The Analysis of the Factors Affecting Household Water Consumption in Mpumalanga, South Africa

Masters Dissertation

For the Masters in Economic Development

School of Economics, University of Cape Town

Student Details

Name: Thomas van Huyssteen

Student Number: VHYTHO001

Peoplesoft Number: 1502921

Supervisor Details

Title: Djiby Racine Thiam

Job Titile: Associate Professor

Institution: School of Economics, University of Cape Town

Abstract

Understanding the evolution of water demand is of paramount importance for countries that want to implement the correct water demand management strategies which aim at increasing water use efficiency. This paper analyses household water demand in the capital city of the Mpumalanga Province of South Africa, in order to develop a better understanding of residential water demand in developing country contexts. Using survey data from 526 households in the Mbombela Municipality of Mpumalanga, South Africa, we estimate the price and income elasticities of household water demand, and investigate the factors that drive water demand of households which are located in heterogenous income groups. Households in the study areas have the unique characteristic seen in developing countries of having access to several sources of water, such as tap, ground and rainwater, implying the possibility of substitution. We run different estimation strategies that range from OLS, 2SLS and instrumental variable approaches to identify the factors that influence urban water demand. The findings reflect that price and income elasticities vary across different household groups, with price elasticities ranging from -0.140 to -0.879 and income elasticities ranging from 0.172 to 0.628. Other statistically significant variables which drive household water consumption are household size, education level, use of water saving technologies, and the use of rainwater tanks and systems. A crucial finding in this study was that water saving technologies were revealed to reduce water consumption levels by between 28.3% to 43.4%, and we hence provide specific policy recommendations based upon this finding. Overall, the results from this study can contribute substantially towards the development of appropriate and sustainable water policy making in South Africa.

Keywords: water demand, Mpumalanga, heterogenous demand sources, elasticities.

Table of Contents

List of Tables and Figures

List of Tables

List of Figures

List of Annexures

List of Abbreviations

2SLS	Two-stage least squares regression
3SLS	Three-stage least squares regression
AWA	Australian Water Association
CMAs	Catchment Management Agencies
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DCC	Discrete Choice Models
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EMG	Environmental Monitoring Group
FBW	Free Basic Water
FOA	Food and Agriculture Organization
GDP	Gross Domestic Product
GLS	Generalised Least Squares
GMM	Generalised Method of Moments
HH	Household
Inc.	Income
IV	Instrumental Variable
IWRM	Integrated Water Resources Management
m^3	Cubic Metre
NWA	National Water Act
NWIS	National Integrated Water Information System
NWRIA	National Water Resource Infrastructure Agency
NWRS	National Water Resource Strategy
OLS	Ordinary Least Squares
RSA	Republic of South Africa
WRM	Water Resources Management
WUA	Water User Associations

Acknowledgement

This research dissertation marks the ends of my masters degree and is the culmination of various opportunities and learning experiences which have been afforded to me over the last two years. This research would not have been possible without the guidance, support, and assistance of many people. First and foremost, I would like to express my sincere gratitude and appreciation to my supervisor, Associate Prof Djiby Racine Thiam, who provided excellent guidance and continuous support to me throughout this research. His patience and availability to discuss even the most mundane of questions makes him an excellent supervisor and research mentor. Without him, I certainly would not have completed this task and am sincerely grateful to him. Secondly, I would like to thank Professor Haroon Bhorat and the Development Policy and Research Unit (DPRU) at UCT who have chosen to fund my masters studies over the last two years through their collaboration with the National Research Foundation (NRF). I am eternally grateful for this support as it has allowed me to have complete focus on attaining my masters degree and achieving my true academic capabilities. I would also like to extend a thank you to Marian Garcia-Valinas, associate professor in the school of economics at the University of Oviedo, who offered some valuable suggestions during our various skype discussions. I would also like that thank all the staff at the University of Cape Town, particularly the school of economics, for all what they have provided me with over the last few years. Finally, to my parents, Karen and Richard, I would like to thank you for the continued support and bearing with me throughout this period.

This work is conducted under the project: Decentralized grey water treatment as alternative option for water scarcity mitigation: Exchange of experience and best practices between South Africa and Oman, under the grant program: IRG – Oman/South Africa Research Cooperation Programme. This research is funded by the National Research Foundation (NRF) of the Republic of South Africa. The authors are grateful to the NRF for funding this research.

