national level puts in place the rules for water-service provision, followed by local or municipal governments providing services or regulating private utilities (EEA Technical Report, 2013). South Africa follows this framework, with the Department of Water and Sanitation (DWS) as a policy leader, and Water Services Authorities and Water Service Providers (WSAs and WSPs) – which includes municipalities – following the policy-leader's framework. The EEA Technical Report (2013) points out that there are exceptions to this; for example, in Scotland, where the sole public utility, Scottish Water, operates on a national scale and is overseen by a national body.

The importance of regional authorities in policymaking (for example, in crafting economic instruments) varies widely in some parts of the world. Germany exhibits somewhat more independence at the regional level, permitting states to determine how water prices should be calculated to consider the issue of cost recovery, while other national governments play a more concrete role. For example, in Slovenia, the government sets the rules for tariff calculation in addition to a price ceiling. There are cases in which the restructuring of a country's administrative framework for the provision of water services will depend on its specific characteristics, such as environmental and economic (e.g. funds available for the development of the water sector) conditions (EEA Technical Report, 2013).

According to Quesada (2011), when looking in more detail at the governance of price-setting mechanisms, three main approaches are identified in the literature:

- Regulatory agency approach: a national independent body is responsible for setting a price cap on the maximum bill increases allowed.
- Bilateral contract approach: a local authority such as a municipality delegates water provision to a third party by means of a contractual agreement, which establishes the terms for service provision, including the charges imposed on customers and the level of service they will receive.

- Self-regulatory approach: in some cases, the procedures for setting water prices and customer standards can be defined by the same authorities as those responsible for supplying the services, such as municipalities. Generally, national regulators establish the minimum requirements for service provision, but the responsible authorities retain wide-ranging discretionary powers in the definition of water prices and in standard-setting.

It must be noted that depending on the administrative structures put in place in each country, some countries adopt only one approach; whereas in other countries, two approaches can coexist (Quesada, 2011). For example:

- In England, Wales and Scotland, prices are set exclusively through the regulatory agency approach.
- In the Netherlands, only the self-regulatory approach is applied.
- In France and Spain, the bilateral contract approach and self-regulatory approach coexist.

South Africa follows a self-regulatory approach, with the policy leader (the DWS) setting pricing guidelines for all water-service providers. According to Gowlland-Gualtieri (2007) and the Department of Water Affairs and Forestry (2004), the legal and policy framework of the water-services tariff structure in South Africa is based on the constitutional recognition of the right of access to water. Everyone has the right to have access to enough water (Bill of Rights, Constitution of South Africa, Section 27(1)(b)). This right, formally recognised at constitutional level, both allows for physical and economic access to water, and underpins the law and policy framework for water in South Africa within which water supply, sanitation services, and water use takes place.

4.5 Theoretical literature

4.5.1 Monopoly market theory

The governance structure detailed in chapter 5 shows that South African water tariffs are not set endogenously through the interaction of demand and supply, but within a constitutionally mandated monopoly market setting. In such a market setting, a single supplier serves an entire market. Pure monopoly water supply and sanitation service providers are created as a matter of law rather than as a matter of economic conditions. The risk of not legally enforcing a monopoly market structure is that the industry will not organise itself in the desired way.

The argument usually put forward in favour of creating these franchised monopolies is that the industry in question is a natural monopoly, and that the minimum average cost in the industry can be achieved only by organising the industry as a monopoly. The water supply and services sector in South Africa is also a natural monopoly. Production processes and activities required to supply water and related services are very capital-intensive. Moreover, the capital assets used in water supply cannot be moved to another location and are generally unusable for any other purpose (le Blanc, 2007; Snyder and Nicholson, 2012; Stigler, 2008).

The traditional models of cost recovery and price determination for a monopoly do not quite apply to public utilities involved in the provision of water supply and services. Because of the increasing returns compared to scale of water production and services, it is typically the case that long-run marginal costs are less than long-run average costs. A well-known but very important consequence of this feature of the production technology is that – supposing it were possible to precisely define a 'marginal cost' that customers had to pay, one-part tariffs based on marginal costs would not allow the utility to break even, since marginal costs are lower than average costs. Hence, municipality water providers tend to produce structural deficits.

This feature is at odds with the objective of cost recovery needed for the long-term financial sustainability of supply and service delivery. Theoretical solutions to this problem have long been known. They involve departing from the traditional monopoly theory, which assumes a single-price policy for its supply. Selling identical goods at different prices to different customers is called price discrimination. The tariff system is therefore the mechanism that should bring about efficiency in terms of cost recovery and price determination (le Blanc, 2007).

4.5.2 Price discrimination strategies

4.5.2.1 Second-degree price discrimination, IBT strategy, and the principle-agent model

Economic theory suggests that differential price schedules that include options targeting each type of customer are a form of second-degree price discrimination. Thus, a monopoly supplier can extract the maximum surplus possible from its customers, and so is able to at least reduce the deficit, if not to achieve full cost recovery (Snyder and Nicholson, 2012).

The uniform (linear) and increasing block price (non-linear) tariff schedules applied by all local government municipalities is one of three forms of price discrimination strategy explained by Snyder and Nicholson (2012), namely second-degree price discrimination through price schedules. An application of a simple macroeconomic model of asymmetric information called the hidden-type principal-agent model can be used to analyse the behaviour of market participants in monopoly markets under conditions of asymmetric information and will be used to represent the municipal water supply sector for the purposes of this report. In the municipal water supply sector, the customer represents the principal and the municipality represents the agent. In the hidden-type model, the agent has private information about an innate characteristic they cannot choose.

The agent is a party with information who acts on behalf of the principal, ordinarily with reference to their own utility function. If the utility function of the supplier municipality is translated to reflect cost recovery, and it is assumed for the purposes of this study that the supplier municipality has perfect information concerning the actual cost incurred to supply the good or water services, then the model can be used to determine the efficiency of the price structure in terms of cost recovery (Snyder and Nicholson, 2012).

The hidden type model is relevant to the water supply and services market in South Africa, because municipalities exercise total market power, as they are monopolies. Consumers need the water supply and related services provided by the municipalities, as there are few substitutes for retail water and sanitation services. Although consumers place a subjective value on water supply and related services provided by municipalities, they have very little power to influence the price of the supply. The nature and necessity of retail water and sanitation services ensure that consumers pay the market price for the good, regardless of the value they attribute to the supply, if the market price is not too much higher than the value they attribute to the supply. The hidden-type model is therefore relevant to this study.

Unlike the simpler linear two-part pricing policy of second-degree price discrimination, which allows consumers to buy as much as they want at a constant and stated price, non-linear pricing structures provide customers with a price schedule of different-sized bundles at different prices, from which the consumer makes their selection. One limitation of applying the model to the municipal water supply sector is that in the case of water supply and services, the principal's type is not completely hidden, in that they are forced to select the option targeting their type, which violates one of the fundamental assumptions of the model. Consumer classes and price schedules are specified. The only factor that the customer can directly determine is the quantity of water they choose to consume over any given period, which is also limited to what is needed for basic living. Consequently, though the traditional confines of the model limit the possibility of the agent extracting more of the principals' surplus, the restriction above imposed on customers creates an opportunity for monopoly municipal water suppliers to extract more if not most of the consumer surplus.

4.5.2.2 Alternative pricing solutions for cost recovery: third-degree and first-degree price discrimination strategies

The other two forms of price discrimination strategy are third- and first-degree price discrimination (Snyder and Nicholson, 2012). Unlike second-degree price discrimination, in which demanders differentiate themselves depending on how much they wish to buy (according to a price schedule), third- and first-degree price discrimination requires the monopoly to separate demanders into a few categories, and then choose a profit-maximising price for each such category.

First-degree price discrimination imposes a considerable information burden on the monopolist, as it is possible only if each customer in the market can be separately identified and traded with by the monopolist. The application of a first-degree price discrimination policy is not a possible strategy for municipality water providers.

A less stringent requirement would be to assume the monopoly could separate its buyers into relatively few identifiable markets and pursue a separate monopoly pricing policy in each market. This is known as third-degree price discrimination through market separation. Knowledge of the price elasticities of demand in these markets is enough to pursue such a policy. The monopoly then sets a price in each market according to the inverse elasticity rule[2]. Assuming the marginal cost is the same in all markets, the result is a pricing policy in which:

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[2] See Snyder, C. and Nicholson, W. 2012. Microeconomic Theory: Basic Principles and Extensions. 11th edition. Pp. 451-454.

$$P_i \left(1 + \frac{1}{e_i} \right) = P_j \left(1 + \frac{1}{e_j} \right) \quad (3)$$

or

$$\frac{P_i}{p_j} = \frac{(1 + 1/e_j)}{(1 + 1/e_i)},$$

where Pi and Pj are the prices charged in markets i and j, which have price elasticities of demand given by ei and ej (Snyder and Nicholson, 2012).

Figure 1 illustrates the result for two markets that the monopoly can serve at a constant marginal cost.

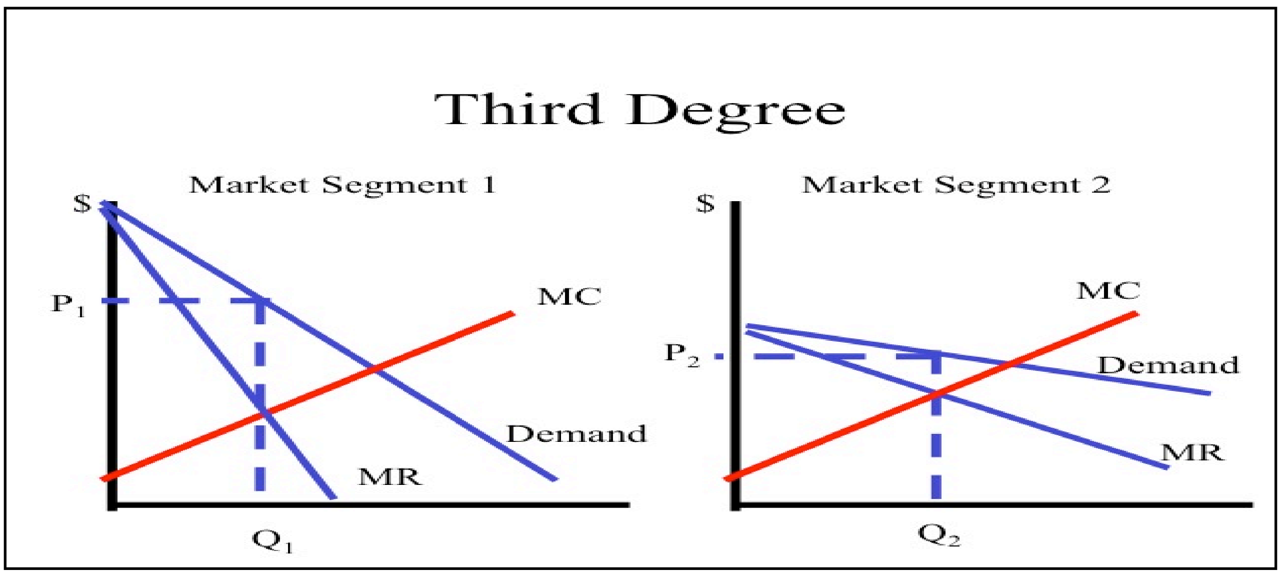


*Figure 1: **Third degree price discrimination***

Source: BYU IDAHO, 2018

An immediate consequence of the third-degree pricing policy is that the price will be higher in markets in which demand is less elastic. For example, if ei = -2 and ej = -3, then the first equation shows that Pi/Pj = 4/3. Prices will therefore be one third higher in market i, the less elastic market. A better understanding of elasticities is essential for designing tariff rates and better comprehension of the effects of tariff rate adjustments on water usage and sales revenue.

The welfare consequences are ambiguous in such a situation, as changes in differentiated segments have an offsetting effect on the allocation efficiency of resources in the sector. As a third-degree pricing policy requires raising the price in less elastic markets compared to more elastic ones, increases in output and allocation efficiency in one segment of the market sector may be offset by a decrease in another. The complexity of the relationships between inter-sector segments are multiplied the more differentiated the market becomes. A more complete analysis suggests that the multi-price third-degree price-discrimination policy will be allocatively superior to a single-price policy only in situations in which total sector output is increased (Snyder and Nicholson, 2012).

Previous analysis addressing the topic of the price elasticity of water demand suggests that water demand is inelastic (Olmstead, Hanemann and Stavins, 2005). The results also suggest that price elasticity of water demand is higher under increasing block prices than under a linear or single-pricing policy. If this is true, it implies that consumers exhibit a demand response to the shape of the supply curve, being the price structure, and not simply its height or the magnitude of marginal price. If consumers react to price structure as well as to the magnitude of marginal price, there may be a behavioural explanation for their demand responses. In such an environment, it will be possible for the monopolist supplier to effectively implement a third-degree price discrimination policy.

Various alternative conditions for consumer welfare (surplus) to be maximised can be identified; e.g. equalising the marginal benefit of attribute variation. Hosking and Jacoby (2013) have pointed out that to maximise compensated variation requires tariffs to be set inversely with the absolute value of own price-demand elasticity, in accordance with Ramsey's (1927) rule.

4.6 How current water pricing performs in South Africa – shortcomings of the second-degree price-discrimination IBT strategy

The second-degree price-discrimination IBT structure recommended for households is linked to what one could describe as an adjusted average cost; this being the average cost of supplying that portion of the water service from which revenue should be derived, after allowing for other income and expenditure flows (including transfers). The primary objectives of the IBT structure are to raise revenue and to cross-subsidise the cost of consumption of low-income households. The guidelines recommend that initial water service demand, termed basic demand, be satisfied at a tariff lower than the adjusted average cost reference value.

The motivation provided for this low (perhaps zero) tariff is that the law and/or policy and/or ethics prescribe or favour individual rights to a (necessary) minimum supply of water service. The guidelines recognise that these individual household members dwell in household clusters, and accordingly interpret these rights as imposing an obligation or social responsibility on WSPs to satisfy basic demand to the household clusters, perhaps irrespective of these households' willingness to pay. As stated in the Water Services Act (Act 108 of 1997), municipalities can use water tariffs as a cost-recovery tool. Although they need to recoup water provision costs, municipalities are obliged by the Free Basic Water Policy of 2002 to provide at least 25 litres per person per day of free basic water, within 200 metres of where the person resides and at a flow rate of at least 10 litres per minute (DWA, 2002). Water-services tariffs will then be levied for any subsequent water consumption over the free basic units.

However, both Hosking and Jacoby (2013) and Whittington (2012) are unconvinced by the merits of the IBT structure, stating that its claim to favour the poor does not stand up to scrutiny, that expectations and estimates of own price demand elasticity for water services are inconsistent with the revenue collection objectives, and that in practice, the structure is randomly designed and neglectful of efficiency and consumer welfare. However, the validity of their arguments under South African circumstances is questionable, given that the tariff for the first block of many municipal IBT structures is zero (free), thus ensuring that in practice, income is no obstacle to receiving the first block allocation (often 6 kl per billed entity per month).

Above a basic level of demand, the guidelines to the IBT become progressively more ambiguous. The application of increasing block tariff structures presents a few problems, the most important of which are the size and price of each block. The guidance provided by the DWA (2011) recommends that water-service tariffs rise incrementally for households, peaking at a maximum equivalent to the marginal cost of supply, and that marginal cost also serves as a reference for the tariffs applied to commercial and other institutions.

However, the guidelines do not identify which marginal cost is being referred to. Their advocacy of the goal of efficiency implies that short-run marginal cost is the reference, but their advocacy of ecological sustainability suggests the extra cost of new water supply schemes – i.e. long-run marginal cost – is the reference. Boland and Whittington (1998) point out that one of the biggest challenges in setting a tariff on water is deciding whether to price water by its average cost based on the financial reasons of cost recovery, or by its marginal cost based on the economic reasoning of promoting an efficient use of the resource.

A related confusion is how the cost-recovery goal could be achieved through marginal cost pricing; a challenge also frequently referred to in the relevant economics literature (Varian, 2003). The costs incurred by the municipalities to provide water services are mainly of a fixed nature. This implies that as more water is supplied, the (marginal and average) cost per unit of water supplied decreases, a result of significant economies of scale (Gibson, 2010). When the capacity of the infrastructure is fully exploited, marginal cost and average cost will tend to equate. For this reason, if only the highest tariff in an IBT structure is set equal to the marginal cost, it follows that full cost recovery through tariff revenue collection cannot be achieved (Varian, 2003). As would be expected, given the ambiguity in the guidelines to the IBT, a high degree of arbitrariness has evolved in how South African municipalities design their IBT structures (Hosking and Jacoby, 2013).

4.7 Fixed and water usage tariff revenue

At first glance, the question of revenue stability looks simply: are the water tariff rates that are set generating adequate revenue for the utility to recover costs? Water service providers around the world use a wide range of tariff structures (Tucker, 2016). Water and wastewater utilities most commonly generate revenue by imposing rates against the customer's water use. When setting these rates, utilities balance multiple and often conflicting objectives. With their respective rate structures, most water providers try to collect enough revenue for operations and system investment, and to encourage the efficient use of water while maintaining affordability for basic levels of consumption (Tiger, 2012).

The underlying components of all water providers are the water rate structures that have a base charge (fixed charge) payable irrespective of consumption levels, or a variable charge that is dependent on how much water the customer uses. Often, the revenue budgeted for by water utilities, and thus their rate decisions, comes disproportionately from the variable side of the ledger, thus keeping the base charge low. This may assist low-income customers (who use small amounts of water) to afford water services (Tucker, 2016).

However, on the expense side of the water provider's budget, a typical water utility will usually have a disproportionately large share of expenses that are fixed (e.g. salaries, metering and debt service on loans), rather than variable expenses (e.g. chemicals for water purification). The difficult question that arises is: what happens when there is a disruption to water sales? Revenues may decline substantially, while expenses decline marginally. This will obviously put the water utility in a very difficult financial position, at least temporarily – or for multiple years, such as in the recent severe drought conditions experienced in the western United States (Tucker, 2016).

This concern also applies to the South African water sector. The country is going through a period of drought, and with (deliberately) very low fixed charges intended to accommodate the population's poor majority, the water providers face great financial risk. For this reason, cost allocation and tariff setting present the biggest challenge to South African municipalities. According to Beecher (2010), once a utility's annual cost of service, or 'revenue requirement' is set, costs must be allocated to customers as informed by a cost of service study. Many water utilities in the USA water systems use the 'base-extra capacity' method for allocating costs, which distinguishes between the cost of providing for average demand and the cost of providing capacity for meeting peak demand.

Furthermore, water utilities are increasingly including a fire-protection charge as part of their fixed costs. For most water utilities, a significant share of the fixed cost related to water capacity is recovered through variable charges. For water utilities, recovering more costs through fixed charges enhances revenue stability, because revenues are less reliant on sales. However, high fixed charges tend to weaken price signals (Beecher, 2010).

Prices constitute the most efficient information system. When prices do not reflect the full costs and benefits of production and consumption, the facts about actual cost of supply, resource scarcity and environmental values are not made known. There is a direct causal connection between mispricing and unsustainable development. To trace mispricing, one can look at two well-known failures: policy and market.

Government interventions – arising from subsidies, exemptions from water charges, taxation policies, price controls or regulations – may distort the market. This engenders a type of failure known as 'policy failure'. If not responsibly managed, this can have large-scale negative impacts. If governments want to promote sustainable development, they must make sure the prices and incentives are right. The design and implementation of any one of these policy instruments should include a thorough assessment of the direct and indirect impacts they may have, including other policy goals.

Another concern is that by their nature, fixed charges are regressive and less affordable, which implies that they will take a larger share of the income of low-income households. Conversely, recovering more costs via variable charges reduces revenue stability, as revenues are more reliant on sales. Variable charges send better price signals to users and are more affordable and less regressive. Users and environmental advocates alike prefer higher variable charges relative to fixed charges, although consumer advocates worry about the effects of the total bill (Beecher, 2010).

Water utilities presently face a conundrum, due to their simultaneous goals of revenue sufficiency and promotion of conservation. For example, when customers are more efficient with their water use, a utility's sales base erodes. There are currently efforts to find alternatives to the classic water utility retail pricing that would better align utility revenue stability, as well as promoting efficient water use (Tiger, 2012).

One such alternative solution is the Peak Set Base Pricing Model (Tiger, 2012). Under this pricing structure, the utility would charge individualised base charges based on a customer's maximum month of consumption. This theoretical model is based on demand charges used by many power utilities yet is grounded in the limitations of current water-metering technologies. Under this pricing regime, a customer's base charge would be set individually, based on the three-year rolling average of their peak month of demand. The utility would still charge its users variable rates, but the variable rates would constitute a lower proportion of a customer's bill. This model permits utilities to build more of their cost recovery into the base charge, while still promoting customer conservation and efficiency. More specifically, it encourages steady water use.

The proposed theoretical model above is vital, as it sheds more light (resulting in better comprehension) on how pricing can advance conservation and efficient water use without necessarily undermining the water and sanitation utilities' revenue goals. Given the increasing pressure on water utilities to improve their services, maintain infrastructure, operate more efficiently considering continued rises in costs and expand their network systems, there is a need for confident, accurate and reliable revenue projections.

4.8 International water pricing frameworks and performance

4.8.1 Current pricing framework in Europe

The most common water pricing structures used in EU member states are two-part tariff models combining fixed and usage components. Household water bills vary greatly across countries in Europe. A noteworthy distinction is that bills not establishing a direct link with the actual amount of water consumed (i.e. price structures that consist of only a fixed charge and not a usage/volumetric charge) are higher than those for which water pricing reflects both fixed and variable (volumetric) components. This applies to all countries except for Germany. The volumetric aspect of water bills can provide incentives. In Scotland, and in some places in England and Wales, water is charged in relation to the value and size of the property. Not only is this water billing method more expensive for the customer, but it also reduces any incentives for increased household water-use efficiency (EEA Technical Report, 2013).

The WFD does not define 'adequate incentives' that must be contained in water pricing schemes in EU member states, but a water-pricing scheme must contain a variable element to provide an incentive. In other words, the price should be at least partly related to the quantity of the water service used. The EEA Technical Report (2013) concludes that households not facing volumetric water charges consume about a third more water than similar households that do incur such charges.

Nevertheless, there is also a risk that by decreasing the proportion of fixed charges in favour of volumetric billing, water companies will find it difficult to recover the costs of water provision and sanitation, as customers become more water-wise with their consumption. The bigger the variable part is, the greater will be the incentive to economise on water use. Clearly, regardless of pricing levels, the structure of the water tariff per se (volumetric pricing versus flat rates) can provide an incentive for more efficient water use. If water pricing must provide adequate incentives for efficient use of water resources, metering is indispensable.

An effective incentive tax or charge may undermine its own function as a source of revenue, and therefore cost recovery. If high water prices reduce water consumption, the supplier's revenues decrease, and the cost of water supply may no longer be covered. If the water supplier increases prices further in response, a vicious cycle may result. In practice, this usually does not happen, given the low-price elasticity of water demand, and the fact that water prices are only partially variable, as we indicated earlier. If one considers the variability in demand elasticity for different types of water use, a more sophisticated system could perform even better in terms of incentive provision. This means that an increasing block tariff (that also considers household size) could be the best model from an incentive point of view.