Quotes

"Water ... lies at the heart of a nexus of social, economic, and political issues – agriculture, energy, cities, trade, finance, national security, and human livelihoods within rich and poor countries alike. Water is not only the indispensable ingredient for life, seen by many as a right, but also indisputably an economic and social good unlike any other."

- World Economic Forum, 2011.

"In this century wars will not be fought over oil, as in the past, but over water. The situation is becoming desperate. The world's water is strained by population growth. There is no more fresh water on earth than two thousand years ago when the population was three percent of its current size. Even without the inevitable droughts, like the current one, it will get worse as demand and pollution increase. Some countries will simply run out of water, sparking a global refugee crisis. Tens of millions of people will flood across international borders. It means the collapse of fisheries, environmental destruction, conflict, lower living standards." She paused for a moment. "As people who deal with the ocean you must see the irony. We are facing a shortage on a planet whose surface is covered two-thirds with water."

- Clive Cussler, 2019. Blue Gold.

"Although two thirds of our planet is water, we face an acute water shortage. The water crisis is the most pervasive, most severe, and most invisible dimension of the ecological devastation of the earth."

- Vandana Shiva, 2002. "Water Wars: Privatization, Pollution and Profit", p.1, Pluto Press.

Chapter 1: Introduction

Water is an essential resource for the survival of all living organisms, both as a way of direct consumption and maintaining the environment (Boccaletti et al., 2010). Water is also a crucial resource in the functioning of almost all economic activities, and hence concerns about the supply of freshwater, and the impact of water shortages on economic activity, have placed sustainable water management at the top of the global research and policy agenda. As we progress into the 21st century, water resource management will be one of the greatest global challenges, and with the predicted future scarcity of water for consumption purposes, there is need for urgent and in-depth economic analysis on these issues. Businesses, governments and policy makers around the globe will need to work together in moving beyond a business as usual approach to not only increase the supply and productivity of current water resources, but also to reduce withdrawal levels by reshaping underlying economic activities (Jansen, 2012). Recently, these concerns have been growing in developing countries, and there has been wide-spread debate regarding water policy design and implementation. One crucial outcome of the recent policy debate has been a reorientation of public policy in that agricultural, industrial, and commercial water use is no longer the sole focus of attention. With households now accounting for a substantial, and growing, proportion of total water consumption in most developing economies, residential water demand has now become a principal concern of policymakers (Ahmed et al., 2016). In light of this fact, this dissertation will analyse the factors affecting household water consumption levels in the City of Mbombela in Mpumalanga, South Africa. This research is of particular importance to South Africa as the country possesses rainfall levels well below the global average and it has water resources which have become highly polluted, making it a highly water scarce country.

In South Africa, water plays an extremely important role in the economy. The reliable supply of sufficient water, of the required quality, represents a critical input into the country's economic growth and job creation (Carden & Armitage, 2012). With the increased effects of rapid population growth, industrialisation, climate change and pollution on water supply in South Africa, cities are being placed under increased pressure to respond to the challenges of water availability and quality. Most South African cities are also under pressure to respond to pressing issues of economic transformation and social division, resulting from the country's difficult past, making the challenge even more complex (Jansen, 2012). The supply of clean and safe water to citizens is a fundamental pillar of socioeconomic development, and thus effective water management policy design and implementation will be crucial to the success of South Africa going forward. This study hopes to provide a basis for more effective water policy design in order to achieve this. The remainder of this introductory chapter provides the context for this study. It begins with a discussion regarding the water scarcity problem in South Africa, followed by a more specific discussion on the water situation in Mpumalanga, the area in which our study took place. The purpose and importance of this research will then be outlined, before a relatively detailed breakdown of the rest of this study will be provided at the chapter's culmination.