4.8.2 Barriers to cost recovery

The cost of installation of water meters in the EU represents a deterrent both for the entities responsible for the provision of water services and for their (low-income) customers. To overcome this, it is important that transition to metering does not imply an imbalance in the financial accounts of service providers, or impose difficulties in access and affordability, especially for low-income groups. However, providing the infrastructure necessary for the operation of new water-pricing schemes poses one of the main obstacles to efficient water pricing around the world.

In South Africa, one of the biggest challenges is the high number of users who are yet to be connected to both the potable and the wastewater piped network. This is a major constraint on a cost-recovery strategy's ability to perform optimal implementation. As a result, the majority of users' usage cannot be monitored, as they are not metered. As pointed out by the EEA Technical Report (2013) and Arcadis et al. (2012), variable and volumetric pricing provide an incentive to reduce water use, but volumetric pricing in domestic and agricultural sectors requires efficient metering devices, which can be complex to install and monitor.

The second barrier identified is resistance from stakeholders and users to the rise in water prices. This resistance may in some cases originate from a lack of information, while in others it is a matter of compounded social issues. Generally, customers (particularly households) have at best limited knowledge of the economic instruments set up by water agencies. The third barrier is the counter-effect that certain subsidies may have on the achievement of cost-recovery objectives.

4.9 Balancing the water accounts

Water utilities make expenditures in their daily operational provision of water and sewerage services. They fund these services and the infrastructure associated with them from several sources, mainly user fees, government grants, subsidies and debts. There is also evidence of private-public partnership in some parts of the world. However, user fees represent most of a utility's revenue. The main revenue sources for a water utility often include (Water Research Foundation, 2014):

- water supply fees;
- volumetric water rate charges;
- interest income;
- non-operating income (e.g. property leases or contracting services); and
- other miscellaneous fees and charges.

It is well documented that most water utilities are under pressure to find additional revenue sources. According to Raucher et al. (2012), several utilities are exploiting additional business lines that are beyond the core mission of providing safe potable water. These new services, which could potentially generate new revenue and enhance customer satisfaction, include:

- real estate leasing or sales;
- plumbing services;
- contracted lab services;
- advertising on water towers; and
- service line insurance policies.

These new revenue opportunities leverage assets already owned by the water utility and develop other assets to take advantage of the utility's core functions (Raucher et al., 2012).

4.10 Summary

Water utilities around the world, irrespective of whether they are public or private, have regulated billing structures. Fixed and variable tariffs are a common feature among the water utilities. A delicate balance is required when designing rate structures (fixed and variable charges) for the cost recovery requirement, bearing in mind other multiple policy goals. In our view, this can be achieved by ensuring that a customer is charged a fixed price in proportion to fixed costs, and a variable price that is in proportion to variable costs. A two-part tariff enhances cash flow, particularly when consumption is subjected to high seasonal variations. This will obviously affect the affordability of the service of low-income households, which often consume small quantities of water.

As water rates continue to increase, more low-income customers have difficulties paying their water bills. In fact, affordability is typically a major issue for water bills that approach or are greater than 2.5 per cent of median household income (Mumm, 2012). To address these affordability challenges, some water utilities have developed customer assistance programmes to ensure that necessary water services remain available to those who cannot afford them. Such programmes can include a wide number of fixed or variable discounts and credits as well as specifically tailored (or lifeline) rates (Cromwell III et al., 2010). A dilemma faced by many water utilities is the implications of the impact of successful water conservation and efficient-use campaigns on their revenue goals. In other words, they are faced with decreasing revenues because of successful conservation and efficient water-use campaigns. An important point here is that these struggles are short-term. In the long term, they can be an effective tool for increasing water supply.

Water service providers should also work at transforming customers into partners. As already indicated, financial sustainability is just one of the parameters in the equation aimed at providing universal access to safe, reliable, environmentally sustainable and equitable water services. The trust of existing and potential customers in the ability and capacity of a water service provider to improve the quality of the service is vital for ensuring the payment of cost-reflective water and sanitation bills.

Finally, there is also scope for water utilities to raise additional revenue by engaging in non-traditional initiatives. This is particularly crucial in South Africa, where government financial support of the water sector is unlikely to increase significantly in the face of ongoing budgetary challenges. Government cannot afford to fix the aging infrastructure and make all the required new investments. Thus, more innovative water funding schemes are required.

CHAPTER 5: MEASURING WATER AFFORDABILITY: A PROPOSAL FOR SOUTH AFRICAN RESIDENTIAL WATER TARIFFS

5.1 Introduction

The process of utilities setting water-tariff rates is a very complex undertaking. Utilities cannot pursue economic efficiency only when setting tariffs but must also take into consideration social goals such as equity (access and affordability), sustainability, and the political economy. In South Africa, the IBT pricing structure has often been used to help municipalities achieve some of the multiple goals of water-service provision, such as cost recovery, revenue efficiency, equity and affordability, as described in previous chapters.

In practice, however, there has been little empirical evidence quantifying the efficiency of IBTs in simultaneously achieving some of these goals. In this regard, this chapter empirically assesses the equity and affordability of IBT pricing, as applied across the various South African municipalities.

5.2 Study approach

There have been questions related to both the adequacy of 25litres per person per day and the average household size assumed in the policy. To determine whether the current basic 'lifeline' level of domestic use is adequate, we propose to model both a minimum level of water consumption that does not depend on price, and another with price variations.

Specifically, we propose to use the Stone-Geary utility function (see Garcia-Valinas, Martinez-Espineira and Gonzalez-Gomez, 2010; Al-Quanibet and Johnston, 1985; Gaudin et al., 2001; Martínez-Espiñeira and Nauges, 2004; Madhoo, 2009; Meran and von Hirschhausen, 2009; Nauges et al., 2009; Schleich, 2009; Monteiro, 2010; Clarke, Colby, & Thompson, 2017), which calculates an inelastic portion of water consumption in which households have limited ability to adjust in the short run. We also estimate the resulting affordability indexes.

There are currently 254 municipalities in the country, with eight metropolitan municipalities, 44 districts and 244 local municipalities. The selection of municipalities for the sample was determined by the nature and availability of data, with more emphasis on the big metros and big district municipalities because of their high representation of households with piped water. Data was collected for 73 municipalities across the country.

The Stone-Geary utility **function** is as follows:

$$U = \beta^{w} \ln (Q^{w} - y^{w)\,+} \beta^{Z} \ln (Q^{z} - \Upsilon^{z}) \tag{4}$$

The average household in the municipality is assumed to have a given level of income and faces different set of prices for water supply. Q^{w} and Q^{z} are the demands for water and for all other goods/ services respectively, Υ^{w} and Υ^{z} are the minimum amounts (or subsistence level/s), and I is income. β^{w} and β^{Z} denote the fixed proportions of the supernumerary income (the income left over after the household has purchased the minimum amounts of water and all other goods, Υ^{w} and Υ^{z}, respectively) that the household will allocate to water (β^{w}) and the numeracy good (β^{Z}).

The household will then maximise its utility, subject to the relevant budget constraints, such that its water **demand model** becomes:

$$Q^{w} = (1-\beta^{w})\, y^{w} + \beta^{w} (I/P^{w}) + Z + \mu \tag{5}$$

Where $\mathbf{Q^{w}}$ is the average level of water consumption in any given municipality per household, **1** is the average level of annual income, $\boldsymbol{\beta^{w}}$ represents the marginal budget-share allocated to the good considered, $\mathbf{P^{w}}$ is the average price of water in the municipality, **Z** is a set of contributions that best describe the municipality and are restricted by data availability, and **u** is the idiosyncratic error term.

According to a simplified Stone-Geary demand model, water consumption ($\mathbf{Q^{w}}$) is assumed to be a function of only two parameters (Clarke, Colby, & Thompson, 2017):

a) The first is the amount of water consumption that is perfectly inelastic to price, called the 'conditional water-use threshold' (denoted as y^{w}) to underscore the fact that this threshold may vary with household or environmental characteristics. This amount may or may not represent ‘essential’ uses of water, but it does represent the amount of water consumption a household is unwilling to part with regardless of the price.

b) The second parameter in this model is the marginal budget share allocated to water (denoted as β^w). This represents the proportion of supernumerary income (I) – i.e. income left over after consumption of essential levels of all other goods – that a household spends on water consumption at a given price of water (P^w).

5.3 Descriptive Statistics

Household panel data was sourced from the National Income Dynamics Study (NIDS) database at the University of Cape-Town (UCT) for each single household in a municipality of the 73 municipalities. NIDS is the first national household panel study in South Africa. It is an initiative of the Department of Planning, Monitoring and Evaluation (DPME), and is part of an intensive, multi-million-rand effort on the part of the government to track and understand the shifting face of poverty.

NIDS examines the livelihoods of individuals and households over time. The study began in 2008, with a nationally representative sample of over 28,000 individuals in 7,300 households across the country. The survey continues to be repeated with these same household members, every two years – termed ‘waves’. The NIDS data is implemented by the Southern Africa Labour and Development Research Unit (SALDRU), based at UCT’s School of Economics. It provides information about how households cope with positive or negative shocks, such as a death in the family or an unemployed relative obtaining a job. Other themes include changes in poverty and well-being; household expenditure on water and electricity; household composition and structure; fertility and mortality; migration; labour market participation and economic activity; human capital formation, health and education; vulnerability; and social capital. We used secure data (low-level municipal household data not available publicly – a researcher must apply for access to the data housed at UCT for the four waves (2008, 2010, 2012, and 2014) of the study).

a) The NIDS variable data below was used in the demand estimation:

- household size (hhsizer) and number of dwelling rooms (dwlrms);

- household panel data for residential water consumption – the amount spent on water in the last 30 days (water expn);
- income (I) data per household;
- age of household (best_age_y);
- ownership of a washing machine (ownwash);
- household with flushing toilet (toi); and
- amount spent on swimming pool in the last 30 days (nfswimspn).

b) Data on the **price structure** (price) of each municipality, based on the IBT, was collected for 73 municipalities across the country by collecting primary data from the municipalities, which was then captured in a data spreadsheet; the code (WC033) is the unique identifier of the municipality in the NIDS data. The price data was merged with the NIDS panel household data in the municipality; Table 1 below is an example of the data collected (Blue Cape Agulhas municipality in the Western Cape):

Table 1: Tariff price data for a municipality

Municipality	Blocks	Number of Blocks	Tariffs(Rand)-Vat Inclusive								
			Wave 1		Wave 2		Wave 3		Wave 4		
			2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
	0-6 KL		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic Water Tariff-Prepaid Meter	7-20 KL	7	3.64	3.86	4.24	4.66	4.99	5.35	5.87	6.40	6.98
CAPE AGULHAS (WC03)	21-40 KL		3.76	4.02	4.39	4.82	5.16	5.53	6.05	6.60	7.19
	41-60 KL		4.09	4.59	5.31	5.84	6.25	6.68	7.32	7.98	8.73
	61-80 KL		4.72	5.30	6.12	6.74	7.20	7.71	8.44	9.28	10.25
	81-100 KL		6.22	7.06	8.23	9.05	9.69	10.37	11.35	12.49	13.86
	>101 KL		9.83	11.15	13.01	14.31	15.31	16.38	17.94	19.73	22.01
Fixed basic charge			63.53	67.98	74.1	81.51	87.22	93.33	102.19	108.53	118.79

c) Annual rainfall data for the municipalities:

Data was requested from the South African Weather Service for the 73 municipalities, but only 46 (63 per cent) of the municipalities had complete data.

d) Quantity derived, or kilolitres consumed (kl):

This was estimated for each household in each municipality across the different waves. Municipal-level water tariff structure combined with household water expenditure were used to back out the levels of water consumption

5.4 Empirical Results

The empirical exercise included two steps. First, an average 'lifeline'/basic free water amount was estimated for all households in the 73 municipalities. Despite the differences in municipality pricing structures, the average was used, because all poor households in the different municipalities have similar characteristics. Then, from that estimated `lifeline', we used quantile regression to calculate affordable indexes using average income.

In summarising Table 2 below, it must be noted that the summary statistics were summarised before estimating a truncated regression (model-dependent variables for which some of the observations are not included in the analysis, because they are not significant, and/or they reduce the bias in the results).

Table 2: Descriptive Statistics

Variable	Observation	Mean	St. Dev	Min	Max
Households with more rooms	106.545	4.427	2.460	1	44
Average household size	106.621	5.998	3.561	1	41
Household Income	106.554	5827.699	10835.47	0	1015900
Annual Rainfall	58.730	549.424	268.404	1.8	1591
Average amount spent on water	40.109	126.385	267.690	0	10008
Kl_	15.545	20.872	29.3152	0	716.599
Price_	8.205	29.662	36.486	0	136.17
Income-price	5.632	497.755	938.376	1.139	13022.73
Water sources	106.545	2.678	2.341	1	13
Best_age_y~	117.500	26.740	20.259	0	113
Age dummy	117.500	0.0848	0.0278	0	1
Washing machine	105.343	0.259	0.438	0	1
Households owning a washing machine	105.343	1.740	0.4385	1	2
Households with a flushing toilet	100.502	2.892	1.88765	1	9
Households with a Swimming pool	22.882	4.950	48.791	0	1600

The most notable statistic from the table is that the average household size (hhsizer) in the sample was six. The average household income was calculated to be R5,827.70 per annum, while the average amount spent on water (water expn) was R126.39 per month. Average amount of water used per month was 20.87 kl, and the average price paid for water across municipalities was R29.66 per kilolitre.

In the final estimation (Table 3 below), the amount of water used per month was limited to an upper bound of 42 kl per household per month and excluded households in the sample that reported consuming 0 kl (the lower bound). There were different water sources (watsrc) in the data, but the analysis was restricted to only piped water connected to the household.

Table 3: Stone-Geary water demand estimation (truncated)

Kl_	Coef.	St.Err	z	P>|z|	[95% Conf.Interval]	
Income price	0.0015	0.00034	4.60	0.000	0.00091	0.00226
Age_dummy	0.2690	1.3775	0.20	0.845	-2.4308	2.9689
Washing machine	8.1062	1.0318	7.86	0.000	6.0838	10.1286
Average household size	-0.0526	0.1153	-0.46	0.648	-0.2787	0.1734
Annual Rainfall	-0.0042	0.00217	-1.97	0.049	-0.0085	-0.000022
Having more rooms	1.9819	0.0210	9.42	0.000	1.5697	2.3940
Households with swimming pool	0.5955	0.0093	6.38	0.000	0.04125	0.0778
Households with a flushing toilet	-0.9730	0.2979	-3.27	0.001	-1.5569	-0.3891
_cons	8.4078	1.6055	5.24	0.000	5.2610	11.55472

As mentioned previously, estimating a water demand function based on the Stone-Geary utility function makes it possible to explicitly distinguish between the fixed portion of water use that cannot be easily adjusted in the short run after a price and/or income change (it is highly price-inelastic and income-inelastic), and an additional quantity that can adapt almost instantaneously to price and/or income changes. The first component constitutes a proxy for the `lifeline'/basic free water, which is difficult to alter in the face of changing prices.

As shown in Table 3 above, most of the estimated coefficients are significant at the 5 per cent level. Most importantly, both the constant and income-price terms are positive and significant, as expected. Owning a washing machine increases the demand for water significantly (by 7.86 kl) and having more rooms in the house also contributes to greater water usage. Households that have a swimming pool spend more money on their water bill (R6.38 more). Additionally, household water demand was found to be positively affected by age. A variable with an unexpected negative sign was households with a flush toilet. The negative coefficient shows that (for the municipalities in the sample) having a flush toilet does not increase demand for water.

Table 4: ‘Lifeline’/basic free water which is unresponsive to price

Random Effects	*Coefficient*	*Constant*	*Lifeline*	*Mean Price (R)*	*Lifeline (R)*	*Income-Mean (R)*	*Affordability-%*
All Households	*0.0016*	*8.408*	*8.4215*	*29.66*	*249.80*	*5827.70*	*4.286*

The `lifeline’/basic free water portion of annual consumption that is not responsive to price in the short run was computed as $y^w/(1\text{-}\beta w)$, based on the demand estimation **y^{w} = 8.42 kl** or **8,420** litres of water per household per month. This translates to 46.7 litres per person per day, for a family of six. This results in a monthly bill of R249.80, which represents an average 4.29 per cent of monthly household budget on an average income of R5,827.70.

The second step in the econometric analysis was to develop a water affordability index by income deciles. We used quantile regression to see the impact of the different socio-economic variables on different categories of water demand consumption levels.

Table 5: Quantile regression results

Litres of water per household per month	Coef.	Bootscrap St. Err.	t	P>|z|	[95% Conf.Interval]	
q25						
Income-price	0.00124	0.000674	1.84	0.066	-0.000079	0.002564
Age_dummy	-0.01502	0.032948	-0.46	0.648	-0.079658	0.049606
Wash machine	0.05618	0.085245	0.66	0.510	-0.111034	0.223409
Average household size	-0.00887	0.004096	-2.17	0.030	-0.016910	-0.000837
Annual Rainfall	0.00226	0.002213	1.02	0.306	-0.002077	0.006605
Households with more rooms	0.00720	0.004723	1.53	0.127	-0.002057	0.016472
Households with swimming pool	0.04413	0.021528	2.05	0.041	0.001902	0.086365
Households with flushing toilets	0.00638	0.006352	1.01	0.315	-0.006074	0.018849
_cons	7.37661	1.551608	4.75	0.000	4.332897	10.42032
q50						
Income-price	0.0006	0.000871	0.70	0.485	-0.001101	0.002319
Age_dummy	-9.82e-17	0.054109	-0.00	1.000	-0.106141	0.106144
Wash machine	4.75827	1.498873	3.17	0.002	1.81800	7.698537
Average household size	-0.00038	0.002525	-0.15	0.879	-0.005337	0.004569
Annual Rainfall	-0.10946	0.002018	-5.42	0.000	-0.014904	-0.00698
Households with more rooms	0.002028	0.013296	0.15	0.879	-0.024055	0.02811
Households with swimming pool	0.095013	0.034713	2.74	0.006	0.026918	0.163108
Households with flushing toilets	0.000699	0.002874	0.24	0.808	-0.004939	0.006338
_cons	16.49355	1.392317	11.85	0.000	13.76231	19.22479
q75						
Income-price	0.00217	0.000813	2.67	0.008	0.000576	0.003766
Age_dummy	-2.78e-15	1.876258	-0.00	1.000	-3.680561	3.680561
Washing machine	14.05706	1.258931	11.17	0.000	11.58748	16.52664

Average household size	0.123626	0.113175	1.09	0.275	-0.098381	0.345640
Annual Rainfall	-0.11506	0.002017	-5.70	0.000	-0.154636	-0.007548
Households with more rooms	1.362353	0.387911	3.51	0.000	0.601407	2.123299
Households with a swimming pool	0.103196	0.049794	2.07	0.038	0.005517	0.200875
Households with a flushing toilet	-0.40582	0.170630	-2.38	0.018	-0.740544	-0.071110
_cons	14.3259	1.725272	8.30	0.000	10.94152	17.71028
q95						
Income-price	0.01730	0.007041	2.46	0.014	0.00349	0.031119
Age_dummy	-2.01162	3.930992	-0.51	0.609	-9.72285	5.699611
Washing machine	18.96597	4.473252	4.24	0.000	10.1910	27.74092
Average household size	-0.19513	0.269582	-0.72	0.469	-0.72395	0.333694
Annual Rainfall_	-0.00381	0.008554	-0.45	0.656	-0.02059	0.012964
Households with more rooms	3.211017	1.076264	2.98	0.003	1.099763	5.32227
Households with a swimming pool	0.410087	0.115873	3.54	0.000	0.182783	0.637391
Household with a flushing toilet	-2.80330	0.533478	-5.25	0.000	-3.849801	-1.756805
_cons	21.93227	5.044671	4.35	0.000	12.03639	31.82815

In Table 5 above, the data is broken down to 4 quantiles of water demand, from the lowest users of water to the highest. The first quantile (q25) shows that the lowest users of water need a ‘lifeline’ basic water amount of $\mathbf{y^w}$ = 7.38 kl, or 7,380 litres of water per household per month for a family of six, based on the demand estimation. This translates to a monthly bill of R219.08, as calculate below in Table 6. Household size and age are insignificant for low consumers. The second quantile is where most households spend on water, as the ‘lifeline’ is much higher at $\mathbf{y^w}$ = 16.49 kl or 16,490 litres of water per household per month for a family of six, which translates to a monthly bill of R489.53.

The biggest water-consumer households need about $\mathbf{y^w}$ = 21.93 kl or 21,930 litres of water per household per month for a family of six, which translates to a monthly bill of R662.02. Interestingly, as mentioned above, having a flush toilet does not increase demand; but owning a swimming pool and a washing machine significantly increases the demand for water.

Table 6: 'Lifeline'/basic free water

Quantile	Lifeline(monthly)	Mean Price (R)	Expenditure-lifeline (R)
Q25	7.3857	29.6622	219.08
Q50	16.5036	29.6622	489.53
Q75	14.3570	29.6622	425.86
Q95	22.3185	29.6622	662.02

The last part of the analysis constituted calculating affordability indexes, using income quantiles of 10 (income categories subdivided into 10 groups) to analyse how affordable water is compared to household income. The results are shown in Table 7 below:

Table 7: Affordability index percentage (by income deciles)

Affordability Index		*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*
Income(Mean)	*Quantile*	*835.4285*	*1588.8445*	*2221. 2578*	*2887. 6408*	*3646. 6745*	*4594. 1418*	*5933. 1418*	*11755 .7900*	*29474. 8600*
	Q25	*26.22*	*16.38*	*11.91*	*9.22*	*7.33*	*5.88*	*4.61*	*2.32*	*0.74*
Lifeline Exp/Income	*Q50*	*58.60*	*36.59*	*26.61*	*20.61*	*16.37*	*13.13*	*10.29*	*5.19*	*1.98*
	Q75	*50.98*	*31.83*	*23.15*	*17.93*	*14.24*	*11.43*	*8.96*	*4.51*	*1.72*
	Q95	*79.24*	*49.48*	*35.99*	*27.87*	*22.14*	*17.76*	*13.92*	*7.01*	*2.68*

An analysis of the income deciles in relation to the expenditure lifeline calculated monthly in Table 7 above reveals that water is affordable for households who earn R7,961.58 per month and more (Q8 on the table0. The lowest consumers (Q25) use about 3.4 per cent of their income for water, while the biggest water users (Q95) spend 10.37 per cent of their income on water. The table also shows that water is very affordable for the richest (Q10), who only spend 2.68 per cent of their monthly income on water. However, for the poor households, with income of R835.43 (Q1), if they don't receive free water from their municipalities, the lowest water users (Q25) would have to spend 26.22 per cent (Q1) on water, while most households in the second quantile (Q50) will use an astonishing 58.60 per cent of their income to pay for water. In fact, Table 7 shows that any household with income of R5,933.14 or less should be receiving a basic free water 'lifeline' in the first block.

5.5 Policy Recommendations

- There must be a revaluation of the minimum 'lifeline' basic water provided to poor households in South African municipalities, considering whether they have a flush toilet or not, household income, and demographic area. The study recommends that the current 'lifeline' be increased to 8.42 kl or 8,420 litres of water per household per month for households that earn less than R6,000 per month. This translates to 46.7 litres per person per day, for a family of six, especially for households in urban areas.
- Water in South African municipalities is currently very affordable for the 'rich' household, but less so for the 'poor', based on income. Incorrectly designed IBTs are not effective in incentivising households reduce water wastage. Rich households tend to have bigger yards and gardens, swimming pools, washing machines and dishwashers, so there should be a steep increase between blocks. Therefore, policy efforts should be concentrating more on the design of the IBTs than the implementation. Water providers/WSAs must re-evaluate whether the tariff design still meets its desired outcomes.
- In addition, environmental climate change has seen the country face one of the worst droughts in recorded history, with the Western Cape, the Eastern Cape and the Northern Cape declared national disaster areas in late 2017; which has led to water shortages. Though some of the big municipalities have been successful in implementing systems, there are still shortages in cost recovery, which has led to reduced investment in infrastructure, which will limit supply to households in the future. The recent drought in some parts of South Africa has also shown that the biggest users of water were in the affluent suburbs; so even if the implementation of the IBTs is done correctly, the design might still not be cost-reflective.

- Municipalities need to fully reflect their costs of providing water to households to be able to charge the correct tariff price. Municipalities are inconsistent in charging a dual price to households; there should be a fixed charge for providing the water to the household, and a variable cost for the usage. Currently, some municipalities only charge the variable usage cost, while others adjust their tariff prices by below-inflation amounts. Therefore, all municipalities should be obliged to charge the fixed rate.
- Most small municipalities have a huge population of households that are unemployed or classified as 'Indigent', which means less revenue would be derived from an IBT – a simple fixed rate would be more applicable. The recommendation from the study would be to have all small municipalities move away from an IBT to other structures such as a fixed rate, based on historical consumption patterns.
- Rebates and subsidies should be limited to poor households, rather than lowering the price of water, as this has not been proved to reduce waste. In general, more practical research needs to be undertaken on reviewing the current tariff structure, in relation to both social and cost-recovery objectives.

CHAPTER 6: THE IMPACT OF DIFFERENT TRANSFER BURDENS ON ECONOMIC DEVELOPMENT

6.1 Introduction and background

As stated in the Water Services Act (Act 108 of 1997), municipalities can use water tariffs as a cost-recovery tool. Retail water-service tariffs also vary between user categories (residential, commercial, industrial or public buildings) and levels of water consumption. The water-service tariff structure is not only the key element in raising revenue to offset the costs incurred in provision, but also a key element in allocating water services provided, and it influences a wide range of choices and decisions – many of which are closely linked to local and regional economic development.

Given that water is a scarce resource, it is critical for water-resource management to balance the growing social and economic needs with the sustainability of the resource and with environmental health considerations. In this context, this paper contributes to the policy inputs for water resources by estimating water demand in South Africa. Despite the long history of estimation of water demand, Nauges and Whittington (2009) argue that the analysis of household water demand in developing countries first appeared only in the work of White et al. (1972), Katzman (1977), and Hubbell (1977), and remains limited even today, due to variations in the conditions surrounding water access.

The need to estimate the price elasticity of water demand in South Africa was emphasised by representatives of the World Bank, during a meeting with the Department of Water Affairs and Forestry in November 1996 to discuss water tariffs (WRC, 2000). Since then, however, Nahman and de Lange (2013) have argued that limited literature exists on the estimation of price elasticity of water demand in South Africa.

6.2 Literature review

6.2.1 Overview of the water demand elasticity theory

There are significant gaps in the DWA (2011) guidelines for water-service tariff setting; for instance, the guidelines lack analysis of the revenue consequences of raising tariffs under different municipal circumstances. The consequences of raising tariffs to raise revenue differ in the short and the long run, with more revenue likely to be raised from a tariff increase in the short run than in the long. Similarly, the revenue that could be expected to be raised by raising tariffs would be less, the greater the demand that has already been satisfied (because price elasticity should increase along the demand curve), and the more substitutes there are to the water services provided – for example, river or underground water supplies. This is explained by Dockel (1973), and Nahman and de Lange (2013).

Mohr et al. (2008) define elasticity as a measure of responsiveness or sensitivity of the dependent variable to changes in the independent variable. In the case of demand, the dependent variable is the quantity demanded, and the independent variable is the price of the commodity. Therefore, price elasticity of demand is the degree of responsiveness of quantity demanded (quantity of water demanded, in the context of this research) to changes in the price of the commodity (in this instance, change in water tariffs), *ceteris paribus*.

The following formula is used to calculate price elasticity of demand (PED):

PED = (% change in the quantity demanded of a commodity) / (% change in the price of the commodity) (6)

Elasticity is calculated by using percentage changes that are relative, not absolute. Absolute changes in prices and quantities are not used because prices are expressed in monetary units, whereas quantities are expressed in physical units. The use of percentage changes therefore prevents the units in which prices and quantities are measured from affecting the result. Elasticity coefficients enable economists to compare how consumers react to changes in the prices of commodities. In the context of this research, elasticity coefficients enable decision-makers in the water sector to compare how water consumers would react to changes in water tariffs.

The calculated price elasticity of demand value has a negative sign, due to the law of demand; that is, the change in the price level and in quantity demanded move in opposite directions. It is general practice in economics to ignore the negative sign and concentrate on the absolute value of the price elasticity of demand. Mohr et al. (2008) distinguish between five different categories of price elasticity of demand:

- Perfectly inelastic demand (PED = 0)
- Inelastic demand (PED lies between 0 and 1)
- Unit elastic demand, or unitary elasticity of demand (PED = 1)
- Elastic demand (PED lies between 1 and ∞)
- Perfectly elastic demand (PED = ∞)

In deciding whether the demand of a commodity will be elastic or inelastic, all possible determinants of price elasticity should be considered. The most common determinants of the price elasticity of demand, according to Mohr et al. (2008), include the availability of possible substitutes, the degree of complementarity of the commodity, whether the commodity satisfies needs or wants, the period under consideration, the proportion of income spent on the commodity, and advertisement, durability and addiction, among others.

The quest to balance the provision of affordable water services with the need to recoup costs associated with water treatment, storage and transportation creates some complexity for municipalities. Determining a reasonable tariff structure that will be accepted across the board is a difficult task. This is due to income inequalities and other discrepancies in the South African dual economy. Even though municipalities offer some free basic units of water per month, as outlined in the Water Services Act (Act 108, 1997), such generosity is received with mixed feelings. This is evident in the increasing number of water-provision protests, with poor South Africans accusing authorities of neglecting their right to adequate water for a dignified life.

South African municipalities generally struggle to maintain water infrastructure because of insufficient revenue collection due to low tariffs (see Tsegai, Linz and Kloos, 2009). Together with the absence of ring-fencing revenue for maintaining assets, municipal water infrastructure is usually run to failure. A new set of guidelines for setting optimal tariffs that are both lucrative to municipalities and economically affordable to all South Africans should therefore be devised. To draft new guidelines for tariff setting in South African municipalities, several questions must be asked. Are South African municipalities using the best and most reasonable tariff structures? What is the degree of responsiveness of the demand for water services to changes in water tariffs? Are there alternative revenue-raising instruments for South African municipalities? This chapter seeks to answer these questions regarding water-service tariff structures in South African municipalities.

6.2.2 Empirical literature

Microeconomic theory predicts that users will reduce water consumption when prices are relatively higher. The enormity of this depends on price elasticity. This rationale depends on the implicit assumption that users have perfect knowledge of prices – a strong assumption that does not always hold, given ex-post billing. When prices are not transparent, elasticity approximates may be lower than they could be, given full information. It is hypothesised that low-use residential users' unsatisfactory reaction to price is partly because of the lack of price information on water bills (Gaudin, 2006).

The issue of water demand has been extensively researched A study conducted in Australia emphasised that the effectiveness of policies in engaging with water consumption depends on the price elasticity of consumption. The greater the price elasticity, the more effective these policies are at reducing water consumption (Arbues et al., 2010). If consumers are not aware of these policies or are insensitive to the way water prices decrease or increase, then the use of these policies will not be effective. These characteristics may be different in different countries.

Other studies have found evidence that there is a wide range of water use under which demand is insensitive to price (Gaudin et al., 2001; Martinez-Espineira and Nauges, 2004). A study undertaken in Oklahoma City, assessing a residential water demand model under uniform volumetric prices, found that consumers show a low level of awareness regarding the water rate structure – mainly because water bills represent only a small portion of most households' income (Chung et al., 2015). Further studies undertaken in California and Canada confirm these findings (Renwick and Green, 2000). This is unsurprising, given that the studies were conducted in North America, where household incomes are very high. The opposite can be expected in developing countries, due to the significant number of poorer households (Worthington and Hoffman, 2008).

A study conducted in Israel examines the effects of policies on the demand side of water. Lovee et al. (2013) suggest that the most important results show that, of the economic policy equipment available, an increase in water tariff was not effective, while a drought enhancement decreased the amount demanded by residents. This shows that economic policy on water demand can be effective in some instances. Results such as these help policymakers to make efficient decisions.

A factor that seems to be ignored by economic studies is the issue of weather conditions, business cycles, and their relationship to water demand. A study was conducted in the Chicago metropolitan area to explore these issues. Interestingly, in summer, residents are more sensitive to water prices, compared to winter (Mieno and Brade, 2011). It is expected that in summer there will be high water usage, either through consumption or for leisure purposes, because of the many festivals and the hot weather conditions. This high summer water usage then results in high water rates, making the consumer feel the pinch of these prices and thereby reducing water use.

Although consumers are price-elastic to water prices, this is not true for electricity. This is the case in South Africa, where consumers are disconcerted by the incredibly high price of electricity compared to water. As a result, many households opt to switch off geysers and use alternative ways to heat water, such as electric elements and kettles. To a certain extent, this reduces water wastage.

Dandy, Nguyen and Davies (1997) used a regression analysis with linear data from the metropolitan area of Adelaide in Australia to estimate the impact of a tariff structure that included a free allowance for residential water consumption. An 8.5-year sample was drawn from the 14-year period of the study (1978 to 1992), producing a sample with 2,710 observations of annual consumption. Using the marginal price variable to measure the effect of the next unit of water, results from the study revealed that the overall price elasticity of water demand for residential users was between -0.6 and -0.8 in Australia. The implication was that in the long run, a 10 per cent increase in real marginal price would result in a reduction in demand of up to 8 per cent, and an increase in revenue of at least 1 per cent.

Dandy et al. 1997 further revealed that any increase in the price of water would result in a greater reduction in demand in summer than in winter. Subsequently, the bill-difference variable was used to incorporate the income effect of the tariff structure, and it was found that income had a statistically significant but numerically small effect on consumption in Australia. The study further discovered that consumption above the free allowance was more sensitive to income, climate variables, and pool ownership than consumption below the free allowance, but responded to the need for water as determined by plot size, household size, and number of rooms no differently than consumption below the allowance. The study finally concluded that the free water allowance resulted in water wastage, and that its removal would be an efficient way of reducing water consumption.

According to Dandy et al. (1997), the removal of the free allowance would not raise any equity concerns, because the size of the allowance tended to be related to property value; so, the households (with consumption below the allowance) that benefited from the allowance tended to be rich rather than poor. These results greatly inspire the need to conduct similar research in South Africa, which also has a free basic water policy.

Espey et al. (1997) adopted the meta-analysis approach, which uses reported empirical elasticities from studies to explain their variation, using inter-study differences as explanatory variables in a regression. The ordinary least squares estimation method was employed to estimate the price elasticity of residential water demand, using data from 24 reviewed journal articles published between 1967 and 1993.

Only studies that provided an estimate of price elasticity of demand (and two models that estimated a non-negative price elasticity of demand) were reviewed. The 24 journal articles reviewed yielded 124 estimates of the price elasticity of demand for residential water use in developed countries, ranging from -0.02 to -3.33, with an average own-price elasticity of -0.51. These 124 estimates were then used as the dependent variable to estimate the residential demand for water.

In the studies reviewed, Espey et al. (1997) discovered the most common determinants of price elasticity in residential water demand to be evapotranspiration rates, rainfall, and the pricing structure. This study also revealed that studies based on regions with increasing block rate structures had larger price elasticities. It was also found that models that account for evapotranspiration and rainfall predicted less elastic demand; while including variables for temperature, population density and household size did not affect the elasticity value. Even though that study inspired the need to estimate the elasticity of water demand, and the establishment of factors influencing such demand, Espey et al. (1997) admitted that their estimated results should be interpreted with caution, because all the regressors in the meta-analysis model were binary variables.

The work of Espey et al. (1997) is confirmed in a follow-up study by Dalhuisen et al. (2003) that also uses meta-analysis as a tool to identify important factors explaining variations in estimated price and income elasticities of residential water demand in developed countries. The study reviews 64 journal articles that appeared between 1963 and 2001, from which 314 price-elasticity estimates and 162 income-elasticity estimates of residential water demand were derived. Results from the analysis revealed that variations in estimated elasticities were associated with differences in the underlying tariff system, and that relatively high price elasticities and relatively low-income elasticities were found in studies concerned with demand under the increasing block tariff structure.

It was also discovered that studies using prices other than marginal prices (for example flat, average, or Shin prices), and with controls for income differentials, a difference variable or a discrete-continuous choice specification, led to relatively higher absolute values for price and income elasticities. Finally, the study suggested that differences in estimated elasticities were positively correlated with differences in per capita income pertaining to the underlying study area, with higher-income regions tending to have larger price elasticities (Dalhuisen et al., 2003). Taylor et al. (2004) and Carter and Milon (2005) attest to the work of Dalhuisen et al.

Taylor, McKean and Young (2004) used cross-sectional data from a sample of 34 Colorado utilities over a two-year period (1984 and 1985) to suggest alternative price specifications for estimating residential water demand with fixed fees. The two stages least squares (2SLS) and the ordinary least squares (OLS) methods were employed to estimate the linear and double-log functional forms, which were subsequently used to construct estimates of average versus marginal prices after controlling for possible simultaneity bias. The double-log model fitted well with both the OLS and the 2SLS methods. When marginal price was specified with a double-log functional form, Taylor et al. found that the 2SLS estimate for demand was more price-inelastic (-0.3) than the OLS estimate (-0.2). It was further discovered in the study that when the fixed fee is purged from the data, the average price becomes insignificant, while the marginal price remains significant. The estimated inelastic water demand revealed in the study suggested that conservation programmes had no significant effect on water demand in Colorado.

The results from Taylor et al. (2004) agreed with findings from the study by Renwick et al. (2000) that used the marginal price variable to estimate water demand elasticity in California and revealed an inelastic residential water demand of between -0.16 and -0.21. Findings from both studies confirmed findings from a study by Griffin and Chang (1990) that analysed water demand in 30 USA communities using the average price variable and revealed inelastic water demand for residential users of between -0.16 and -0.37. In the spirit of Taylor et al., Carter and Milon (2005) developed a simultaneous equation model to examine how price knowledge affected household demand for utility services in the USA. Results indicated that informed households were more responsive to average and marginal water price signals, and that they used less water.

Martinez-Espineira (2006) used the co-integration and error-correction methods to estimate short- and long-run price elasticities of residential water demand in Seville, Spain. Monthly time series data for the period 1991 to 1999 was used, obtained from EMASESA, a private company in charge of supplying water and sewage collection in Seville. Estimates of the price elasticity of water demand revealed in the study were -0.1 in the short run and -0.5 in the long run. These estimates are less than one in absolute value, which confirmed the inelasticity of household water demand with respect to the price of water.

Results from the work of Martinez-Espiñeira confirmed the intuition that long-run elasticities are higher (in absolute value) than short-run elasticities, as suggested by Dandy et al. (1997), Nauges and Thomas (2000), and Martínez-Espiñeira and Nauges (2004). The use of the co-integration and error correction techniques, as well as the estimation of residential water demand using time-series monthly data, makes the work of Martinez-Espiñeira quite creative.

Binet (2012) in France used Shin's (1985) perception price method to estimate the residential water demand function derived from a Stone-Geary utility function. Cross-sectional data covering a representative sample of 2,000 households in 2004 was used in the study. In the spirit of Shin, the study applied a non-linear Generalised Method of Moments (GMM), with prices that the household would face at different fixed levels of water consumption as instruments. The results revealed that the perceived price to which consumers respond is lower than the marginal price, which leads to households consuming too much water. It was further revealed that at least 60 per cent of consumption reacts to price variations, justifying the need for an appropriate water-price specification.

Some ambiguity can be seen in the data used by Binet, as one cannot easily understand the exact sample used. Additionally, the results are not clearly explained to give a proper impression of the actual elasticities of water demand. However, the study by Binet is unique, because it applies Shin's methodology when using a Stone-Geary functional form in estimating residential water demand by a cross-sectional approach. This inspires the need to check for the applicability of such a methodological combination in an analysis of South African cross-sectional data.

However, clearer research on France had been conducted earlier by Nauges and Thomas (2000), who estimated residential water demand in France using the average and marginal price variables and concluded that the price elasticity of demand for residential water services in France is -0.22. This inelastic result is compatible with results from other developed countries.

Other studies on price elasticity of water demand in developed countries include Hoglund (1999), who found an elasticity value of -0.2 for residential water demand in Sweden, and Hansen (1996), with a -0.1 inelastic estimate for Copenhagen, Denmark. Earlier studies include the work of Foster and Beattie (1979), which used cross-sectional data analysis and found elasticity values between -0.35 and -0.67 in the United States. Also notable are Howe and Linaweaver (1967), who also used cross-sectional analysis and found income elasticity of 0.35 to 1.40 and price elasticity of -0.23 to -1.60 for residential users in the United States. Gottlieb (1963) obtained an income elasticity of 0.45 to 0.58 and a price elasticity of -1.23 to -0.68 for residential users in Kansas.

Hussein and Kuperan (1980) used primary data from a stratified random sample survey of 101 households and secondary data from the Alor Setar Water Works Department for the period January 1975 to July 1977 to examine the impact of price and income on domestic water consumption in Alor Setar, Kedah, in Malaysia. The primary data were drawn from the socio-economic variables of the consumers, while the secondary data were from the water-consumption figures of the individual households included in the survey. Regression equations were done using linear and log-linear data to estimate income and price elasticities of water demand in Kedah.

Results from the study revealed income to be significant at 1 per cent level in both linear and log-linear equations. The average income elasticity in Kedah was discovered to be 0.24 (linear equation) and 0.34 (log-linear equation). The income elasticity results suggested that elasticity generally increased with increases in household income. This was shown by empirical results which estimated income elasticity for the very poor to be between 0.05 and 0.09, while that of very rich households ranged from 0.29 to 0.40.

Subsequently, Hussein and Kuperan (1980) found price elasticity to range from -0.09 for the poorest group to -0.62 for the richest group in Kedah. Increasing elasticity with income level suggested that higher-income households could conserve or reduce water consumption in response to price increases. Findings from the work of Hussein and Kuperan (1980) were generally consistent with those of Katzman (1977), who used cross-sectional and time-series analyses to estimate income and price elasticity of domestic water respectively for Penang Island, Malaysia. Adopting a random sample of 1,400 households, Katzman indicated an income elasticity of zero for low-income families and an income elasticity of 0.2 to 0.4 for higher-income families. Using a time-series analysis of a sub-sample of individuals of varying income levels, Katzman suggested a short-run price elasticity of -0.1 to -0.2 in Penang Island.

Ayadi, Krishnakumar and Matoussi (2003) used a panel data analysis to examine residential water demand in the presence of non-linear progressive tariffs in Tunisia. Among other objectives, the study aimed to determine the impact of changes in water price on residential water consumption in Tunisia. Quarterly data for the period 1980 to 1996 collected from the National Water Distribution Company (classified by brackets of consumption level and by regions) were used to estimate residential water demand. Among other key findings, the study showed that the price elasticities of the lower block were smaller in absolute value (around -0.1), while the price elasticities of the upper block were bigger in absolute value (around -0.4).

These results imply that water demand in Tunisia is relatively sensitive to prices in the upper bracket, and in regions of dynamic economic activity characterised by alternative sources of supply, than it is to prices in the lower bracket and in regions of less economic activity. Findings from Ayadi et al. indicate that water prices should not be increased for consumers in the lower blocks, as they are essentially low-income earners whose elasticity is very small; hence, increasing water prices erodes their purchasing power, and reduces their quality of life.

Kayaga and Motoma (2009) used data from studies in Uganda and parallel survey findings from the city of Cape Town in South Africa to model a water-conserving tariff for domestic consumers in the city of Kampala, Uganda. Monthly household billing data sets from Kampala were used, translating to 54,024 household properties for the July 2006 to June 2007 financial year. The data were arranged in a hierarchy based on customer reference numbers and were reduced using SPSS to a five per cent random sample of 2,701 household properties. Since price elasticity of demand is an important input into a model for pricing decisions, Kayaga and Motoma used estimated price elasticity figures for Cape Town, as reported by Jansen and Schulz (2006).

The use of Cape Town estimates was mainly because no price elasticity studies had been conducted in Kampala prior to the research by Kayaga and Motoma. Elasticity estimates from Jansen and Schulz were adopted because according to Kayaga and Motoma, the City of Cape Town had similar characteristics to Kampala and was presumed to be the closest match for the parallel surveying method. Results from the study estimated the average price elasticity of water demand in Kampala to be -0.99 (high income), -0.32 (middle income) and -0.23 (low income). Since all consumption groups have inelastic demand, Kayaga and Motoma suggested that raising tariffs would be a source of revenue for authorities.

However, the authors subsequently acknowledged that such a policy would have an erosive effect on the income and buying power of households. The effects of raising water tariffs to increase revenue in Kampala would be experienced more by low-income earners, whose demand is relatively more inelastic because they do not have access to other sources of water. High-income earners have relatively higher elasticity than low-income earners and would resort to other sources of water following an increase in water price.

According to Kayaga and Motoma (2009), a price increase for high-income earners in block 3 would reduce the proportion of consumption from about 39 per cent to 22 per cent, with a few of the consumers having to revert to block 2. This also suggests that increases in the price of water also make the high-income groups worse off. Although the study can be criticised for using Cape Town as a city with the same characteristics as Kampala, results from the study contribute relevantly to the limited literature on elasticity of water demand in developing countries.

A study by Onjala (2001) estimated industrial water demand in Kenya using both time series and cross-sectional datasets. Industrial water demand was estimated to range from -0.6 to 0.37. A study by Kumar (2001) employed similar datasets but using trans log cost functions. The average price elasticity of Indian industrial water demand was estimated to be -1.11. Across a wide number of industrial and developing countries, Nauges and Whittington (2009) found that most estimates of price elasticity for water services ranged from -0.3 to -0.6.

Nauges and Whittington (2009) reviewed studies that had used data for the period 1985 to 2006 from various developing regions in the world: Central America (El Salvador, Guatemala, Honduras, Nicaragua, Panama, Venezuela), Africa (Kenya, Madagascar), and Asia (Cambodia, Indonesia, the Philippines, Saudi Arabia, Sri Lanka, Vietnam). Except for the research conducted in Ukunda, Kenya, the reviewed studies were conducted in medium- to large-sized cities in developing countries. The study revealed that water demand functions for households in developing countries suggested own-price elasticity for water from private connections to be in the range -0.3 to -0.6, while income elasticity was in the range 0.1 to 0.3. These elasticities were similar to those reported for developed countries (see Espey et al., 1997).

Nauges and Whittington found evidence of elastic water demand in only two of the reviewed studies: David and Inocencio (1998), and Rietveld et al. (2000). The study by David and Inocencio used data from Metro Manila in the Philippines to estimate price elasticity for vended water at -2.1. Rietveld et al. (2000) used data from Jakarta in Indonesia to estimate price elasticity for piped water at -1.2.