1.1 Water Situation in South Africa

1.1.1 Overview of Water Scarcity in South Africa

Water is indispensable for human life and for economic activities. In South Africa, however, water supply is extremely limited, unequally distributed, and negatively impacted by climate change, population growth, pollution and the prevalence and spread of invasive alien plant species (Blignaut & van Heerden, 2008; WWF-SA, 2016; Donnenfeld et al., 2018). Fortunately, South Africa explicitly recognises this fact and emphasizes the essential nature of water in the preamble to National Water Act of 1998, with regards to both the livelihoods and health of citizens, and from a socio-economic development perspective (Blignaut & van Heerden, 2008). For the sake of providing more context regarding the water situation in South Africa, one should start by noting that South Africa is a largely semi-arid water-stressed country, with an average annual rainfall of approximately half the global average (WWF, 2016). The country has a long and proud history of water infrastructure and has constructed many dam systems. The problem, however, is that the water resources within these dams are highly threatened by the presence of alien species, sand mining operations, industrial effluent discharge, high evaporative rates and a number of other factors (Coetzee et al., 2010). The rapid rural to urban migration in the country has compounded the problem as there has been a dramatic increase in urban dwellers living in informal settlements, which have ultimately had a disastrous impact on natural resources such as river water (Nyenje et al., 2010; WHO, 2015).

Looking at the water resources available in South Africa, there are three crucial things to be aware of, and these revolve around the country's rainwater trends, its transboundary flow sharing and its strategic Water Source Areas (WSAs). Looking firstly at rainfall, which is South Africa's primary input into its water resources, the country receives an estimated 495mm per year, as shown in Table 1 below. This volume is approximately half the world average, a problem which is amplified by rainfall in South Africa being extremely seasonal. Looking at the table below, one sees that despite South Africa receiving approximately double the amount of rainfall as neighbouring Namibia, due to low inputs and a large population, the country is significantly more water scarce than Namibia. In terms of transboundary flow sharing, a substantial 60% of South Africa's river basins include flow to or from another country. Transboundary flows are mandatory in South Africa, with obligations stipulated in the National Water Act of 1998 to ensure the sustainable management of a portion of flow across borders (NWA, 1998). Surface water entering the country is estimated to be 6 600 million m³/year (FAO, 2016). Examples of this transboundary flow are the Orange-Senqu River which has its headwaters in Lesotho and the Pongola which has tributaries from Swaziland. In terms of WSAs, where water comes from, South Africa's WSAs are grouped into 21 areas. There is less than a 1% overlap between coal deposits and WSAs, however this overlap is significant in the Enkangala Drakensberg and Mfolozi headwaters in Mpumalanga. Deeper concern revolves around the fact that over 50% of the Mpumalanga Province is under either a mining or prospecting license, which could result in widespread acid mine drainage pollution. Securing the future of these WSAs in the long run will require protection, and a worrying statistic is that only 16% of South Africa's WSAs are formally protected. Internal renewable surface water resources in South Africa are estimated at 43 000 million m³/year and renewable groundwater resources at around 4 800 million m³/year. 3 000 million m³/year, however, is considered to overlap between surface water and groundwater, which gives a value of total internal renewable water resources (IRWR) of 44 800 million m³/year (FAO, 2016). An important distinction to be aware of concerning South Africa's water scarcity is the difference between physical and economic water scarcity. The case for physical water scarcity has already been made by highlighting the low and uneven rainfall patterns experienced across the country. In addition to this physical water scarcity, South Africa currently lacks adequate water infrastructure, resulting in a highly unequal distribution of water resources across society. This has largely been the result of poor infrastructural renewal programs, leaving the country with both physical and economic water scarcity.

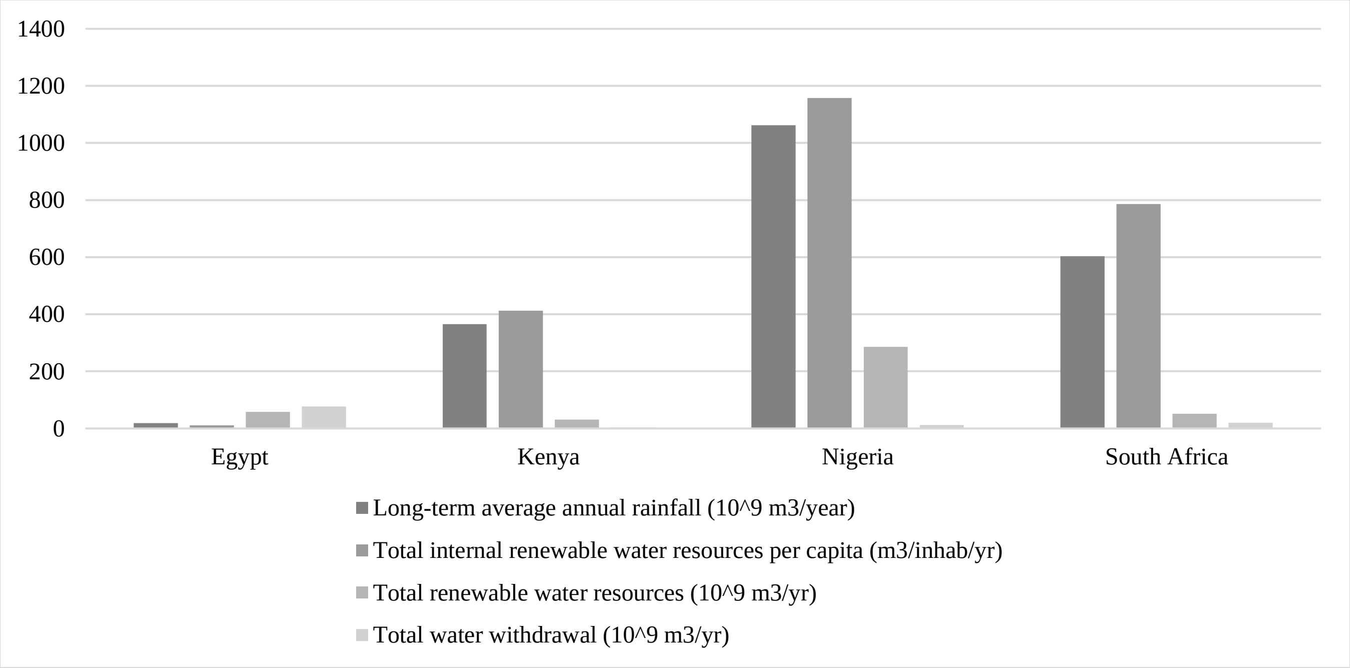
Table 1: Water Availability annually per capita in Selected Countries

Water Availability annually per capita in Selected Countries		
Country	**Water per capita per anum (m³)**	**Average Rainfall (mm)**
South Africa	**843**	**495**
India	1155	1083
Botswana	1187	416
Namibia	2674	285
France	3033	867
USA	8914	715
DRC	13331	1543
Australia	21272	534
Brazil	28254	1761

- Data Source: WWF, 2016

Despite South Africa being shown to have the low water availability per capita as seen in Table 1, it is important to note that the country fairs quite well in coparison to other African countries in terms of water trends. Africa is largely an extremely dry countinent and the Figure 1 below shows key water trend for South Africa and 3 of Africa's other major economies. South Africa is shown to fair relatively well accross all trends presented, with only Nigeria performing better.

Figure 1: Water Trends in Africa's Major Economies



Looking at average per capita daily water consumption levels seen in the Table 2 , South Africa is shown to have relatively high water consumption levels, with an estimated 235l per person per day. One notes, however, that the figures provided in Table 2 are highly inflated, as they represent overall national water consumption divided by the population, as opposed to national household water consumption divided by the population. The figure thus may only reflect South Africa's relative consumption levels compared to other countries, as opposed to an accurate per capita figure. One of the key drivers of higher consumption in South Africa is the high level of non-revenue water which is consumed due to the provision of free basic water (DWA, 2012).

Table 2: Average Daily Water Consumption (L)

South Africa	Global Average
235	**175**

Data Source: WWF, 2016

As was briefly mentioned at the start of this section, there are three predominant threats to water security in South Africa, namely, climate change, both population growth and urbanisation collectively, and finally the threat of pollution. Climate change is predicted to have a substantial negative effect on water security in South Africa as the country is already a semi-arid country with sparse and irregular patterns of rainfall, something which will be intensified by increasing temperatures. This is coupled with the fact that South Africa possesses limited and often highly polluted groundwater resources. Higher temperatures and more erratic rainfall patterns resulting from climate change will lead to flooding in some areas and drought in others, furthering the water security problem. Urbanisation is already having a substantial effect on water consumption in South Africa, and with the ever-present population growth trend compounding this problem, South Africa will likely be unable to meet the basic demand for water of citizens going forward. In terms of pollution, the pollution of surface and groundwater is adversely affecting the amount of water available for consumption purposes (Jansen, 2012). The key contributors to water pollution in South Africa being industrial and mining pollution, something particularly relevant in the Mpumalanga Province.

Looking at water access in South Africa briefly now (Table 3), approximately 46% of households in South Africa have access to piped water in their dwelling, with a further 27.1% having piped water in their yard. These levels of access are not reflected equally across all provinces, however, with the Eastern Cape, Limpopo and Mpumalanga having the poorest access to water in the country. One notes that this data is from 2011, and some changes have occurred since, although not drastic.