As further reviewed by Nauges and Whittington, the work of Nauges and Van den Berg (2009) in Sri Lanka and that of Cheesman et al. (2008) in Vietnam revealed that piped water and non-piped water are used as substitutes. Therefore, households that relied solely on piped water were reported to be less sensitive to price changes than connected households that complemented their piped-water consumption with water from a private well. The work of Nauges and Whittington inspires our quest to calculate elasticities of water demand in South Africa, where some rural habitants barely have piped water while others have access to both piped and non-piped water sources.

Results from these studies were also compatible with findings from Gunathilake et al. (2001), who studied household water demand in the Kandy Municipality of Sri Lanka, and estimated price and income elasticity in the area to be -0.34 and 0.08 respectively. Other studies also suggesting that price is not a significant variable in determining industrial and commercial water demand include Malla and Gopalakrishnan (1999), and Schneider and Whitlach (1991).

6.2.3 Literature from South Africa

Bailey and Buckley (2005) estimated water demand in Durban using monthly average household water consumption data between 1996 and 2003 for low, middle and high-income group samples. The sample data was used to generate a frequency distribution for the annual mean monthly demand. Using both the linear and log-linear regression models, the study revealed price elasticity of water demand to be -0.55 (log-linear) and -0.52 (linear) for the low-income group, -0.14 (both linear and log-linear) for the middle-income group, and -0.10 (both linear and log-linear) for the high-income group.

Bailey and Buckley (2005) suggest that the price elasticity found using the log-linear model is a better estimate, since the log-linear model performed marginally better than the linear model in the regression analysis. Although water demand in Durban is inelastic, as revealed by the study, it can be noted that a comparison of the elasticity figures show that water demand is more elastic among low-income earners than among middle- and high-income earners.

Such findings confirm the results from Vuuren et al. (2004) that revealed the price elasticity of water demand in eThekwini to be -0.13 (low income), -0.13 (middle income) and -0.14 (high income). Coupled with results from Dockel (1973), and Jansen and Schulz (2006), it can be noted that the responsiveness of water demand to changes in price is inelastic in South Africa. However, it is worth observing that the -0.55-elasticity figure for low-income earners produced by Bailey and Buckley, suggesting higher elasticity among the poor, contradicts the results of and those of Jansen and Schulz (2006), who suggest the opposite. These inconsistencies inspire the need for further research on the nature and form of responsiveness of water demand to water price changes in South Africa.

Vuuren et al. (2004) used the participative payment strategy testing (PPST) and contingent valuation (CV) methodologies to determine the price elasticity of water demand for low-, mid- and high-income groups, and to compare different water payment strategies in the Tshwane, Cape Town and eThekwini metropoles. The hypotheses tested in the study were that price does influence the amount of water demanded by all classes of water consumers, and that the perception of water consumers about water consumption may be changed by appropriate water-payment strategies. Surveys were conducted through face-to-face interviews among low, medium and high-income population groups of residential water users in the three metropolitan areas.

The results confirmed the hypotheses of the study to be true. The price elasticity of demand for low-income groups was -0.37 (Tshwane), -0.11 (Cape Town) and -0.13 (eThekwini). The price elasticity of water demand for middle-income groups was -0.17 (Tshwane), -0.10 (Cape Town) and -0.13 (eThekwini). High-income groups were revealed by Vuuren et al. to have price elasticity of water demand of -0.12 (Tshwane), -0.09 (Cape Town) and -0.14 (eThekwini). The results suggested inelastic water demand in all three metropoles and for all income groups, because the absolute price elasticity of water demand was less than -1. Findings from this study are compatible with those produced by Dockel (1973), and Jansen and Schulz (2006), because they all have elasticities of less than -1. However, unlike Vuuren et al., Jansen and Schulz suggest that the demand for water services in South Africa is more elastic among the rich and inelastic among the poor.

Jansen and Schulz (2006) used panel data analysis as well as the two-stage least squares method in a model that aimed to demonstrate how different factors influence water consumption; among them, the price of water in Cape Town. The study also aimed to estimate the price elasticity of water demand using data from households in the Cape Flats area of Cape Town. Jansen and Schulz used data covering a period of up to 60 months, from July 1998 to June 2003.

Both primary and secondary data were used in the study. Primary data was harvested through a survey in five suburbs of the Cape Flats, while secondary data was obtained from local government and the City of Cape Town. Jansen and Schulz discovered that water consumption was insensitive to price changes among the poor, while the richest group of households reacted to price changes much more. It was also revealed that the short-run price elasticity of water demand on the Cape Flats is negative. The key finding from the study by Jansen and Schulz was achieved when the data was split into two groups: low income and high income. It was discovered that the price elasticity for water demand for the low-income group was only -0.23, whereas the high-income group had a price elasticity of -0.99.

The results of the study by Jansen and Schulz agreed almost in absolute terms with the results from Dockel (1973), who used the contingent valuation method and estimated the price elasticity of demand for Gauteng residents to be -0.69. This supports the study by which estimated the short-run price elasticity of water demand for high-income Alberton residents to be -0.19 in the short run and -0.73 in the long run, and the short-run price elasticity for Thokoza residents to be -0.14. Such consensus leads to the conclusion that the degree of responsiveness to changes in water-service tariffs in South Africa is higher among the rich, and lower among poor South Africans who do not have alternative sources of water.

Nahman and de Lange (2013) used a trans log production function approach (the marginal productivity approach, as proposed by Wang and Lall, 1999 and 2002) to estimate the marginal value of industrial water use, and the price elasticity of demand associated with industrial water use in South Africa. The adopted model assumed the price elasticity of water demand to be equal to the marginal cost of water use. Nahman and de Lange used both primary data (obtained through a survey) and secondary data. The secondary data, obtained from 30 companies that had not responded to the survey, was used as a supplement to the original primary data set of 28 survey respondents; which was initially considered insufficient, since the estimated model had a lot of explanatory variables (14 explanatory variables). The total sample used in the study therefore rose to 58 companies.

Results from the work of Nahman and de Lange showed that the price elasticity of water demand for South African businesses averaged -3.00, ranging from -0.78 for food producers to -6.81 for forestry and paper businesses. These results suggest that the companies examined are highly responsive to changes in water price (an increase in water price would lead to a reduction in water use, therefore water demand is deemed to be highly elastic). The implication of this result is that increasing water tariffs could be an effective strategy for reducing water use among industrial users, *ceteris paribus*. However, it is worthwhile noting that the South African estimates of the price elasticity of industrial water demand, as revealed by Nahman and de Lange, appear to be something of an outlier among those of other developing countries, and the authors themselves raised doubts about the validity of their estimates This therefore inspires the need for further research on the exact degree of responsiveness of water demand by South African business to changes in the price of water.

6.3 Methodological approach

An important feature in designing a tariff structure is its capacity to raise revenue (to cover the target portion of costs). The revenue-raising design considerations need to be informed by an analysis of the revenue-raising merits of two-part tariff structures and third-degree price discrimination (such as an IBT structure), and the costs associated with gathering the information required to calculate optimal revenue-raising discrimination. One of the information requirements is the price elasticity of the sub-markets defined by the proposed volumetric steps of the IBT structure. Another informational requirement is the identification of other key factors that influence demand, such as the availability of substitutes (which serves to increase the absolute value of the price elasticity of demand). This theory may be applied in order to derive formulas through which to populate a revenue-raising structure, such as an IBT structure.

An IBT structure for water services is consistent with minimisation of an inevitable cost deficit (Hosking and Jacoby, 2013). To reflect on the revenue-raising merits of current tariff structures, it is required that own price elasticity is estimated for both short-run and long-run time horizons, and for differing sections of the demand curve (as volume of service increases). The object is to estimate the demand function for water services. Our estimation equation will relate to the volumetric ranges of the IBT, thereby enabling volumetric-related price elasticities to be calculated.

We will also consider introducing lags, to test for long-run effects on own price elasticity. The reason single-equation models are typically applied to estimate demand for water services is that no substitutes are available – at least in metropolitan municipalities. Often a double-log functional form is estimated; but it may be appropriate for this study if instead of two equations, only one is estimated, and it must allow for elasticity changes along the demand curve. Under the double-log functional form, elasticity is constrained to be a constant; but under a generalised Cobb-Douglas form, it can change (Gaudin et al., 2001).

A sample of municipalities is randomly selected. This is done as a measure to avoid the need for the correction of bias in sample, which is normally the case when using the two-step Heckman estimation approach. In the South African literature, it is common practice that preference in municipal selection is given to metropolitan municipalities, because they constitute the main peer reference group for municipal water-service tariff setting.

6.4 Empirical Results

This report intends to shed light on the revenue consequences of raising water tariffs for municipalities in South Africa. We elicited the data necessary to estimate required water-service demand functions. We began the analysis by collecting a comprehensive dataset, spanning six years, from the City of Tshwane. The water consumption trends for the City of Tshwane, considering adjustments in water tariffs over the period, are shown in Figure 2 below:

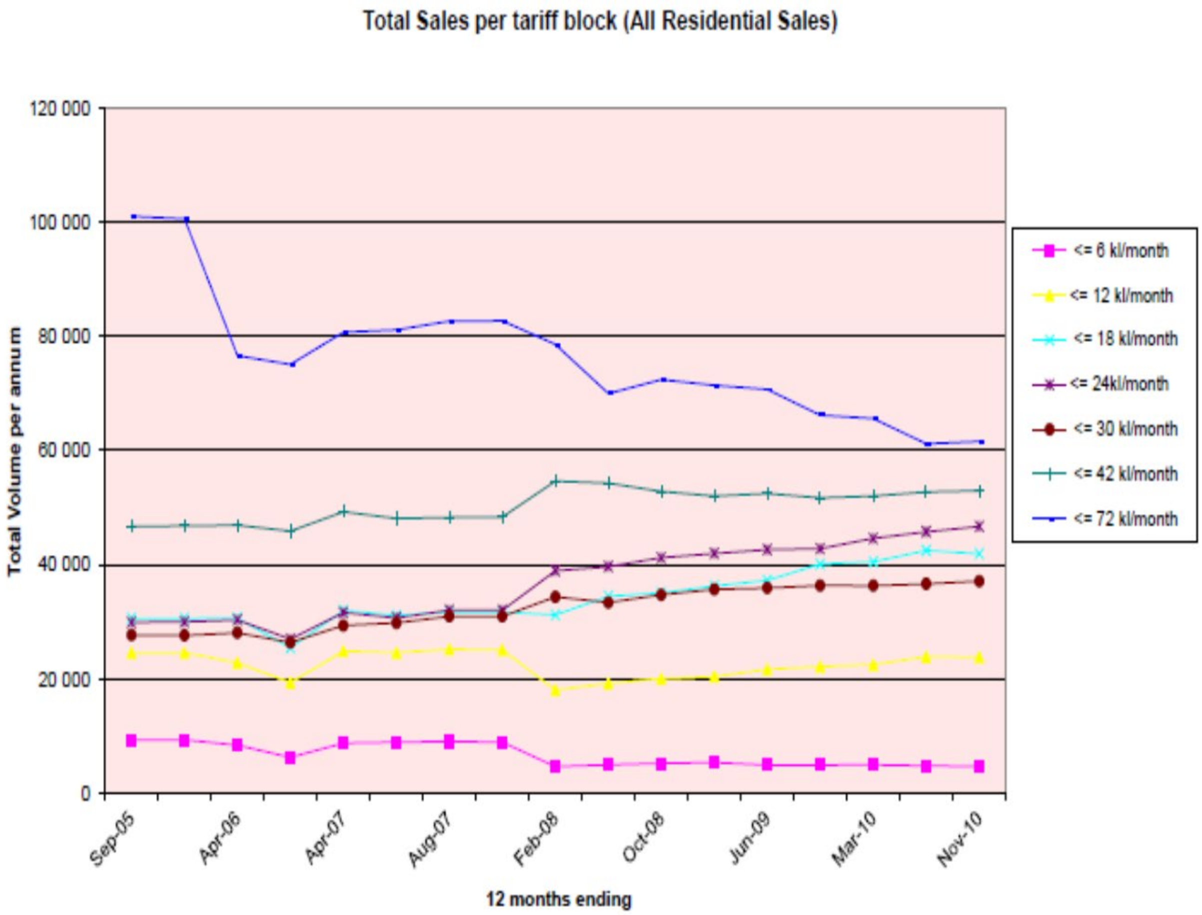


Figure 2: Water consumption trends

Source: Rall, 2016.

For the period under review, the City of Tshwane water tariff structure had seven blocks. The trends capture how each block responded to increases in water tariffs over the years. The trend in pink represents the 'least costly' block, comprising mostly the poor. The trend in blue is the other side of the coin, representing the 'costly block', comprising mostly high-income households that consume significant quantities of water per month. Water-service tariffs in the block shown by the pink trend are low and not cost-reflective, because the primary purpose for this block is to meet the basic households' water need. However, for the blue trend, water tariffs are either cost reflective or closer to being cost reflective.

The picture that emerges is that lower-income groups reduce their water consumption marginally as water tariffs increase. This may be because lower-income groups have fewer options, as they are only getting the basic water required to meet basic needs. There is a significant reduction in water consumption for high-income earners (blue trend), indicating that users in this category are sensitive to water-tariff increases. Users in this category spend more on water already, which could be the reason there is a decrease in consumption as tariffs increase. The implication is that municipality revenue goes down as water tariffs are increased, such that the municipality loses its high-income payers permanently as they switch to less water-consuming activities. Subsequently, the ability of the municipality to cross-subsidise is compromised. We expand on this dataset by putting together a dataset of 48 municipalities and apply a random effects model to analyse the water demand in these municipalities. The estimation results are presented in Table 8 below:

Table 8: Water demand function for South African municipalities

Water demand	*Coef.*	*Std.Err*	*Z*	*P>|Z|*	*[95% Conf.Interval]*	
Increase in water tariffs	*-0.03760*	*0.02686*	*-1.40*	*0.161*	*-0.09025*	*0.01504*
Increase in household income	*0.77863*	*0.18739*	*4.16*	*0.000*	*0.41134*	*1.14592*
Increase in the number of households	*-0.45204*	*0.19130*	*-2.36*	*0.018*	*-0.82700*	*-0.07709*
Increase in rainfall	*0.04047*	*0.02234*	*1.81*	*0.070*	*-0.0033*	*0.08426*
_cons	*-3.86772*	*1.89864*	*-2.04*	*0.042*	*-7.58900*	*-0.14645*

As predicted by economic theory, there is an inverse relationship between a water tariff and water demand. This is captured by the negatively-signed water tariff coefficient (indicated by lprice). This suggests that an increase in water tariff will be accompanied by a reduction in water demand, which means that there will be a decrease in revenue generated by the water sector. However, we find that 'lprice' is not statistically significant, which implies that increases in water tariffs do not matter. More precisely, the results suggest that changes in water tariff do not affect water consumption at all.

We find that the other variables (that is, other factors) – such as income, rainfall and the number of households – are important determinants of water demand. In other words, the results show that increases in the income of households will result in increases in the demand for water. Equally, the results reveal that increases in rainfall levels are also predicted to lead to more consumption of water. In addition, the results show that an increase in the number of households results in a reduction in water consumption.

6.5 Conclusion

The Increasing Block Tariffs (IBT) structure is the preferred water-pricing policy in South Africa. IBTs allocate prices to the volume of water used within a defined block. The price and size of the first block is given much attention, such that in most cases, it is deliberately set below the cost of delivery. In South Africa, the first block is provided free, under the Free Basic Water (FBW) policy. The IBT pricing structure therefore operates as a subsidy with respect to the first block. The FBW policy prescribes the free provision of the first 6 kilolitres of water, even though the exact amount provided free above this level is at the discretion of the individual water provider. However, the effectiveness of such subsidies in developing countries is questionable, as most poor people do not have access to metered water. Subsidies can have the unintended consequence of being to the advantage of high-income groups instead.

In South Africa, water tariffs and the FBW allocation vary across municipalities, for reasons that reflect water-scarcity conditions, local municipality objectives and political considerations. However, a comparison of average water prices across municipalities will generally not be informative, as these prices are not weighted to account for differences in socio-economic or political characteristics (Hoque and Wicheln, 2013).

The solution to the water supply and rapid demand challenge requires efficient water use, efficient management, technological innovation, water conservation and appropriate pricing. Our study focused on water pricing, as one of the main reasons water is often wasted is its under-pricing. According to Global Change (2006), in developing and developed countries (particularly for agricultural use) the government grants subsidies. Eradicating such subsidies and setting tariffs for water at the right levels would provide incentives for conservation and create a conducive environment for more investment in more efficient technologies.

A water tariff is simply a price that is assigned to water services by a water utility. Water tariffs are often formulated by governments, who must often find a delicate balance between their various goals. Among others, these goals include efficiency, and social goals such as equity and fairness.

Water tariffs vary widely in their structure and levels between countries. Hillards and Symmonds (2011) argue that charging for water was introduced precisely to nudge users into using this precious resource more sparingly.

However, the correlation between water demand and water price is questionable. If water was a private good, it would fluctuate according to certain events, such as weather conditions. For example: if there was a drought, the price of water would increase, and the demand for water would decrease. However, water is a public good, and influenced by many other non-monetary issues

This deliverable assesses the sensitivity of the price of water under an increasing block and determines the correlation between water demanded by households and the price of water, and other determinants influencing water demand. To approximate a neutral value for the price elasticity of water, we use the random effects models.

Revenue from the sale of water in South Africa increased from R8.09 billion in 2014/15 to R8.69 billion in 2015/16, due to annual increases in the water tariff. The augmentation funds declined from R2.4 billion in 2014/15 to R1.5 billion in 2015/16 due to a budget reduction by the national treasury, while construction revenue declined from R853 million in 2014/15 to R449 million in 2015/16, due to uncertified work. Construction revenue reflects a decline of 47 per cent during 2015/16.

Economists have traditionally urged the use of the price mechanism to allocate scarce commodities, except for certain types of public goods. However, water is not considered a public good, because its units can be separated and charged at a price. The characteristics of water that nominate it for public control and research are its economic explosion as a public utility, and the unscientific feeling that water is special; as a result, it has been under-priced and overdeveloped. The price mechanism has not been used before to allocate water, only to raise revenues. The relationship between the cost of water and consumption is described as price elasticity. The relationship in its simplest form can be presented as a linear relationship, where consumption (Q) decreases linearly as the price of water (P) increases.

The demand functions estimated in this study, as well as established trends, reveal that increases in water tariffs are more likely to result in a decline in revenue generated by the water sector. There is a trade-off between the need to raise revenue and the need to conserve water. If the policymakers' goal is to conserve water and reduce water consumption, increasing water tariffs is the means to achieve this. However, if the aim is to raise revenue, significant increases in water tariffs are not the way to go. Partly due to successful water restrictions programmes, water conservation and technological advancements, both water sales and water-related revenues are falling in South Africa as a whole. With sales and revenues declining, it is not clear how the water authorities will be able to cover the costs associated with water treatment and delivery. Most importantly, it is not clear how WSAs will be able to meet these costs while still encouraging much-needed water-conservation efforts.

CHAPTER 7: AN ANALYSIS OF INTERGOVERNMENTAL TRANSFERS AND MUNICIPAL BAD DEBTS

7.1 Introduction

Municipalities make an important contribution to poverty alleviation and economic development, through the provision of free basic services (FBS) to poor households and by investing in infrastructure and associated services that are critical for economic growth (National Treasury, 2011/12). To deliver these services effectively, a municipality relies on two important sources of revenue. One is from the national sphere (local government equitable-share allocation, or LES, and conditional grants from national government), while the other is the municipality's own revenue, which is composed mainly of property-rate taxes and charges for providing water, electricity, refuse removal, sanitation and other services. Figure 3 below shows a breakdown of municipal revenue as a proportion of total revenue for the 2014 and 2015 financial years.

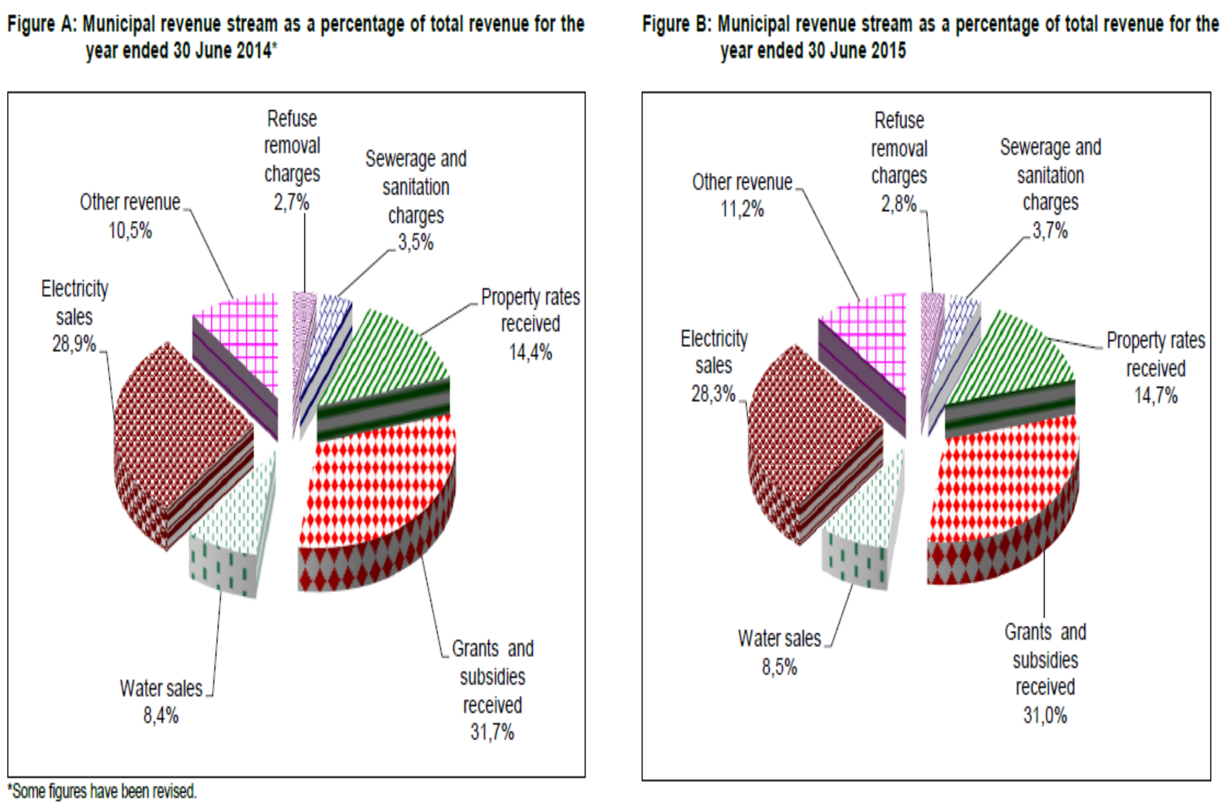


Figure 3: Municipal revenue stream as percentage of total revenue, for years ending 30 June 2014 and 30 June 2015

Source: Statistics South Africa, 2016

Municipalities in South Africa generate about 92 per cent of their own revenues (Republic of South Africa, 2001). The remaining 8 per cent of revenues are transfers from the national and provincial governments. However, huge differences exist among the municipalities. For instance, metropolitan councils mobilise on average 97 per cent of the revenues themselves, while some smaller municipalities only raise 65 per cent of their revenues from own sources. Revenue sources also differ between municipalities, depending on local circumstances (Mavahungu, 2011).