Table 3: Water Access in South Africa - 2011

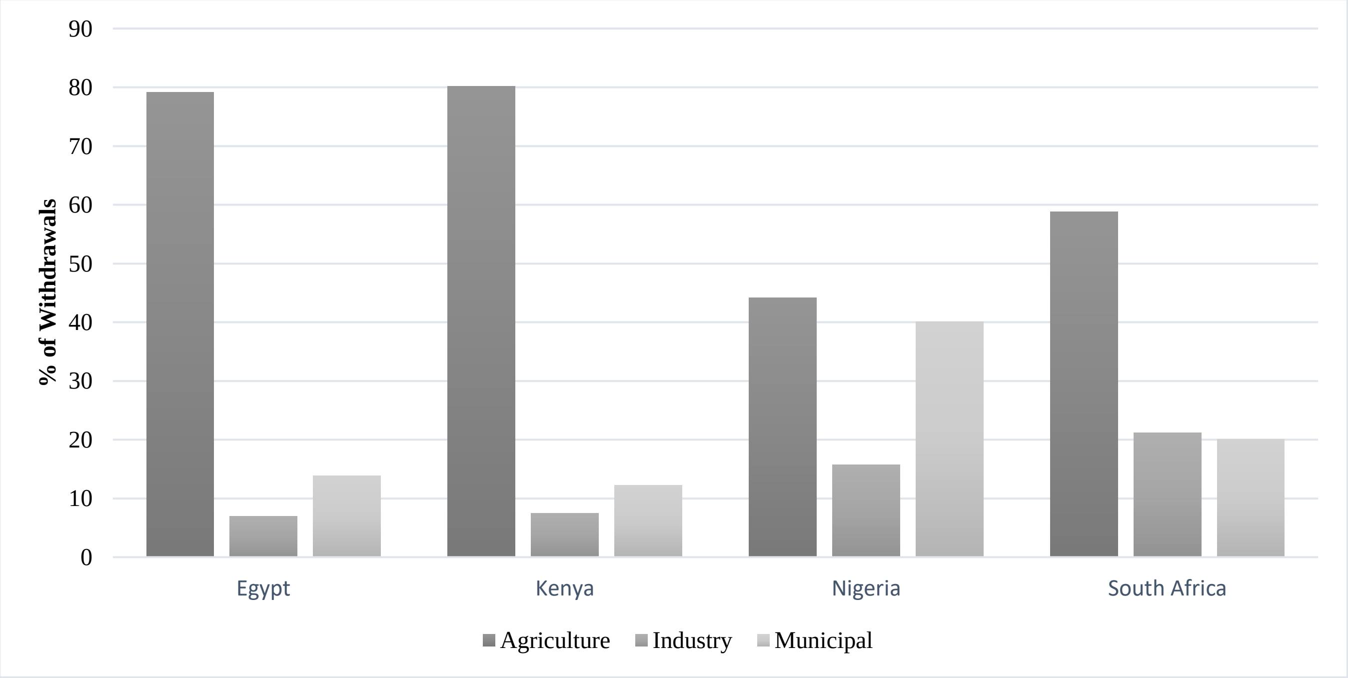
Water Access in South Africa (2011) (%)					
	Piped Water in dwelling	**Piped water inside yard**	**Piped water in community (<200m away)**	**Piped water in community (>200m away)**	**No Access to Piped Water**
Western Cape	75,1	13,3	8,3	2,4	0,9
Eastern Cape	32,8	16,6	18,6	9,9	22,2
Northern Cape	45,8	32,3	12,8	6,6	2,6
Free State	44,8	44,4	6,2	2,6	2,2
KwaZulu Natal	40	23,6	14,8	7,6	14,1
North West	29,3	40	14,3	8	8,4
Gauteng	62,1	27,3	6	2,8	1,8
Mpumalanga	**35,7**	**36**	**9,2**	**6,6**	**12,6**
Limpopo	18,4	33,9	20,5	13,2	14
South Africa	**46,3**	**27,1**	**11,7**	**6,2**	**8,8**

- Statistics SA 2011 Census

1.1.2 Current Situation/Problem

Renewable water resources in South Africa are currently being overexploited. Dam levels are at dangerously low levels, a problem which is compounded by highly inadequate water infrastrucuture. Furthermore, the country is expected to increase withdrawals in all three primary sectors – agricultural, industrial and municipal (Donnenfeld et al., 2018). This paints a rather ominous picture and more details regarding current and future withdrawals and water supply are required to better understand the problem facing South Africa. South Africa’s withdrawals were approximately 17 300 million m³ in 2013, a 5 million m³ increase from 2000 (FAO, 2016). The Figure 1 below shows the sectoral withdrawal trends for South Africa and a few other Sub-Saharan African countries. The figure reveals that the agricultural sector is the largest consumer of water among all the countries represented. The country accounts for approximately 60% of withdrawalas. The municipal and industrial sectors are shown to consume similar amounts in South Africa, while in the other countries the municipal sector is clearly the second largest consuming sector. Importantly for this study, in South Africa the municipal sector is expected to have the most significant increase going forward (WWF, 2016). Estimates predict that the municipal sector will soon account for over 30% of withdrawals, an increase which will be driven by South Africa’s growing and rapidly urbanising population, rising incomes and an increase in the proportion of people with access to piped water.

Figure 2: Proportion of Water Withdrawals by Sector for Selected Countries



Data Source from Aqua Stat - FAO.

To better understand the water allocation problem facing South Africa, Table 4 below is useful, with it using data provided by the World Wildlife Fund – South Africa (2016). The table shows that according to the WWF's base scenario, the estimated demand for water in South Africa will reach 17.7 billion m³ by the year 2030. By contrast, annual water supply currently equals only 15 billion m³. With remaining usable water at 0,3 billion m³, there will be an expected annual water shortage of approximately 2.4 billion m³. Furthermore, the effects of climate change could substantially exacerbate the problem, resulting in a gap as large as 3.8 billion m³ (Boccaletti et al., 2010). One of the largest drivers of the increased demand will be household demand driven by rising incomes, population growth and the national drive to improve basic services. Projections indicate that municipal demand will be approximate 3.6 billion m³ by 2030 (Boccaletti et al., 2010).

Table 4: The Water Demand Problem

The Problem	
Water Allocation Available in South Africa per year	15 billion m³
South African Demand for Water in 2030	17,7 billion m³
Remaining Usable Unallocated Water	0,3 billion m³
Therefore - Water Shortage in 2030	2,4 billion m³