According to National Treasury (2011/12), municipal dependence on grants as a source of revenue has risen dramatically. Municipal own revenue is expected to grow at a slow rate of 2.3 per cent, while grants to municipalities are expected to grow by 14.9 per cent over the medium term, in real terms. This reflects both the expansion of the expenditure responsibilities of municipalities as well as a decline in own-revenue collection efforts. Co-ordination between transfer programmes within locally funded municipal expenditure remains problematic.

A major financial problem in many municipalities in South Africa is the inadequate collection of service charges, due to widespread non-payment. In South Africa, municipal consumer debt refers to the non-payment of property rates and fees or charges for services provided by municipalities. Municipal consumer debt encompasses late payments for property rates, service and other municipal charges, and amounts that are considered irrecoverable.

Municipal consumer debt has several potential impacts. It can cripple the cash position of a municipality, and therefore its ability to fulfil constitutionally-mandated responsibilities. Municipal consumer debt can also reduce the finance available for the delivery of basic services, infrastructure, and maintenance and upgrading. In addition, it can prompt the need for greater cross-subsidisation from richer households/businesses, potentially overburdening the existing tax base.

Outstanding payments also represent foregone resources that could have been used to improve the living conditions of the poor. There are several possible reasons as to why this debt arises. Poor performance by municipalities, such as inaccurate billing, weak credit control measures and dysfunctional customer-service mechanisms may serve to reinforce non-payment, as those consumers who can pay become unwilling. On the other hand, consumers may be unable to pay because of unemployment and poverty. The causes of non-payment in South African municipalities have been the focus of various studies. However, most of the studies were carried out in the early to mid-2000s; changes in the local government sphere warrant a thorough and updated investigation of the factors that drive this kind of debt.

The trend towards an increase in municipal debt is a disturbing national phenomenon. In some 31 per cent of the municipalities, "service debt is growing at a rate of less than 5% per year", while in another 37 per cent of municipalities, "service debt is growing at a rate greater than 10% per year". For 32 per cent of municipalities service debt is growing at a rate greater than 20% per year

Aggregated year-to-date expenditure reported by metropolitan municipalities amounts to R141.4 billion, or 65 per cent of the adjusted budget of R217.5 billion. The aggregated adjusted capital budget for metros in the 2015/16 financial year was R35 billion, of which they spent 46.6 per cent, or R16.3 billion. When billed revenue is measured against their adjusted budgets, the performance of the metros shows surpluses across three core services for the third quarter of 2015/16. This does not consider the collection rate.

Water revenue billed was R17.7 billion, against expenditure of R16.5 billion; electricity revenue billed was R50.5 billion, against expenditure of R46.1 billion. The revenue billed for wastewater management was R7.1 billion, against expenditure of R4.7 billion, and levies for waste management billed were R5.6 billion, against expenditure of R5.7 billion (National Treasury, 2011/12).

As at 31 March 2016, aggregated revenue for secondary cities was 70.1 per cent or R35.1 billion of their total adjusted budgets of R50.1 billion for the 2015/16 financial year. Year-to-date, the spending level for the secondary cities on average was 61.4 per cent, or R32 billion. Capital spending levels averaged 42.2 per cent of the adjusted capital budget. The performance against the adjusted budget for the four core services for the secondary cities for the third quarter of 2015/16 also shows surpluses against billed revenue, without considering the collection rate. Water revenue billed was R4.3 billion, against expenditure of R3.5 billion; electricity revenue billed was R12.6 billion, against expenditure of R10.8 billion; the revenue billed for wastewater management was R1.9 billion, against expenditure of R1.2 billion; and levies for waste management billed were

R1.4 billion, against expenditure of R1.1 billion (National Treasury, 2011/12).

The aggregated year-to-date actual collection rate was 91 per cent, compared to an adjusted budgeted collection rate of 92.1 per cent. This represents an aggregated underperformance of 1.1 per cent. Furthermore, very high levels of non-revenue earning water persists in South Africa, which includes both physical water loss through leakages in the system, and water that is not paid for. It is estimated that on average, 37 per cent of water managed by municipalities yields no financial return; and this excludes free basic water (National Treasury, 2011/12).

A study by the Centre for Development Support (CDS, 2001) at the University of the Free State concluded that non-payment is primarily an issue of inability to pay. It argued that the poverty of many households made them unable rather than unwilling to pay; hence the need for free basic services to the poorer segments of the population, and/or a lowering of the rates. This argument is supported by Fiil-Flynn (2001). However, other studies claim that widespread unwillingness to pay exists, due to an 'entitlement culture' and a 'culture of non-payment' inherited from the apartheid era (Ajam, 2001; Johnson, 1999). It is assumed that an understanding of the relationship between payment and the provision of services is a critical factor for compliance. Consequently, the prescription is education and the political mobilisation of ratepayers, combined with the restoration of law and order.

7.2 Context and objectives of the study

Water availability is the single greatest and most urgent development constraint facing South Africa. Scarcity of water has been linked with the incidence of poverty and disease in developing countries (Falkenmark, 1994); Ashton and Haasbroek, 2002). While Smakhtin et al. (2001) argue that water-resource managers should use supply-side solutions (such as major inter-basin transfers and water pumping schemes) to meet rising water demands, such solutions are not sustainable in the long run. This is partly due to their high running costs, and the fact that exploitable water sources are limited. The South African government, through the Department of Water and Sanitation (DWS), has therefore turned to demand-side policies, such as including a mandatory water-resource management fee in the water tariff charged to consumers.

While poor households registered as indigent qualify for additional free basic water, determining the quantity of free basic water for each household is particularly challenging for municipalities. Firstly, municipalities face difficulty in determining who is poor and thus qualifies for free water. This difficulty has often resulted in wealthy households receiving free basic water that was essentially meant for poor households. Secondly, most of the poor in the rural areas receive limited amounts of free water through standpipes, and therefore do not benefit fully. In addition, those without access to publicly provided water do not benefit at all from the programme.

As already indicated in previous chapters, the retail setting guidelines recommend the inverted block tariff (IBT), linked to an adjusted average cost. However, the guidelines do not indicate what type of marginal or average costs to consider, leading to arbitrary setting of water tariffs among municipalities. More guidance and insight is therefore required in the guidelines for tariff setting for municipal water services. This chapter brings that insight, by analysing the long-run consequences of different transfer payments and revenue-raising arrangements in the water-services tariff structure using regression analysis. Municipal time series and cross-sectional data for eight water-service authorities is elicited through surveys and other means on the scale of local transfer payments in water-service cost collection (implicit in the tariff and bad debts), as well as tariff-increase rates over time, and correlated with available development-correlated variables, such as value of building plans passed, and demand for electricity. Based on the results of various regression analyses, implications will be drawn for discussing the long-run consequences of tariff increases and changing relative water-service costs between municipalities.

7.3 Theoretical literature

The theoretical literature sub-section presents the views of various theories regarding the topic of this study. Theories discussed are: the pure theory of local expenditure, the X-inefficiency theory, and the public choice theory.

7.3.1 The pure theory of local expenditure (Tiebout Model)

Developed by Charles Tiebout (1956), the pure theory of local expenditure (Tiebout model) asserts that if there were a large enough number of local government jurisdictions, and each of these local governments offered a different mix of local public goods and taxes, individuals would reveal their true preferences for public goods by choosing a local government jurisdiction in which to live (Tiebout, 1956). The Tiebout model suggests that citizens – who have different tastes – are mobile and choose to live in the local government jurisdiction that produces a mix of tax and public good outputs that corresponds most closely with their preferences. Their choice of location therefore reveals their preferences for public goods. The greater the number of communities and the greater the variation in taxes and public services offered, the closer the consumers will be to satisfying their preferences. Tiebout described a theoretical solution for the problem of preference revelation, a phenomenon that inhibits the achievement of allocative efficiency (Black et al., 2005).

In the Tiebout model, it is assumed that all individuals are fully mobile and have full information, many jurisdictions to choose from exists, no geographical employment restrictions exist, no spill-overs across jurisdictions exist; and there are no economies of scale in the production of public goods. The Tiebout model demonstrates that a decentralised fiscal system can be welfare-increasing, compared to a centralised system that imposes a standardised public-good tax mix on people, irrespective of their varying tastes. In principle, fiscal decentralisation can contribute to more efficient provision of local public goods and services, by aligning expenditure more closely with local priorities (Black et al., 2005).

The Tiebout model is directly applicable to this study, in the sense that it looks at the provision of public goods and how citizens make choices. However, it should be noted that the Tiebout model is based on a few strict assumptions. If there are a limited number of communities, these may compete to attract outsiders. Although this behaviour may provide an incentive for efficient production of public services, the mix and level of public services provided may not be Pareto efficient.

Moreover, most of the assumptions underpinning the Tiebout model do not really exist in the real world. Although the Tiebout model has several weaknesses, it is applicable in South Africa, where power is decentralised. The devolution of power within different tiers of government in South Africa makes the Tiebout model more applicable. Another reason this study considers the Tiebout model appropriate is because it explains the behaviour of local authorities as concurring with the main area of analysis in this study.

7.3.2 The X-inefficiency theory

Developed by Leibenstein (1966), the X-inefficiency theory explains X-inefficiency (also referred to as technical inefficiency) as a situation in which existing resources are not utilised in the most efficient manner; which is to say, not obtaining the maximum possible output from a given set of resources. X-inefficiency is the difference between the efficient behaviour of organisations implied by economic theory, and their observed behaviour in practice. Sometimes called organisational slack, it occurs when technical efficiency is not being achieved due to a lack of competitive pressure, lack of motivation by production agents, lack of market information, and/or incomplete knowledge of production functions. The X-inefficiency theory assumes allocative economic efficiency where organisations seek to maximise economic profits. Organisations accomplish this by adjusting the inputs used or the output produced.

It is possible with monopolies for X-inefficiency to persist, because the lack of competition makes it likely the monopoly will use inefficient production techniques and still stay operational. The X-inefficiency theory looks at the outputs that are produced with given inputs and is the result of factors such as human inertia, lack of motivation stemming from a lack of competition, pressure from labour unions, sub-optimal performance, and waste. These inefficiencies are mainly due to intra-organisational activities and errors made by individuals, which affect the organisation's performance. X-inefficiency because of monopolistic powers is explained with the aid of the diagram in Figure 4 below:

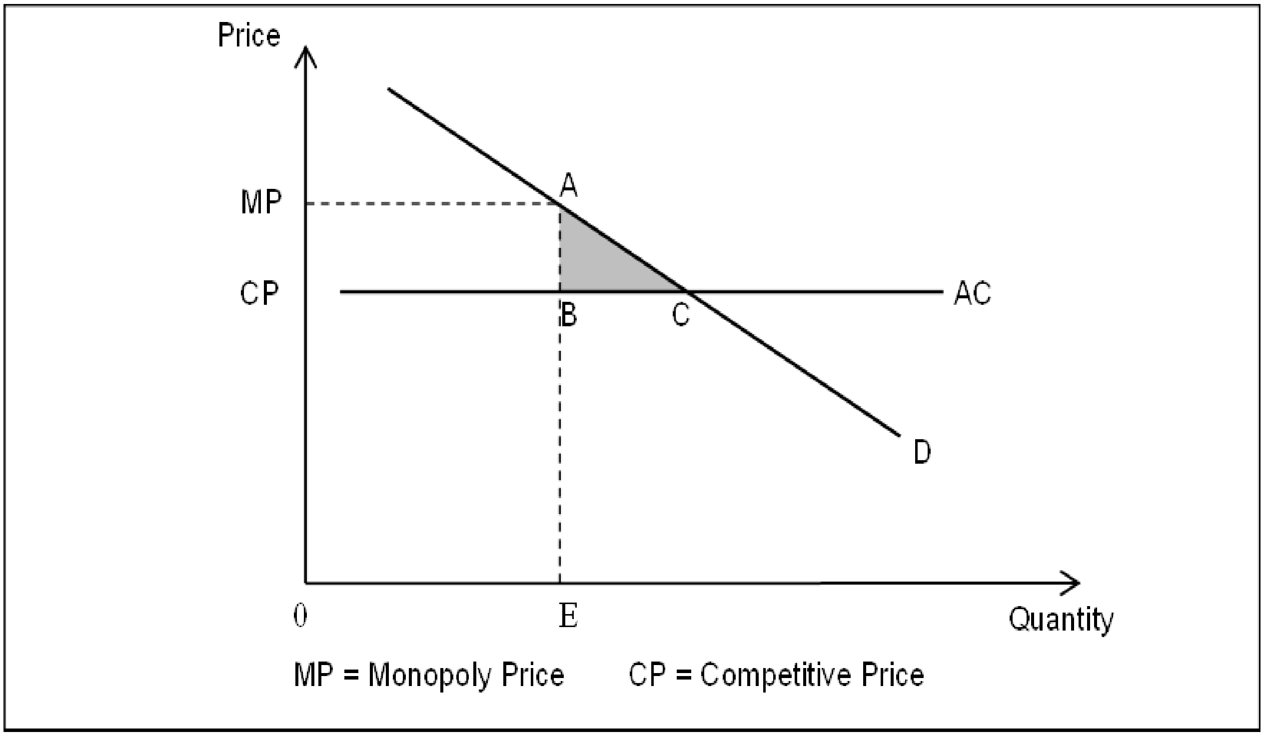


Figure 4: Monopoly and X-inefficiency

Source: Leibenstein (1966)

In Figure 4, costs are assumed to be constant within the relevant range. D is the demand function. Under competition, price and quantity are determined at the intersection C. The monopoly price (MP) is greater than the competitive price (CP) by AB. Monopoly output is determined at point A. Welfare loss due to monopoly, which is the same as the welfare gain if we shift to competition, is equal to the triangle ABC.

Black et al. (2005) criticised the theory, explaining that X-efficiency alone is an insufficient measure of economic efficiency, since the technically efficient production of goods and services by itself does not necessarily reflect the needs of consumers. Using the production possibility curve (PPC), Black et al. argued that X-efficiency ensures that society is on its PPC but cannot determine where exactly it should be on the PPC. However, although the X-inefficiency theory may be criticised, it is strongly applicable to this study, as some of the reasons municipalities have for failure to provide adequately affordable water supplies are human inertia, lack of knowledge and lack of competition, among other reasons. Some municipalities even buy expensive water equipment that they can neither operate nor maintain (see Banerjee et al., 2008). Such errors increase the costs of water provision, which may be difficult to recoup. The water supply industry is protected by the government, leading to municipalities and other water providers enjoying some undeserved monopolistic powers. The X-inefficient theory is therefore applicable to this study.

7.3.3 The public choice theory

Buchanan and Tullock's (1962) theory asserted that policymakers act to maximise personal welfare rather than social good. It states that policymakers are ordinary men who make the most of their decisions in terms of what benefits them, not society – that is, when elected officials make policy decisions, their emphasis is on votes. The only appropriate loss that policymakers seek to achieve is:

$$L = b_1 VL \qquad b_1 > 0 \tag{7}$$

where L is the social welfare loss, b_1 is the weight given to votes lost and VL is the vote loss. Policymakers are assumed to maximise votes gained, not social welfare. Economic goal variables enter the picture because the behaviour of the economy affects votes. Therefore, vote loss might be represented as:

$$VL = c_0 + c_1(U - U^*)^2 + c_2(P - P^*)^2 + c_3(y - y^*)^2 \tag{8}$$

where, U is the level of employment, P is the inflation rate, y is the growth in real income, U*, P* and y* represent the target levels of these variables respectively, c_1, c_2 and c_3 represent the loss of votes resulting from the macroeconomic goal variables from target levels. The representation assumes that vote loss depends on the squared deviation from the target level, if a heavy weight is given to large deviations from desired target levels. The c_0 parameter represents all other influences on voter behaviour.

Actions by policymakers who aim to minimise vote loss differ from the actions of those who wish to minimise social loss. This is a result of the 'collective rationality' assumption, where vote loss because of 'economic concerns' is proportional to social-welfare loss. The collective rationality assumption suggests that when economic and social variables affect voting behaviour, voters reward or punish incumbent politicians depending on their performance in minimising social-welfare loss. In this case, the optimal strategy to minimise vote loss (equation 1.1) is to minimise social-welfare loss (equation 1.2). In the absence of collective rationality, it is suggested in this theory that the behaviour of the vote-maximising policymaker deviates from social-welfare-maximising behaviour.

The public choice theory is applicable to this study because setting water service tariffs in South Africa is a political decision, made considering the consequences politicians and other policymakers would bear should their water-service policies make citizens worse off. Coming up with a new set of guidelines for water services in South Africa therefore requires a clear understanding of the country's politics. Politicians automatically dismiss any set of guidelines that may cost them the electorate.

However, it can be noted in criticism that although the model has proved useful in explaining an important element of politics, not all individuals in the real world always act in accordance with the behavioural assumptions made. The hypothesis that voters are myopic is directly inconsistent and holds no water in the modern world. Voters today are sufficiently rational that they can distinguish between politicians who strive for personal gain and those who seek to maximise social welfare.

In conclusion, this section explained some theoretical literatures that underpin the topic investigated in this study. Theories discussed in this section are the pure theory of local expenditure (Tiebout theory), the X-inefficiency theory, and the public choice theory. The Tiebout theory and the public choice theory gave insight into the motives and behaviour of policymakers who have a final say on the setting of water tariffs. An understanding of the behaviour and motives of policymakers, as explained by these theories, helps to determine the right set of tariffs that will give satisfaction to both policymakers and society. The X-inefficiency theory explained the behaviour of institutions when there is a lack of competitive pressure, lack of motivation by production agents, lack of information about market conditions, and incomplete knowledge of production functions. These theories are therefore relevant to the topic discussed in this study, because they give insight into what to consider when determining guidelines for tariff setting for municipal water services.

The long-run consequences of different transfer payments and revenue-raising arrangements in the water services tariff structure will be analysed by regression analysis. Municipal time series and cross-sectional data for water service authorities (WSAs) will be sourced to assess the relationship of national transfer payments to bad debts and with development.

7.4 Findings

In this section, we firstly present the trends, and discuss the correlations found between the levels of bad debt accumulated by municipalities and the amounts of the water-specific grants they receive from government. Secondly, we analyse the consequences of different transfer payments and revenue-raising arrangements in the water-services tariff structure. We use data from the National Treasury covering a five-year period (from 2011/12 to the 2015/16 financial year). The emphasis here is on presenting trends, both for bad debts and for transfers from national government to municipalities in the form of grants earmarked for water provision. These results are presented in Table 9 below:

Table 9: Grants, write-offs and revenue collection in the water sector

Financial Year	Water Grants		Water Write-off		National Collection Rate – water revenue
2011/12	2,806,889,000	11.32%	286,220,000	1.40%	84.57%
2012/13	3,218,133,000	11.53%	641,380,000	2.80%	90.33%
2013/14	4,424,201,000	14.31%	511,469,000	2.60%	90.33%
2014/15	5,680,764,000	17.07%	353,686,000	1.60%	84.10%
2015/16	8,682,629,000	22.91%	1,306,060,000	5.80%	90.40%
Total	**24,812,616,000**		**3,098,815,000**		

Source: National Treasury, 2011/12-2015/16

The first column in the table above shows the financial year. Our table shows a five-year period, from the 2011/12 financial year to the 2015/16 financial year (the most recent data we could obtain). The second column reflects the total transfers from national government to the water sector derived through the Division of Revenue Act, No 6 of 2011. The third column shows the percentage of revenue distributed to the water sector as a proportion of total conditional grants transferred from national government to all South African municipalities. The fourth column shows water debts written off by municipalities, while the column that follows reflects the written-off amount as a percentage of aggregate municipal water debts. The sixth and final column captures the national (i.e. all municipalities) collection rates related to water-service charges.

A picture that emerges from column three is that the share of revenue going to municipalities over the five-year period increased over time. In real terms, the share that goes to the water sector has increased by 323.28 per cent from the 2011/12 period to the 2015/16 financial year. Column five shows that this is accompanied by an increasing trend in the amounts of write-off by water service authorities. Bad debts have gone up by 219.15 per cent. The national collection rates have improved marginally over this five-year period. Overall, it is not clear whether there is a correlation between transfers to municipalities and their tolerance levels for bad debt. Figure 5 below is also intended to assess whether these two are correlated.

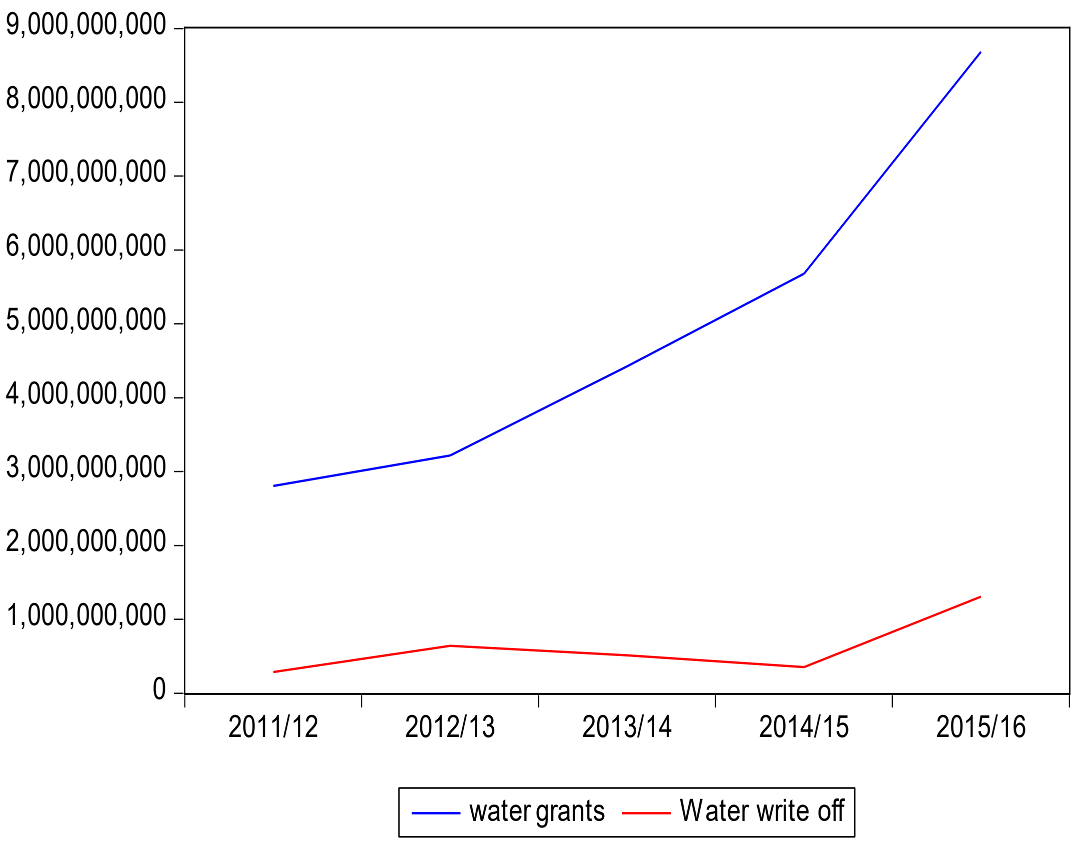


Figure 5: The trends in the municipal debtors and intergovernmental transfers to municipalities

Source: National Treasury, 2011/12-2015/16

Figure 5 above shows the trends for the levels of water grants received by municipalities and the number of water-related write-offs between 2011/2012 and 2015/2016. The value of water grants received by municipalities increased quite substantially, from R3 billion in 2011/2012 to just under R9 billion in 2015/2016. The yearly totals for water-related write-offs have increased since 2011/2012, with the most significant increase occurring between 2014/2015 and 2015/2016.

The general trend shows a positive relationship between municipal debt and the amounts received in water grants. The increments in bad debts may potentially impact negatively on ability to deliver services. This is because a customer's defaults on an amount due are matched to the revenue associated with them. It is for this reason that we also present levels of revenue collection in Figure 6 below:

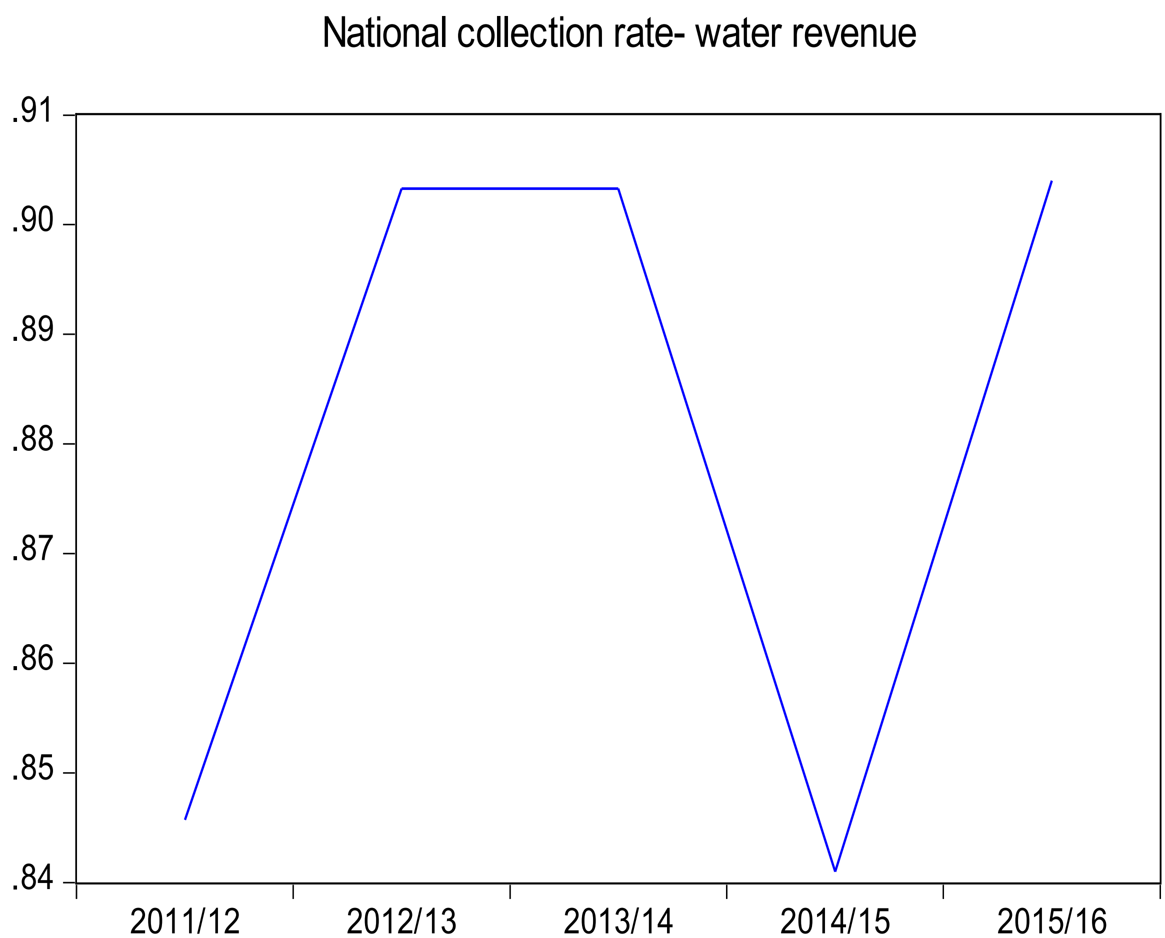


Figure 6: Overview of Municipal revenue trends

Source: National Treasury, 2011/12-2015/16

In South Africa, municipal sales and property taxes are widely used to generate revenue. This is one of the two main ways in which revenue is generated. The other major source of revenue is through intergovernmental fiscal transfers. Some municipalities can generate a lot of own revenue, while poorer – especially rural – municipalities raise virtually nothing and are almost totally dependent on funding from national transfers. The higher the bad debts, the less own revenue is generated by municipalities. Revenue collection matches bad debts, which was expected. Essentially, poor consumer debt collection constrains municipal own-revenue generation ability and leads to irrecoverable debts. Figure 7 below sheds light on the main sources of bad debts.

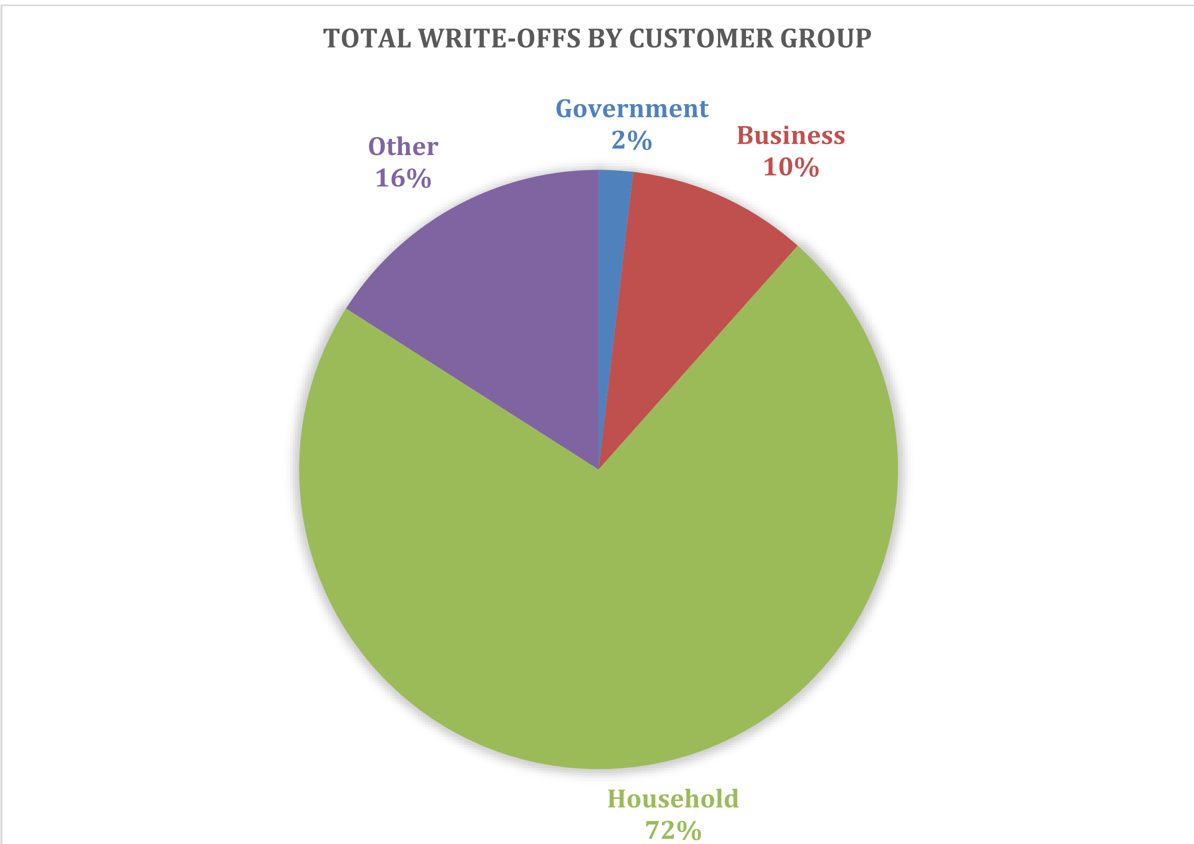


Figure 7: Sources of municipal bad debts

Source: National Treasury, 2011/12-2015/16

Figure 7 above shows the total write-off percentages incurred by a municipality attributed to different consumer groups. The total write-off includes contributions from water write-offs, electricity write-offs, property rates write-offs and wastewater management write-offs. The greatest contributors to the write-offs are households, with almost three-quarters of total write-offs emanating from this group.

Municipalities are constantly faced with financial capacity challenges, and thus the accumulation of bad debt is a major concern. Figure 7 also showed a positive relationship between write-offs and water grants received. The following section provides empirical findings for the household consumer group, and the relationship between water grants and water bad debts. A more detailed breakdown of bad debts by customer groups is illustrated in Table 10 below:

Table 10: Total write-off by customer group

Financial Year	Government	Business	Household	Other
2011/12	63,335,000	87,240,000	455,129,000	516,341,000
2012/13	83,607,000	251,824,000	1,765,514,000	195,288,000
2013/14	6,792,000	99,086,000	1,002,450,000	99,237,000
2014/15	24,868,000	105,682,000	916,480,000	98,617,000
2015/16	3,330,000	415,942,000	3,005,308,000	665,241,000
Total	**181,932,000**	**959,774,000**	**7,144,881,000**	**1,574,724,000**

Source: National Treasury, 2011/12-2015/16

Table 10 shows detailed bad debts by customer categories. Total bad debts for the South African water sector over the period amounted to R9.86 billion. South African households are the biggest culprits, accounting for a staggering 72.5 per cent of total write-offs by all municipalities. This is followed by a category classified as 'Other', which includes industries, that accounts for 16 per cent of write-offs. This is followed by business, which accounts for 9.73 per cent. Government is responsible for the remainder of the bad debts, at 1.77 per cent.

We could not source data for all South African municipalities; hence, this sub-section presents results from metropolitan municipalities only. Municipal time series and cross-sectional data for eight metros for a period of 10 years. The data was extracted from Section 71 reports, the Auditor General, National Treasury and Global Insight. We use random effects models. According to Hsiao (1986) and Greene (1993), the random effects model makes it possible to draw inferences about the demand preferences of the population given the observed behaviour of the sample to be made.

Table 11 presents the results of the random effects model analysing factors determining water revenue generated by the eight South African metropolitan municipalities.

Table 11: Random effects model for water-revenue generation by metropolitan municipalities

Variable	**Water-Revenue**
Tariff	-0.693
	(0.275)
Local government equitable share-Water Component	0.204
	(0.229)
Population	0.37
	(1.199)
Income	1.419
	(0.426)
Temperature	-2.972
	(0.603)
Constant	-3.011
	(18.03)
Observations	88
Number of Municipalities	8
R-squared	0.786

Water revenue is taken as a function of tariff levels, the local government equitable share allocation (LES) water component, population (number of households), income and temperature. In other words, the revenue generated through water provision is dependent on a few factors, as mentioned above. The results show that only tariff levels, income and temperature are significant in explaining the level of water revenue a municipality will generate. The local government equitable share allocation (LES) water component and population are insignificant factors, and thus do not explain the levels of revenue generated by municipalities.

The coefficient for tariff levels is negative and is significant at a 95 per cent confidence interval. This means that if there is a one-unit increase in the tariff levels of a municipality, there will be a corresponding 0.693-unit decrease in the revenue received. Raising tariffs results in an increase in the percentage of consumers' income devoted to water consumption. If affordability is an existing concern for the municipality's consumers, raising the tariffs will result in non-payment of bills. An increase in the tariff levels will have two significant effects to the municipality: 1) There will be a decrease in the revenue collected; and 2) Non-payment of water bills will result in an increase in bad-debt levels.

The coefficient for income is positive and is significant at a 95 per cent confidence interval. If there is a one-unit increase in the income levels of households, water revenue raised by the municipalities will increase by 1.419 units. An increase in income levels gives households more disposable income, and thus positively impacts the revenue collected by the municipalities. A prior assumption can be made, based on the theoretical relationship between income and the repayment of debts, to assert that the income increases will result in households repaying existing debts. If the assumption holds, an increase in income levels will impact municipal revenue in two ways: 1) There will be an increase in revenue collected; and 2) Non-payment levels will decrease, and bad-debt levels will decrease.

The coefficient for temperature is negative and is significant at a 99 per cent confidence interval. A one-unit increase in temperature levels will result in a -2.972-unit decrease in water revenue collected by a municipality. This is because temperatures affect the water levels in water bodies via the process of evaporation. Higher temperatures result in rapid evaporation and loss of water. Loss of water translates to loss of untapped potential water revenue that would have been available for consumption. Global warming and weather patterns resulting from El Nino become worth noting, as they have a direct and very significant negative impact on the revenue amassed from water sales, because revenue is a function of tariff levels and the amount of water consumed. In extreme cases of evaporation, the water loss may result in rationing of water to consumers, which negatively impacts revenue as well as service delivery.

The local government equitable share (LES) water allocation variable and the population size are insignificant in determining the level of water revenue collected by a municipality. Municipalities with different financial capacities will receive varying amounts in grants from government. However, the value of grants a municipality receives from government does not impact the amount of water revenue collected.

Municipalities are not a homogenous group, and thus have different numbers of households in their respective jurisdictions. Population size, however, is not significant in explaining the amount of water revenue collected by a municipality. This means municipalities with larger population sizes should not have proportionately higher revenues attributed to their size.

Table 12: Random effects model for bad debts associated with water provision in metropolitan municipalities

Variables	Water-Debt
Gini	-7.795
	(5.058)
Unqualified Audit	0.0754
	(0.131)
Population	0.028
	(2.467)
Tariff	0.821
	(0.403)
Constant	22.91
	(32.66)
Observations	88
Number of municipalities	8
R-Squared	0.539

Table 12 above shows the results of the second regression. Water debt is taken as a function of the Gini coefficient, unqualified audit, and population size and tariff levels. The results in Table 12 show that only the tariff level is significant in explaining the level of water debt accumulated by municipalities. The coefficient for tariff levels is positive and significant at a 90 per cent confidence interval. This means that a one-unit increase in tariff levels charged by a municipality will result in a 0.821-unit increase in the water-debt levels. A tariff increase negatively impacts the amount of disposable income available to a household; and thus, due to affordability constraints, non-payment will increase in proportion to levels of non-payment before the tariff increase, resulting in an increase in debt.

The Gini coefficient is a statistical measure used to showcase the level of income inequality present in a country or group of people. The Gini variable is insignificant in explaining the level of water debt accumulated by a municipality. This means that the differences in income levels across households within a municipality's jurisdiction have no impact on the number of households that will default on payment, resulting in bad debts.

An unqualified audit is also referred to as a 'clean' audit and is given when a municipality's financial statements represent their business affairs fairly in all material aspects. Bad debt in a municipal setting is a function of non-payment, or defaulting of payments, and mismanagement within the organisation. One would assume that a clean audit, which indicates sound financial management, would reduce the amount of bad debt accumulated due to mismanagement. However, the variable is insignificant in explaining the level of water debt accumulated by municipalities.

Population size too is insignificant in explaining the level of water debt accumulated by municipalities. This means that the number of households that fall under a municipality do not have a significant effect on the proportion of bad debt accumulated compared to revenue collected.

Table 13: Random effects model for bad debts associated with water provision in metropolitan municipalities excluding tariffs

Variables	**Water-Debt**
Gini	-5.163
	(5.007)
Unqualified	0.0662
	(0.135)
Population	-1.834
	(1.843)
Equitable Share-Water	0.577
	(0.143)
Constant	39.44
	(23.43)
Observations	88
Number of Municipalities	8
R-Squared	0.594

Water debt is regressed as a function of the Gini coefficient, unqualified audit, population size and equitable share (grants) received from government. The equitable share of grants variable is the only significant variable in explaining water debt. The coefficient of the equitable share of grants is positive, and significant at a 99 per cent confidence interval. A one-unit increase in the value of grants received by municipalities results in a 0.577-unit increase in the level of water debt accumulated. Non-payment by households resulting in bad debts negatively impacts the budget available for use by municipalities. The equitable share of grants received from the government is used partly to offset the negative impact of bad debts, by allowing municipalities to spend at the same budget levels despite non-payment by households. The grants received by municipalities serve as a disincentive to collect bad debts, as the funds received are used to counteract the negative effects of bad debts. If grants were to be reduced by one unit, then the water-debt levels would in turn fall by 0.577 units.

The Gini coefficient is again insignificant in the regression shown in Table 13. The level of income inequality faced by households serviced by a municipality has no significant impact on the level of water debt accumulated. Again, an unqualified audit does not have a significant impact on the level of water debt that a municipality will have. The population size or number of households that fall under the jurisdiction of a municipality have no significant impact on the water debt accumulated.

7.5 Summary

Water systems in developing countries should provide water services that are safe, acceptable and affordable to users, and ensure an institutional and viable system that can recoup costs (Stalker and Komives, 2001). Municipal debt is a growing problem faced by a significant number of water providers, especially in developing countries such as South Africa. This chapter undertook an assessment of the relationship between national transfers to water providers and water-account debts written off by these water-service providers in South Africa. The picture that emerges is that there is a significant increase in consumer debt levels in South Africa, including in the water sector. The result is a continuing rise in outstanding debts to water-service providers in recent times, with written-off debt increasing by over 200 per cent since 2011/12. South African households are the biggest culprits among the consumer groups.

Efforts by some water-service providers to introduce prepaid meters were unsuccessful. The Johannesburg High Court ruled in May 2008 that prepaid water meters were unlawful and unconstitutional. The question we pose, considering this, is whether the incentive for customers – particularly households – to settle their water accounts has been ‘watered down’ by the failure to introduce prepaid meters. Has the incentive for customers to pay their water bills been ‘watered down’ by the inability of water providers to cut off a household's water supply? Has the incentive for South African water service providers also been ‘watered down’ by significant increases in the transfers they receive from national government?

The trends in municipal bad debts and revenue collection point to the fact that municipalities are not collecting enough own revenue from their customers, which is partially due to inefficient collection strategies and socio-economic factors. We are also aware that a significant number of municipalities do not write off a good portion of their debt, despite the lack of evidence of them even attempting to recover the debt. This suggests that actual bad debt in municipalities may be higher than is reported here.

Transfers from national government to local government are justified in certain conditions, and may potentially improve financial viability of services, and address equity and affordability issues. Moreover, such grants may also encourage efficient service provision. By contrast, in some environments grants can be inequitable, regressive, and discourage efficient service provision. This induces a greater burden on the budget, encourages write-offs of significant debts, and leads to poor quality of services.

We conclude from our analysis that the incentive for water providers is weakened by significant increases in transfers from national government in the form of grants. Low water tariffs are exacerbating the problem. The ban on prepaid water meters and the inability of municipalities to cut off those who do not pay their water bills has also weakened the incentive for South African households to settle their water bills.

Given rising consumer water-debt levels, water-service providers in South Africa will have to come up with innovative mechanisms to tackle non-payment. In other words, there is a need for them to make some non-payment provisions. The solution to the increasing trend of written-off debts depends to a large extent on the main drivers of the debts. The Department of Water and Sanitation, as policy leaders in the country in crafting future policy to address this growing problem, must consider the fundamental problem underlying the question of why different customer groups – or some elements within a group – are not paying their water bills, and what the implications are for policy development.

If a significant proportion of bad debts are due to customers' inability to pay, then the question that arises is *why* they are unable to pay. Is it perhaps because of higher water bills due to higher tariffs, or is the free basic water social security support not adequate, or is there a high poverty level in the jurisdiction? Even though the tariffs are not cost-reflective, it is not clear what is affordable and not affordable for the average South African household. It is also not clear whether the free basic service is adequate, and whether it takes into consideration factors such as household size. High inequality and high poverty levels in the country may also be a significant factor. How does policy account for this? In countries such as Northern Ireland, a social tariff was introduced in the form of a cap on water bills, which limited the amount of household disposable income to be spent on water accounts. If on the other hand most of the bad debts are driven by unwillingness to pay, then the following could be examples of appropriate policy questions:

- What can be done to provide customers with an incentive to pay?
- Should water providers be allowed, under some circumstances, to disconnect the water supply of those who can afford to pay but opt not to?
- Or should failure to pay be reflected in their credit profiles?

The DWS will have to consider the two extreme scenarios above in future policymaking. These scenarios assume that there are rich and comprehensive datasets which allow different groups and sub-groups to be identified. We are aware that one of the big challenges in the South African water sector is the unavailability of data sets. In instances where they exist, they are often of very poor quality, unreliable and not credible. More effort is required to centralise and standardise the data sets. Frequent auditing of the datasets is also crucial. The DWS is best placed to manage such an initiative. In addition, the DWS and all water-service providers should develop more creative ways to recover their current debts.

CHAPTER 8: USING CHOICE EXPERIMENTS TO ELICIT HOUSEHOLD PREFERENCES FOR WATER-SAVING TECHNOLOGIES: EVIDENCE FROM THREE MUNICIPALITIES IN GAUTENG

8.1 Introduction

South Africa is naturally water scarce, receiving only about 54 per cent of the average global annual rainfall. The water resources in the country are also unevenly distributed, with some areas being arid while others have relatively better water resources. Because of this, efficient water consumption is essential for sustainability. There is a continuous call for South African households to maximise efficiency in their daily water consumption activities. Households can do this through adopting water-efficient technologies, as well as adapting through practising water-saving behaviour. Technological devices that can help conserve water include efficient dishwashers, flow regulators, efficient showerheads, dual-flush and interruptible-flush cisterns, and cistern displacement devices, among others (see Carragher et al., 2012; Makki et al., 2013; Still and Bhagwan, 2008; Willis et al., 2013).

Although the adoption of water-efficient technology is an essential step towards conservation, the conservation goal cannot be achieved if households do not practise water-saving behaviour. It is commonly suggested that households tend to adopt non-water-efficient habits when they install water-efficient technologies (see Davis, 2008; Freire-Gonzalez, 2011; Ghosh and Blackhurst, 2014; Smeets et al., 2014). For example, in one household people may take longer showers, because they have installed an efficient showerhead. Such behaviour will undo the benefits of installing efficient devices. Ghosh and Blackhurst (2014) define this as the ‘rebound effect’, and it has been widely studied in the energy literature. Therefore, for any installation of water-efficient devices to yield results, it is imperative for households to also adopt efficient water-use behaviour.

In addition to reducing pressure on water resources, efficient water consumption essentially reduces a household’s water bill. It is documented in the literature that installing water-efficient technologies and adopting efficient behaviour reduces water demand by about 10 per cent (see Kenney et al., 2008; Renwick and Archibald, 1998; Renwick and Green, 2000). The overall effect of such a decrease is a reduction in the monthly bill, as a household would pay 10 per cent less than they used to pay. Given the progress in technology in recent times, devices do exist that can save more water than the 10 per cent mentioned above. This implies that adopting recently advanced water-efficient technologies would result in massive reductions in water demand, and in household water bills.