- WWF, 2016

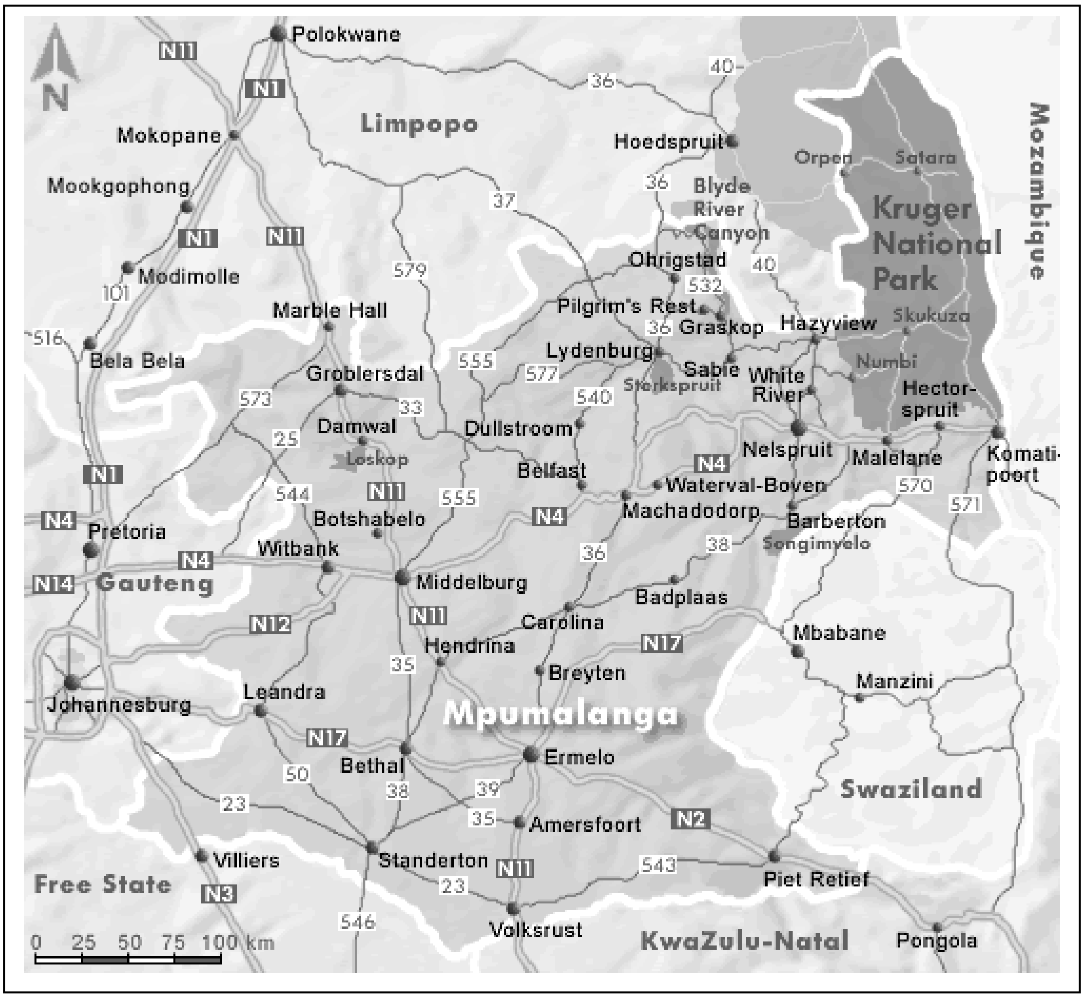
South Africa is a semi-arid country with highly variable rainfall, a growing demand for water and an ever-dwindling supply of usable water. Unless the country can find a solution to its current problem of economic and physical water scarcity, South Africa will soon be unable to support economic transformation and inclusive growth. A fundamental rethinking of South Africa's water sector and water's place within the economy is hence required. Although recent droughts have catalysed the nation-wide conversation around water and, to some extent, brought water security into the policy debate, it was not these droughts that caused water scarcity. The droughts simply highlighted the vulnerabilities present within South Africa's water system and emphasized the size of the challenge of securing water security confronting the country. On a positive note, it has been internationally recognised that water scarcity does not, in itself, determine the success or failure of a country's economic and social development (Muller et al, 2009). The prime example of this being Singapore, a water scarce country with a booming economy as a result of highly developed water management competences. The key message for South Africa here is that challenges relating to water need not constrain national growth and development if they are properly understood and responded to.

Nevertheless, it is essential that effective water management is practiced if the country hopes to achieve optimal social and economic performance, while ensuring sustainability for future generations.

1.2 Water Scarcity in Mpumalanga

Mpumalanga is one of the nine provinces in South Africa and lies in the North East of the country. Mpumalanga borders two countries, Eswatini and Mozambique, and four provinces, Gauteng, Limpopo, Free State and Kwazulu-Natal – as is shown in Figure 3 below. The capital of Mpumalanga is the City of Mbombela, formerly Nelspruit, and it is households within this city which will be analysed in this study. The total population of the province is approximately 4.5 million people, evenly split between male and female, with just over 1.2 million households present in the province (Manyana, 2019). The Mpumalanga province is governed by three district municipalities and 17 local municipalities (Mpumalanga Community Survey, 2016).

Figure 3: Map of Mpumalanga Province



Source:[*www.suedafrika.net*](http://www.suedafrika.net)

Looking at some crucial water statistics, 77.3% of households in Mpumalanga report to have access to safe drinking water (DWS, 2018). In 2011, 29% of households had access to piped water inside the dwelling and a further 44.4% had access to piped water within the yard (DWS, 2011). With regards to consumption levels, Mpumalanga has relatively moderate consumption levels in comparison to the nation, with an average consumption of 205 L per person per day, compared with the national average of 233L, see the Table 5 below (DWS, 2018).