8.2 Context and objectives of the study

Recently, South African water authorities have been promoting campaigns that encourage households to adopt water-efficient behaviour. Similar campaigns have been reported by Renwick and Green (2000) to reduce water consumption by about 8 per cent. Despite efforts by the water authorities, very little is known about households' consumption activities. Information on households' water-consumption behaviour and activities is important. This is because the household is a key stakeholder in the water-supply chain. Households adopting conservation technologies and behaviour is essential for sustainability (see Millock and Nauges, 2010; Pérez-Urdiales and García-Valiñas, 2016). Due to the scarcity of information on households' efforts towards water conservation, it is imperative to assess such information.

Therefore, this chapter uses the choice-experiment method to elicit household preferences for water-efficient technologies. This is done with a view to understanding the kinds of technologies households would install in their homes to save water. We report on the possible technological devices that can be adopted by households, and their preferred devices from those identified. Additionally, we examine households' water-consumption behaviour to see if it is sustainable. More precisely, this study reports on two main and important aspects. First, it reports on the water-efficient technological devices that are important to households; and second, it reports on households' current water-consumption habits.

Our study is unique in two main aspects. Firstly, it is one of very few studies (if any) that use choice experiments to determine households' technological conservation preferences. This is a step ahead of other studies in the literature that identify water-saving technologies without noting the most preferred from those identified (see Carragher et al., 2012; Makki, 2013; Still and Bhagwan, 2008; Willis et al., 2013). Identifying household preferences is essential for policymakers and water decision-makers. Secondly, our study looks at both water-efficient technologies and household water-consumption behaviour. These issues are usually treated separately in the literature. However, due to the rebound effect explained in Ghosh and Blackhurst (2014), it is essential for these two to be examined concurrently. This is because households are believed to practise inefficient consumption habits when they install water-efficient technologies.

8.3 Literature Review

Studies that use choice experiments to elicit household preferences for water-efficient technologies are scarce in the literature. The studies available examine the determinants of adopting water-efficient devices and water-saving habits (see Makki et al., 2013; Martínez-Espiñeira et al., 2014; Pérez-Urdiales and García-Valiñas, 2016). An analysis of both technology and habits is also not common in the literature. These issues are mostly considered separately. Several studies on water-efficient technologies exist in the literature (see Carragher et al., 2012; Davis, 2008; Lee et al., 2013; Millock and Nauges, 2010; Price et al., 2014; Willis et al., 2010). On the other hand, there is a plethora of studies on household water-consumption habits (see Adams, 2014; Jorgensen et al., 2009; Makki et al., 2013). None of these studies use the choice experiment method; generally, they examine water-efficient technologies and household behaviour.

In terms of choice experiments, studies on water-efficient technologies are mostly found in the agriculture domain, where various irrigation technologies are examined (see Alcon et al., 2014; Blazy et al., 2011; Veettil et al., 2011). Some choice experiment studies on efficient technologies also exist in the areas of wastewater and solid waste disposal (see Cooper et al., 2006; Ndunda and Mungatana, 2013; Pek and Jamal, 2011). A gap exists in the literature on studies that precisely examine household preferences for water-saving technologies. Vloerbergh et al. (2007) attributes this to the reality that water is viewed as a low-involvement product; people do not think much about it if it is available and of good quality. However, climate change is depleting water resources in South Africa and in most parts of the world. This calls for a need to pay more attention to issues of water conservation.

The literature provides several benefits of adopting water-efficient technologies. Millock and Nauges (2010) point out that although the primary benefit of investing in efficient water devices is not water-bill reduction, homeowners usually reap long-term monetary benefits from such investments. When water-efficient devices are installed, homeowners pay reduced water bills due to reduced consumption. In a study on household water demand in Santa Barbara and Goleta, California, Renwick and Archibald (1998) found that installing low-flow toilets reduced consumption by 10 per cent (per toilet), low-flow showerheads by 8 per cent (per fixture), and the adoption of water-efficient irrigation technologies by 11 per cent. Approximately consistent with these findings are the results in Kenney et al. (2008), where installing indoor water-efficient devices was found to reduce a household's water demand by 10 per cent.

On the other hand, the adoption of water-efficient behaviour also plays a significant role in reducing both water demand and the monthly water bill. Renwick and Green (2000) find that promoting sustainable behaviour through campaigns reduces water consumption by about 8 per cent. Therefore, for the desired conservation objectives to be achieved, a combination of technology and behaviour change is essential. Where household behaviours are not sustainable, the rebound effect will reverse the benefits of investing in efficient technologies (see Ghosh and Blackhurst, 2014; Smeets et al., 2014).

In a study on water-efficient technologies and habits, Pérez-Urdiales and García-Valiñas (2016) explore the potential relationship between poor water-saving habits and the adoption of efficient technologies. The study revealed that households who invest in non-electrical water-efficient appliances exhibit poor water conservation habits. The results confirmed findings from Renwick and Green (2000) and other studies in the literature that suggest education, awareness and moral persuasion campaigns are essential for conservation to yield positive results (see Allcott and Rogers, 2014; Brent et al., 2015; Martínez-Espiñeira et al., 2014).

The essentials of promoting water-efficient technologies and aiding such investments with campaigns that encourage people to adopt water-conservation habits are further reiterated in Martínez-Espiñeira and García-Valiñas (2013). This study examines the adoption of water-efficient technologies as well as self-reported conservation habits. Results revealed that educational campaigns have a strong positive effect, both on decisions to invest in water-efficient technologies and on decisions to adapt habits. As reported in Pérez-Urdiales and García-Valiñas (2016) as well as Renwick and Green (2000), water-efficient habits are essential for the realisation of conservation goals through investment in water-efficient technological devices.

Importantly, existing studies in the literature mostly review the determinants of water-efficient technologies and habits. There is a gap in the literature regarding studies that examine households' preferred technological devices. Such information is essential for policymakers. Our current study bridges this gap by examining South African households' preferences for water-efficient technology. In the study, we make use of some of the efficient devices suggested in the literature and present them to households in a choice experiment to determine their preferred devices. Choice experiments of this nature are rare in the literature. Therefore, our study will be one of the few to conduct such research using the choice experiment approach. In addition to the choice experiment, we also collect and analyse information on water-use habits. Such information is essential for South African water policymakers, who may want to know if households are being efficient in their daily water-consumption activities. Knowledge on household habits is important for the framing of awareness campaigns.

8.4 Experimental design

8.4.1 Description of designs

Experimental design involves specialised ways to manipulate the levels of an attribute. Common classes of experimental design are full factorial, orthogonal, and efficient designs. Recent literature recommends efficient designs ahead of full factorial and orthogonal designs. This is because factorial designs are usually criticised for being too simple, and they lack scientific validity. On the other hand, orthogonal designs are criticised for their orthogonality assumption, which contradicts many desirable properties of the logit and probit models used to analyse stated choice data (Hensher et al., 2015; Rose and Bliemer, 2009). Efficient designs are credited for their ability to produce more proficient data, leading to more reliable parameter estimates with even lower sample sizes. According to Rose and Bliemer (2009), efficient designs lead to smaller-width confidence intervals around the parameter estimates, and improve the reliability of results.

To use efficient designs, some knowledge of prior parameters is required. If incorrect prior parameters are used, efficient designs become inefficient. According to Bliemer et al. (2008), researchers can draw parameter estimates using Bayesian parameter distributions when prior parameters are not known. Bayesian parameter distributions are less sensitive to misspecification of priors, because they assume prior parameter values to be approximately known and randomly distributed. Where a D-*error* statistic is used with parameter estimates drawn from Bayesian parameter distributions, the experimental design becomes a Bayesian D-*error* design (also called a D_b-*efficient*). This is represented as:

$$D_b - error = \int_{\tilde{\beta}} \det\left(\Omega_1(X, \tilde{\beta})\right)^{1/K} \phi(\tilde{\beta} \mid \theta) d\tilde{\beta}. \quad (9)$$

Parameter D_b is Bayesian design, K is the number of parameters to be estimated, Ω_1 is the asymptotic variance-covariance (AVC) matrix of the design, $\tilde{\beta}$ represents prior parameters, and X is the experimental design. This Bayesian D-*error* design is commonly used to examine efficient designs for which the true population parameters are not known with certainty.

Our current study adopts the Bayesian D-*efficient* design. Six choice sets of two profiles each are designed using the Ngene experimental design software. To determine the number of draws for Bayesian priors, we use the Gaussian method. According to Bliemer et al. (2008), the Gaussian method is the best approximation method for Bayesian efficient designs. The rule of thumb for determining the absolute minimum Gaussian quadrature is 2^K, where K is the number of Bayesian priors. Our experiment used the maximum possible Gaussian draws (i.e. 32 draws) in the normally-distributed Bayesian D-*efficient* design adopted to populate the six choice sets of two profiles each experimentally designed.

8.4.2 Attributes and levels

Our survey elicits household preferences for water-conservation technologies. Attributes and levels were determined using a combination of literature review and consulting experts. It emerged from these activities that household water-conservation technologies can be categorised based on areas in the home. Typically, a middle-income South African household spends 25 per cent of water in the toilet, 25 per cent in the garden and outdoor activities, 24 per cent in the bath or shower, 13 per cent in the laundry, 11 per cent in the kitchen, and 2 per cent in other activities (Price, 2009). Our study uses these areas as attributes. Technological devices that may be fitted in each of these areas were used as levels[3]. After continuous engagement with experts, four key areas

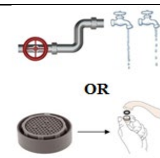
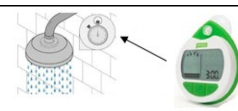
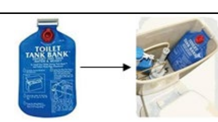
[3] We agree that the chosen levels may also be used as attributes in other studies. However, in the context of our current study the emphasis is on the areas in which households would prefer saving water in a homestead (i.e. kitchen, shower, toilet and outdoor). As such, water-efficient technological devices that can be fitted in these areas will be used as levels in our choice experiment.

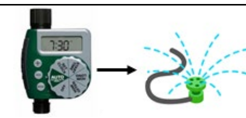
were adopted as attributes: kitchen, shower, toilet, and garden/outdoor. The monthly water bill was also adopted as the monetary attribute.

Although various water-efficient technologies are mentioned in the literature (see Jones and Hunt, 2010; Makki et al., 2013; Mini et al., 2015; Still and Bhagwan, 2008; Willis et al., 2013), our study adopted those that we considered important in the South African context. Kitchen devices adopted were dishwashers, efficient taps, and systems for collecting used water. Shower devices adopted were efficient showerheads and shower timers, while toilet devices adopted were efficient dual-flush cisterns, interruptible (multi-) flush cisterns, and cistern displacement devices (hippo bags). Garden/outdoor devices adopted were time-based irrigation controllers, micro-drip irrigation systems, and water tanks for harvesting rainwater.

Additionally, the monthly water bill is included as the monetary attribute. Investing in water-efficient technologies essentially reduces the monthly water bill. Therefore, the possibilities of reduced monthly water bills were used as levels for the water-bill attribute. These possibilities were determined by considering the average monthly water bill for households in the study site. Using the National Income Dynamics Study (NIDS) data, an average of R450 per month was determined as the current bill paid by households. If households were to adopt water-efficient technologies, their monthly water bill would be reduced by 30 per cent, 50 per cent or 75 per cent, (i.e. from R450 to R315, R225 or R110 per month, respectively). In Table 14 we present the final list of attributes and levels used in the study.

Table 14: Attributes and levels used in the study

Attribute	Description	Attribute Levels	
Kitchen devices 	A typical household uses 11% of water in the kitchen. A standard tap flows at about 8l per minute. Installing water-flow regulators or tap-head aerators makes a standard tap more efficient and reduces water by 60%. An efficient dishwasher uses 15l per cycle, using 50% less water than a conventional dishwasher.	**Level 1:** Efficient dishwasher	
		Level 2: Efficient tap	
		Level 3: System collecting used water	
Shower devices 	A typical household uses 24% of water in the shower. Shower timers result in shorter showers. Efficient showerheads save 65% of water used in the shower.	**Level 1:** Efficient shower head	
		Level 2: Shower timer	
Toilet devices 	A typical household uses 25% of water in the toilet. Replacing a 12l cistern with a 3l dual cistern saves about 75% of water. An interruptible-flush cistern allows the user to control how long the toilet flushes. Hippo bags displace water in the cistern and save about 1.2l per flush.	**Level 1:** Dual flush cistern sized 3-6L	
		Level 2: Interruptible flush cistern	
		Level 3: Cistern displacemen t (hippo bag)	

Garden & Outdoor devices 	A typical household uses 25% of water in garden/outdoor activities. Efficient gardening technologies reduce water use by 30%. These include time-based irrigation control systems and micro-drip systems. Irrigating gardens using water collected with water tanks also saves water.	**Level 1:** Time based irrigation controller	
		Level 2: Micro-drip systems	
		Level 3: Use harvested rain water	
Monthly water bill 	The average water bill for a household is R450 per month. Installing water efficient technologies will reduce the monthly water bill by 30%, 50% or 75%.	**Level 1:** R110 **Level 2:** R225 **Level 3:** R315	

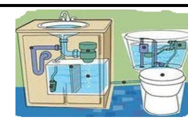
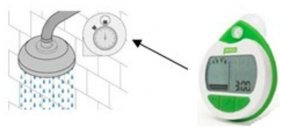
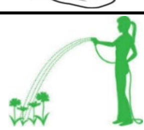
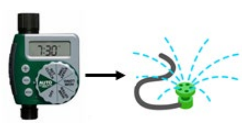
In addition to the experimentally designed profiles, the study included a status quo option. This was essentially to avoid the undesirable effects associated with forced choices, as argued in Ferrini and Scarpa (2007). In each choice set, we include an undefined status quo option. Also known as an individual-specific status quo, an undefined status quo allows each respondent to envisage their own status quo and compare it to the experimentally-designed hypothetical profiles (Hess and Rose, 2009). Similar approaches have been used is other studies (see Campbell et al., 2008; Hess and Rose, 2009; Marsh et al., 2011; Scarpa et al., 2007; Train and Wilson, 2008; Willis et al., 2005).

Household water conservation practices are not clearly documented in South Africa. It would have been difficult to determine with certainty the technologies currently used by households. Therefore, individual-specific status quos help us avoid the problems associated with imposing status quos, which could have been the case in our study. Prior to the survey, draft questionnaires were pre-tested on 30 respondents from the study area (10 respondents from each sub-sample).

Issues observed during the pilot study were addressed, and reliability ascertained. Content and construct validity were maintained by basing the attributes, levels and all other questions on expert advice, information drawn from the pilot study, and the review of literature.

Using the attributes and levels presented in Table 14 and the Bayesian efficient experimental design approach explained, six choice sets with two options and a status quo option were designed and presented to respondents. An example of the choice sets used in the survey is given in Table 15.

Table 15: Examples of a choice set used in the choice experiment

	Status quo	Option 1	Option 2
Kitchen devices 		Efficient dishwasher 	System collecting used water 
Shower devices 		Shower timer 	 Efficient shower head
Toilet devices 		Hippo bag 	Dual flush cistern 
Garden & outdoor devices 		Time-based irrigation controller 	Use  harvested rain water
Monthly water bill 	R450	R225	R225
YOUR CHOICE			

In addition to the choice tasks, our questionnaire contained sections B and C. Section B collected general information on water-conservation technology and behaviour. Section C collected the biographic details of the respondents. Water conservation is an ideal domain to test the impact of response time on utility functions. South Africa is a water-scarce country that is also currently experiencing a serious drought spell. Therefore, household conservation efforts are essential in alleviating the scourge of water scarcity in the country. However, very little is known about how households are contributing towards conservation. The lack of effort put into water conservation could be because water is viewed as a low-involvement product; people do not think much about it if it is available and is of good quality (see Vloerbergh et al., 2007). Therefore, there is need to elicit households' preferences for water efficient technologies. The adoption of such technological devices will play a crucial role in saving water, as well as in reducing the monthly water bill for households. As such, we use a water conservation survey to test the impact of response time on the utility functions.

8.5 Study Site

The survey was conducted in three municipalities in the Gauteng province of South Africa, namely the City of Johannesburg Metropolitan Municipality, Ekurhuleni Metropolitan Municipality and Mogale City Local Municipality. The total population of these three municipalities is around 8.9 million people, distributed as 5.1 million in the City of Johannesburg, 3.4 million in Ekurhuleni, and 383,864 in Mogale City (Statistics South Africa, 2017a). Johannesburg is the busiest and most populous city in South Africa, categorised as an upper-middle-income economy, using World Bank standards (City of Johannesburg, 2016). About 71 per cent of residents in our study site are aged between 15 to 64 years, while the average unemployment rate is around 30 per cent, which is slightly above the country's 28 per cent average but consistent with the 30.2 per cent provincial average in Gauteng (Statistics South Africa, 2017b). Regarding household dynamics, the average household size is 2.7 family members, and almost 80 per cent of the households live in formal dwellings (Municipalities of South Africa, 2017a, b).

On average, about 99 per cent of households in the study site have access to piped water (Municipalities of South Africa, 2017b). However, the average percentage of households accessing water inside dwellings is 56 per cent, with the rest accessing water either inside the yard or within 200 metres of the yard. This average is lower than the 63 per cent national average in South Africa (Statistics South Africa, 2017c). The use of water-efficient technologies such as dishwashers, washing machines and efficient kitchen sinks is gaining traction in the area. The 2016 GHS report reveals that a total of 1,072,000 households across the country own dishwashers, with 506,000 of these households residing in Gauteng province. Households in South Africa owning washing machines and efficient kitchen sinks total 5,709,000 and 6,366,000 respectively. In Gauteng province, these figures are respectively 2,230,000 and 2,518,000 (Statistics South Africa, 2017a).

To explain the location of Gauteng province in South Africa and the geographical positions of the three municipalities that form our study site, we present two maps in Figure 8. The first shows the position of Gauteng province in South Africa. The second map shows the geographical locations of the three municipalities (i.e. City of Johannesburg, Ekurhuleni, and Mogale City).

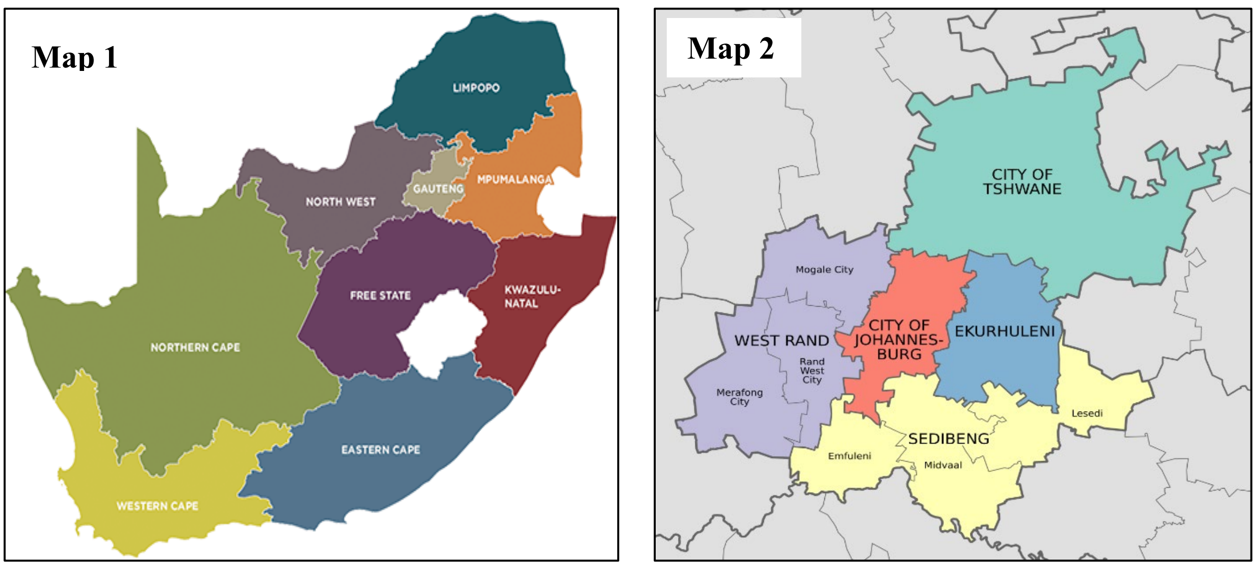


Figure 8: Maps of South Africa and Gauteng province

Due to budget constraints, we selected and surveyed a few areas, based on their population statistics, socio-economic characteristics and geographical location. In the City of Johannesburg, the survey was conducted in Soweto, Ennerdale, Lenasia, Midrand, Randburg, Roodepoort and Sandton, representing the Eastern, Western, Northern and Southern parts of the municipality. In Ekurhuleni, the survey was conducted in Benoni, Kempton Park and Springs, Duduza, Tembisa and Tsakane. In Mogale City, the survey was conducted in Kagiso, Munsieville and Krugersdorp. The surveyed areas contained both suburban and township areas.

In each surveyed area, respondents were conveniently selected until the required data points for each area were reached. Since we had initially stratified our survey areas into suburbs and townships, there was minimum bias, even after using the convenient sampling technique.

8.6 Choice experiment (CE) modelling

A product of the random utility theory, CEs assume that individuals are rational decision-makers who choose the most preferred (utility-maximising) option when faced with a possible set of options (Abelson and Levy, 1985; Howard, 1977; McFadden, 1973; McFadden, 1986). According to McFadden (1973), these rational individuals make choices based on the characteristics of the good, along with a random component. The random component could emerge from the uniqueness of the individual's preferences, or through researchers having incomplete information about the individual observed (Ben-Akiva and Lerman, 1985; McFadden, 1973; McFadden, 1986). In the random utility theory, McFadden (1973) proposes that the utility obtained by an individual from an option is not known, but can be decomposed into a deterministic component and an unobserved random component. The proposed utility function is presented as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (10)$$

In equation 10, parameter U_{ij} represents the utility of individual i obtained from option j, parameter V_{ij} is the deterministic component normally specified as a linear index of the attributes in a choice set, and ε_{ij} is the unobserved random component of latent utility which captures the consequence of a choice of uncertainty due to incomplete information. Equation 11 represents the basic utility function and may be expressed by decomposing the indirect utility function for everyone U_{ij} into two main components (see Ben-Akiva and Lerman, 1985; Hensher et al., 2015; McFadden, 1973). The utility function then assumes the form:

$$U_{ij} = V_{ij}\left(X_{ij}, C_{ij}, \beta\right) + \varepsilon_{ij} \quad (11)$$

Equation 11 decomposes V_{ij} into attributes X_{ij} and C_{ij}. Parameter X_{ij} represents the vector of non-monetary attributes associated with option j, while parameter C_{ij} is the monetary attribute of option j, parameter β is the vector of preference parameters for the population in the sample, and

ε_{ij} is the stochastic component (random term) with a zero mean. The utility function expressed in equation 11 can be expressed as linear in parameters as:

$$U_{ij} = \sum_{k=1}^{K} \beta_x X_{ij} + \beta_c C_{ij} + \varepsilon_{ij} \quad (12)$$

McFadden (1973) and Howard (1977) posit that any rational individual i chooses option j over option k if $U_{ij} > U_{ik}$. Each option consists of a bundle of attributes. When an individual selects one option over the other, it suggests that the hypothetical utility derived by the individual from the chosen option is greater than the utility of the other option not chosen (Greene, 2003; Louviere, 2001). Therefore, the probability P_i of selecting option j because $U_{ij} > U_{ik}$ is illustrated as:

$$P_i(j) = \text{Prob}\left(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}\right) \;\; \forall \;\; k \in C, k \neq j \quad (13)$$

If the error terms are independently and identically distributed (IID) with an extreme value type I distribution, the variance of which is $var(\varepsilon)$=$\pi^2 \tau^2 /5$, where τ is a scale parameter that is used to normalise the model, then the choice probability of an option is expressed as:

$$P_{ij} = \exp\left(\frac{v_{ij}}{\tau}\right) / \sum_{k=1}^{K} \exp\left(\frac{v_{ik}}{\tau}\right) \quad (14)$$

Several logistic models are used to estimate the probability given in equation 14. The most basic of these logistic models is the conditional logit model (CLM). Also known as the multinomial logit (MNL) model, if there are no choice-varying attributes, the model uses the maximum likelihood estimation approach (Hensher et al., 2015). This model has enjoyed extensive use in the literature, and Hensher et al. (2015) identify it as the ‘workhorse’ for discrete choice experiments. However, the model is criticised for assuming respondents have homogenous tastes for observed attributes, and that the random part of utility obeys the independence from irrelevant alternatives (IIA) as well as the independence and identical distribution (IID) properties. These assumptions are unrealistic, as they rule out persistent heterogeneity in taste for observed and unobserved product attributes (see Greene, 2012; Hensher et al., 2015; Keane and Wasi, 2012).

One model that addresses the criticisms of the MNL model is the mixed logit (MXL – also known as the Random Parameter Logit, or RPL) model. MXL allows coefficients to vary randomly across individuals, reflecting the reality that different respondents have different tastes and preferences for attributes in each choice set (Hensher and Greene, 2003). It can account for both observed and unobserved heterogeneity in the preference parameters, and is versatile, with both single cross-sectional and panel data (Hensher et al., 2015).

The MXL model formulation is a one-level MNL model, for individuals $i = 1, \ldots, N$ in choosing option j. It breaks down coefficients into a population mean and an unobserved individual's deviation from that mean (Greene, 2012). This is illustrated using the following functional form:

$$U_{ij} = \beta X_{ij} + \eta_{ij} + \varepsilon_{ij} \tag{15}$$

Parameter β in equation 16 is the population mean, while η_{ij} is the individual deviation from the population mean which shows the individual specific heterogeneity, with mean zero and standard deviation one (Greene, 2012). If θ is used to represent the distribution of the parameters of β, the probability of individual i choosing option j can therefore be represented as:

$$\overline{P}_{ij} = \int P_{ij} \, f(\beta \mid \theta) d\,\beta \tag{16}$$

In equation 16, parameter P_{ij} represents the choice probability of an option as given in equation 6, while $f(\beta \mid \theta)$ is the probability density function for the coefficient β over the vector of parameter θ.

As is common practice in the literature, we also examine the marginal willingness to pay (MWTP) estimates. MWTP estimates show the marginal rate of substitution (MRS) between each attribute and the monetary attribute, and are an important output of choice models, as they give the average estimates of what respondents are prepared to pay for or against each attribute (Hensher et al., 2015). If a linear utility function with attribute X and a monetary attribute C is assumed, then:

$$U_{ij} = \beta X_j + \mu\left(C_i - p_j\right) + \varepsilon_{ij} \tag{17}$$

From equation 17, the MWTP for attribute X is calculated by taking the ratio of the derivatives of attribute X and the monetary attribute C, which in the case of a linear function is given as:

$$WTP_X = \frac{\Delta X}{\Delta C} = -\frac{\frac{\partial U_{ij}}{\partial X_j}}{\frac{\partial U_{ij}}{\partial C_i}} = -\frac{\beta_j}{\mu} = MWTP \quad (18)$$

The MWTP presented in equation 18 is a simple ratio of the coefficients of the parameter estimates (Hensher et al., 2015).

8.7 Data and Results

8.7.1 Descriptive statistics

A total of 894 respondents were interviewed. These were distributed as: 232 (text only), 257 (visuals only) and 405 (text and visuals). The proportion of male to female respondents was 55 per cent and 45 per cent, while the average household size was 4 family members. About 53 per cent of the respondents were married, while the proportion of those single was 44 per cent. Most of the respondents were Blacks (84 per cent) followed by Whites (9 per cent), then Indians (5 per cent) and Coloureds (2 per cent). Most of the respondents had completed high school (67 per cent), while 15 per cent had post-high school certificates and 11 per cent had diplomas. About 56 per cent of the respondents were dependent on income from salaries/wages, while 22 per cent ran businesses and up to 13 per cent were pensioners. Many the respondents earned between R5,000 and R10,000 per month (43 per cent), while 38 per cent of respondents earned less than R5,000 per month.

To gain an understanding of households' use of water-efficient technologies, we asked respondents to indicate whether they currently had water-efficient technologies installed. Eight questions were asked on water-efficient technologies, using a 4-point Likert scale with the choices 'Yes', 'No', 'Not applicable' and 'Not sure'. More precisely, respondents were asked to indicate whether they currently owned water-collection tanks, cistern displacement devices, water-flow regulators, efficient showerheads, efficient toilet cisterns, multi-flush toilet cisterns, dishwashers or efficient garden devices. Table 16 presents the responses to these questions.

Table 16: Frequency distribution of responses to having water-efficient technology

		Frequency	Modal response
	Respondents (N)	894	
1. Water-collection tank (Jojo tank)	Yes No Not applicable Not Sure	5% 90% 4% 1%	No
2. Cistern displacement device (Hippo bag)	Yes No Not applicable Not Sure	3% 82% 13% 2%	No
3. Water-flow regulators	Yes No Not applicable Not Sure	12% 86% 1% 1%	No
4. Efficient showerheads	Yes No Not applicable Not Sure	30% 67% 2% 1%	No
5. Efficient toilet cistern sized 3-6 litres	Yes No Not applicable Not Sure	47% 51% 1% 1%	No
6. Interruptible/multi-flush cistern	Yes No Not applicable Not Sure	91% 9% - -	Yes
7. Dishwasher	Yes No Not applicable Not Sure	14% 86% - -	No
8. Efficient garden devices	Yes No Not applicable Not Sure	9% 89% 1% 1%	No

Apart from interruptible/multi-flush cisterns, the modal response for all questions was 'No'. This indicates that most households in our sample did not currently have water-efficient technological devices installed. Although such a revelation is alarming, it should not be surprising considering that most households in South Africa are low- to middle-income earners. With the current water shortages, it is imperative to make the necessary efforts for such technological devices to be installed.

Furthermore, to understand the possible reasons for currently not adopting water-efficient technologies, we asked households to indicate the most likely reason from a given list of possible reasons. Though more than one reason may be valid, we asked respondents to choose between 'I cannot afford', 'I did not know about them', 'I have no infrastructure to connect them', 'They are not important to me', and 'Other'. Figure 9 below presents the frequency distribution of the reasons.

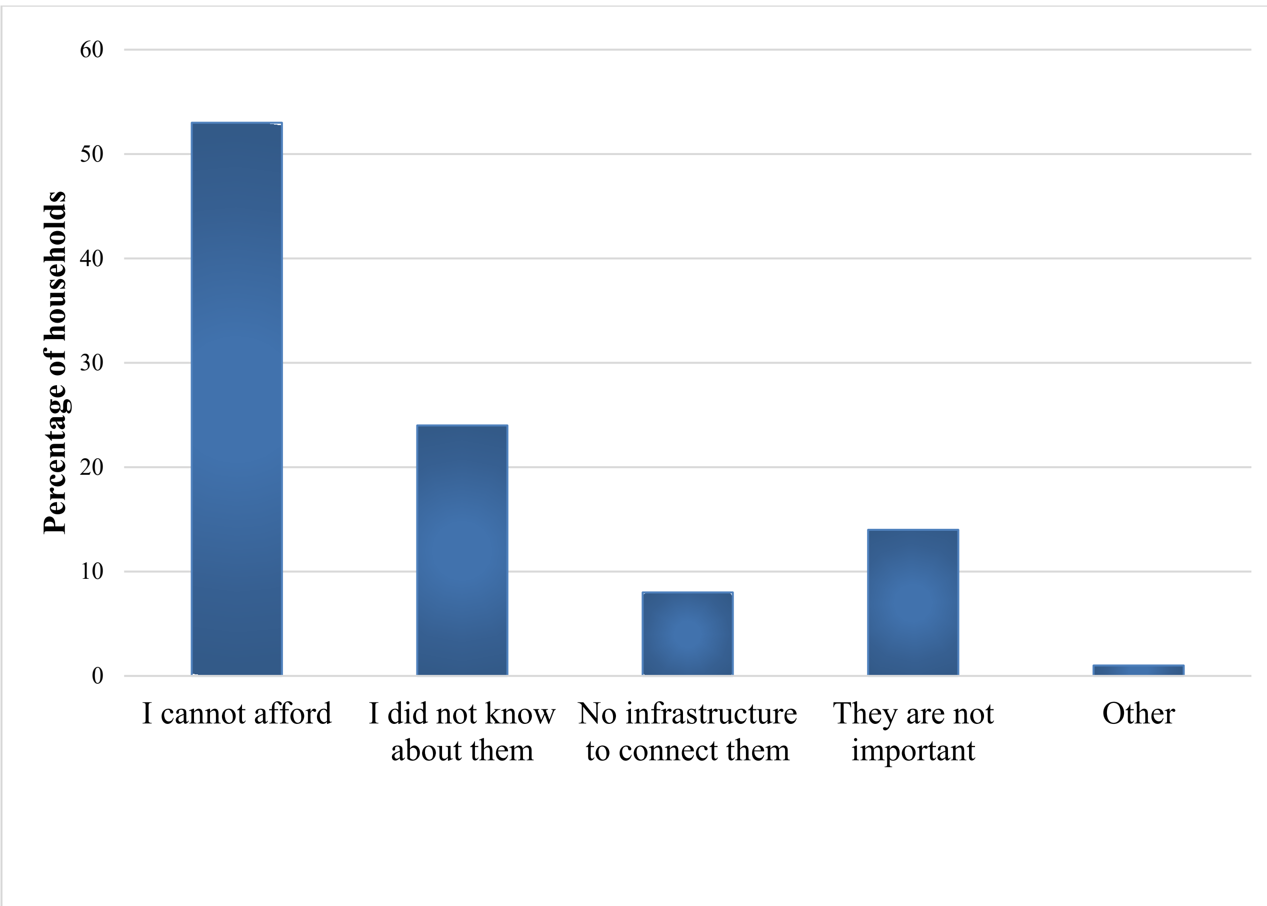


Figure 9: Reason for not having water-efficient technology

The main reason for not adopting water-efficient technology is because households cannot afford the technology. Interestingly, some respondents indicated that they did not know about water-efficient technologies. This justifies the assertion by Vloerbergh et al. (2007) that the nature of water makes it a low-involvement product; people do not think about it as long as it is available and does not have colour, or smell or taste odd. Respondents who indicated that they did not have the infrastructure to connect the technology were slightly marginal, with a proportion of less than 10 per cent, while the proportion of those who indicated that the technology was not important to them was 15 per cent.

Additionally, we elicited the households' daily water-use behavioural practices. We believe that households' daily water-consumption behaviour can be linked to their choices in the water-efficient technology experiment. Following the recent water shortages in South Africa, water policymakers in the country have been encouraging households to adopt water-efficient behaviour. Based on recommendations by policymakers on efficient water-use behaviour, we asked respondents eleven behavioural questions, using a 4-point Likert scale with the choices 'Never', 'Once in a while', 'Always', and 'Not applicable'. If respondents indicated 'Never', it showed that they were practising efficient water-use behaviour, while if they indicated 'Always', it showed that they were not practising efficient water-use behaviour. The frequency distribution of their responses is presented in Table 17 below.

Table 17: Households' daily water-use behavioural practices

		Frequency	**Modal response**
	Respondents (N)	894	
1. Take bath instead of shower	Never Occasionally Always Not applicable	27% 13% 44% 16%	Always
2. Take shower for more than 5 minutes	Never Occasionally Always Not applicable	25% 24% 17% 34%	Not applicable
3. Run shower for some time, waiting for hot water	Never Occasionally Always Not applicable	33% 10% 25% 32%	Never
4. Keep the tap running when brushing teeth	Never Occasionally Always Not applicable	84% 8% 8% -	Never

		Frequency	Modal response
5. Ignore water leaks from the toilet tank	Never Occasionally Always Not applicable	95% 4% 1% -	Never
6. Keep tap running when washing dishes	Never Occasionally Always Not applicable	85% 7% 8% -	Never
7. Rinse cutlery and glasses under running water	Never Occasionally Always Not applicable	74% 12% 14% -	Never
8. Use running water to defrost frozen food	Never Occasionally Always Not applicable	90% 5% 5% -	Never
9. Ignore a dripping tap	Never Occasionally Always Not applicable	97% 2% - 1%	Never
10. Ignore kids wasting water	Never Occasionally Always Not applicable	96% 3% 1% -	Never
11. Keep water running while washing face or hair	Never Occasionally Always Not applicable	93% 4% 3% -	Never

In Table 17 above, inefficient water-use behaviour is only reported in response to the first question ('Take bath instead of shower'), where the modal response is 'Always'. Although a bath is mostly considered inefficient compared to taking a shower, this is only true if households fill 'bigger-sized' bathtubs. In cases where water is collected in buckets, taking a bath becomes efficient. One reason why the modal response for the first question is 'Always' could be because households do not have showers installed in their houses; hence, they mostly use buckets to collect bathwater. Generally, the respondents are water-efficient in their behaviour. The assumption that households take baths instead of showers because they do not have showers installed could be confirmed by the number of respondents who responded 'Not applicable' to the second question. The modal response of ‘Never’ for all the other questions indicates that generally, South African households practise water-efficient behaviour in their daily activities.

8.7.2 Modelling results

This section presents the estimated results of the study. As mentioned earlier, we adopt the MXL model to estimate household preferences for water-efficient technology. We estimate an unconstrained MXL model, with normally distributed random parameters. We use the five attributes as random parameters, and constants (ASCs) as fixed parameters. Results are obtained using the Halton sequence for simulation based on 1,000 draws. The section also presents MWTP estimates. However, since we expect our stated preference data to reflect heterogeneity due to the nature of our sample, we also estimate preferences using the generalised mixed logit (GMXL) model. Using this model, we assess whether the accommodation of scale heterogeneity across choices would improve empirical results. This is because the GMXL model accommodates scale heterogeneity across choices (see Fiebig et al., 2010). After estimating both MXL and GMXL models, we compare the goodness of fit parameters to see which model performs better and is fit for our data. Table 18 below presents the goodness of fit parameters of the MXL and GMXL models.

Table 18: Goodness of fit statistics

	MXL model	**GMXL model**
LL	-4465.3	-4475.4
McFadden R^2	0.24	0.24
AIC	8972.7	8996.8
BIC	9110.9	9148.1
N	5328	5328

The three main measures of goodness of fit in the literature are the log likelihood function (LL), the Akaike information criterion (AIC), and the Bayesian information criterion (BIC). The LL statistic expresses how many times more likely the data are under one model than the other. AIC and BIC are information-based measures of the relative quality of statistical models for a given set of data. The decision rules for the three measures are that a model with a larger LL estimate is deemed more robust relative to the others; while with AIC and BIC, the model with the least value is preferred (Aho et al., 2014; Akaike, 1998; Burnham and Anderson, 2004). Additionally, the

McFadden R^2 statistic is another useful measure of goodness of fit; a value between 0.2 and 0.4 suggests a fit model (Hensher et al., 2015).

The McFadden R^2 statistics in Table 18 above show that both the MXL and GMXL models fit statistically. However, when the LL, AIC and BIC statistics are considered between models, MXL outperformed GMXL. This result is consistent with suggestions by Hensher et al. (2015) that although GMXL is an improvement on MXL, the latter might give robust results, depending on the analysed data. Since the MXL model outperformed the GMXL model in terms of goodness of fit statistics, this section only presents estimation results based on the MXL model[4]. The utility model estimated in this study is a function of five attributes (kitchen devices, shower devices, toilet devices, garden/outdoor devices and monthly water bill). Table 19 below presents the estimation results.

[4] Although GMXL results are not presented, there were no significant differences between MXL and GMXL results in terms of the sign, significance and magnitude of the attribute parameters.

Table 19: Estimation results based on the MXL model

	Par. Est.	Std. Err
Random parameters in utility functions		
B_KITCHEN	0.196***	0.031
B_SHOWER	0.208***	0.054
B_TOILET	0.027	0.027
B_GARDEN	0.102***	0.031
B_BILL	-0.006***	0.0003
Non-random parameters in utility functions		
ASC	0.0	0.441
Diagonal values in Cholesky matrix, L.		
NsB_KITCHEN	0.349***	0.054
NsB_SHOWER	0.408***	0.131
NsB_TOILET	0.025	0.102
NsB_GARDEN	0.114	0.592
NsB_BILL	0.001	0.006
Standard deviations of parameter distributions		
sdB_KITCHEN	0.349***	0.054
sdB_SHOWER	0.691***	0.136
sdB_TOILET	0.176**	0.069
sdB_GARDEN	0.297***	0.062
sdB_BILL	0.297***	0.062

Note: ***, ** and * = significance at 1%, 5%, 10% level, respectively.

Par Est. = parameter estimates. Std. Err = standard errors

The results presented in Table 19 will be interpreted based on the sign, significance and magnitude of the random parameters. The coefficients of the random parameters make up the utility functions. The utility function that emerges from the coefficient parameters of the normally distributed random parameters is presented in equation 18 as:

$$U_{ij} = 0.196xKITCHEN_{ij} + 0.208xSHOWER_{ij} + 0.027xTOILET_{ij} + 0.102xGARDEN_{ij} - 0.006xBILL_{ij} + \varepsilon_{ij} \quad (19)$$

The statistical significance of the attribute parameter is very important when analysing estimation results. Statistical significance shows the importance of an attribute to respondents. In the empirical results presented in Table 19 above, the coefficients of KITCHEN, SHOWER and BILL were statistically significant at a 1 per cent significance level. This implies that there is only a 1 per cent risk of accepting the coefficients. The coefficient of the GARDEN attribute is significant at 5 per cent level. However, the TOILET attribute is statistically insignificant.

Positive coefficients suggest households' preference for the attribute – that is, the attribute increases households' utility, while negative coefficients show disutility. For example, a change in the KITCHEN attribute would increase household utility by 0.196, implying that households prefer changes in their kitchen technology. On the other hand, a unit increase in the BILL decreases households' utility by 0.006, implying that they do not prefer increases in the monthly water bill.

Based on the statistically significant coefficients, the results in Table 19 above can be interpreted to mean that households prefer KITCHEN, SHOWER and GARDEN water-saving technological devices. However, their preference for GARDEN devices is weaker than their preference for KITCHEN and SHOWER devices. The results also show that households have no interest in TOILET devices. This result could be true because the descriptive statistics in Table 3 showed that a significant number of households already have toilet technological devices installed. In such cases, households would prefer the technology they do not have currently. The lesser statistical significance for the GARDEN attribute could be due to the reality that many South African households do not have gardens. In terms of the BILL attribute, the results were consistent with prior expectation that households dislike higher water bills.

It is also common practice in studies such as ours to estimate welfare measures. In the same spirit, we also estimate the marginal willingness to pay (MWTP) for each attribute. MWTP shows the average estimates of what households are prepared to pay for or against changes in each attribute. In the context of this study, MWTP estimates show the monthly water bill that households are willing to pay if they adopt each group of technological devices. Positive and significant figures show the average amount that households are willing to pay for changes in the attribute, whereas negative and significant figures show how much households are willing to accept as compensation for the attribute. Since the study adopted the MXL model, Table 20 below only presents MWTP estimates based on the MXL models[5]. All figures are expressed in South African Rands (ZAR)[6].

Table 20: Marginal willingness to pay estimates

	Estimate	**Std. Err.**
KITCHEN	31.98***	5.34
SHOWER	33.95***	8.58
TOILET	4.49	4.49
GARDEN	16.90***	5.04
Wald Statistic	**95.13**	
Prob. from Chi^2	**0.000**	

Note: ***, ** and * = significance at 1%, 5%, 10% level, respectively.
Std. Err = standard errors.

The statistical significance of the MWTP estimates presented in Table 20 agree with the estimated empirical results presented earlier. MWTP estimates show that households are willing to pay R31.98, R33.95 and R16.90 respectively for KITCHEN, SHOWER and GARDEN technological devices. This implies that households expect their monthly water bills to be reduced to these respective figures if they adopt each of the technological attributes. Important to note is that the MWTP estimates are too low, implying that households expect huge reductions in their water bills if they adopt water-efficient technologies.

8.8 Discussion and summary

The primary aim of this chapter was to determine the preferences for water-efficient technologies of South African households. As other studies on water conservation have done (see Makki et al., 2013; Pérez-Urdiales and García-Valiñas, 2016), this study also assessed households' water-consumption habits, with the aim of exploring whether South African households do practise water-efficient habits in their daily water-consumption activities. A survey was conducted in

[5] Although GMXL estimates are not presented, there were no significant differences between MXL and GMXL estimates in terms of the sign, significance and magnitude of MWTP estimates.

[6] As at 21 June 2018, US$1 was equal to ZAR13.58

Johannesburg, and the choice experiment method was used to collect stated preference data on water-efficient technologies. Profiles used in the choice experiment were designed using a normally distributed Bayesian D-*efficiency* design, where parameters were drawn from 32 Gaussian draws. The mixed logit model was used to estimate households' utility functions. Households' MWTP for the technological attributes was also estimated. Prior to the estimation of the utility functions and estimates, descriptive statistics on households' daily water habits were presented. Also presented were descriptive statistics on the extent of households' current use of water-efficient technologies.

From the descriptive statistics, two main findings were noted. Firstly, South African households do not currently have water-efficient technologies installed on their properties. The study shows that affordability and lack of knowledge about the technology are the main reasons for not installing water-efficient technologies. However, it was revealed that several of the respondents had efficient toilet devices installed. Secondly, the results showed that South African households practise water-efficient habits in their daily consumption activities.

Such a result is commendable, because several studies in the literature suggest that for water-efficient technologies to yield positive results, households should also adopt water-efficient habits, otherwise the rebound effect will result in more wastage (see Davis, 2008; Freire-Gonzalez, 2011; Ghosh and Blackhurst, 2014; Smeets et al., 2014). The revelation that South African households do practise water-efficient habits could be interpreted as signalling the success of calls by authorities for households to conserve. Additionally, it could mean that South Africans take the current drought and water shortages seriously and are playing their part for conservation.

Regarding the choice experiment results, we found that households prefer technological devices for the kitchen, the shower and the garden, but have no interest in toilet technological devices. The result for toilet devices was assumed to emanate from the earlier result that most households already have efficient toilet devices installed and would prefer installing technologies that they do not have already. MWTP results tallied with empirical results in the sense that estimates for all the attributes were statistically significant except for the toilet devices attribute. However, we found that households are willing to pay very little in water bills if they adopt water-efficient technologies.

Based on these findings, we make four recommendations. Firstly, water authorities should continue with their awareness campaigns regarding water conservation; they are yielding positive results. Secondly, there is a need for the promotion of water-efficient technologies, most importantly kitchen and shower technological devices. Households do not have them installed and are not aware of them. Thirdly, authorities should subsidise water-efficient technologies, because there are indications that households cannot afford them. Finally, the price of water should be reduced when households adopt efficient technologies. This is because households are only willing to pay very minimal water-bill amounts if they adopt water efficient technologies.

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