Table 5: Water Consumption Levels by Province

Province	Consumption (litres/person/day)
Eastern Cape	200
Free State	209
Gauteng	305
Limpopo	182
KwaZulu Natal	225
North West	186
Northern Cape	238
Western Cape	201
Mpumalanga	**205**
National	**233**

Source: Department of Water and Sanitation, 2018

1.2.1 The State of Mpumalanga's Water Resources

Water is a highly scarce resource in Mpumalanga which needs to be carefully managed (Mpumalanga Spatial Development Framework, 2018). Surface water accounts for 65% of the province's available water resources, with transfers accounting for 19%, and groundwater a further 6 % (MSPF, 2018). Annual runoff is unevenly spread across Mpumalanga and four large rivers run through the province. Approximately half of the province is drained by these rivers - the Olifants River System, the Orange River system, Inkomati River System and the Pongola River System - which together form part of the Water Management Areas (WMAs) in the province. The most significant factors affecting water quality in Mpumalanga are poor maintenance of sewerage systems, mining, and soil erosion from agricultural activities (MSDF, 2018). The two sectors accounting for the majority of water demand in Mpumalanga are the agricultural sector, 63%, and the industry urban, 25%, with water supply services constituting only 8% (Morokong et al., 2016). With regards to Strategic Water Source Areas (SWSAs), Mpumalanga has a large proportion of South Africa's SWSAs, areas accounting for more than 50% of annual run-off in less than 10% of the country's surface area. The three SWSAs in the province are: Mpumalanga Drakensberg, Mbabane Hills and Enkangala Drakensberg (WWF, 2013). Of particular relevance is that the province regularly experiences water shortages due to drought and poor service delivery, something which was highlighted during the recent 2019 drought.

1.2.2 Drought in Mpumalanga, 2019

2019 was a year of wide-spread water shortages in Mpumalanga, with the severity of the water shortages enhanced by a prolonged drought. By December, ten dams in the province had water levels below 10%, characterising them as in a critical state (Sisulu, 2019). The Department of Water and Sanitation (DWS) reiterated calls for consumers in the province to intensify water saving habits throughout the period, in the hope of reducing consumption levels. One notes that these calls would have definitely resulted in lower than usual household consumption levels, and thus, as the data for this study was collected during this time, one must be aware that household consumption levels will be significantly lower than usual. Water restrictions were also in place from July to December of 2019 to help curb consumption levels and prevent a complete water shortage, further reducing consumption levels. The drought forced the Mbombela Municipality to declare the Ehlanzeni District Municipality a disaster area. The primary response from the DWS seen during the crisis was the allocation of R18 million to the JS Moroka Local Municipality to address water shortages, however how this money was used or has been planned to be used has not been revealed.

The two quotes below from a Kwazamokuhle resident, Belina Kubeka, highlight the severity of the water shortages experienced by communities in Mpumalanga in 2019.

"We have two baths in our house. When there is water, we fill up the one and use the water to cook with and wash dishes. We use the other bath to bath in and use the dirty water to flush the toilets."

"In December we had no water, and no water was provided for us. We had to bath in the dam."

1.2.3 Mining's Threat to Water Security: Mpumalanga

A key contributing factor to water security in Mpumalanga is the massive threat coal mining is having on people's access to water. Large-scale mining has had a substantial negative effect on water quality and the availability of water in Mpumalanga. This has resulted in communities in Mpumalanga, where the coal mining business is flourishing, struggling to access clean and safe water for drinking and other uses such as watering their crops. Despite the devastating impact of mining, the mining companies as well as the South African government shy away from their responsibility to respect and protect people's rights to water, food and a clean environment (CER, 2019). In Mpumalanga, the livelihoods of communities which have traditionally relied on subsistence farming are seriously threatened. Around 60% of the land in the province is currently mined or under exploration and the coal dust laden fields which remain for subsistence farming are becoming barren, their degradation exacerbated by water pollution (CER, 2019). A prime example of mining's negative impact on a community has been seen in the town of Carolina, Mpumalanga. The citizens in this town have not had access to clean water since mid-January, 2015, and acid water is running from their taps, something caused by the outflow of acidic water from the mines (CER, 2019). Upon closer scrutiny of the mines, a 2019 report by the Centre for Environmental Rights (CER) on the compliance of eight large coal mining operations in Mpumalanga revealed numerous cases of significant non-compliance with water use licences – licences which are an essential requirement for the commencement of their mining activities (CER, 2019). The report ultimately revealed the complete failure by the Department of Water and Sanitation to monitor compliance with water use licences for the eight coal mines investigated and to take enforcement actions where violations were clearly obvious. This portrays the image of a national department which has been unable to fulfil its statutory mandate of water resource protection. The report went on to show how so-called independent environmental auditors, including large environmental consulting firms, were repeatedly failing to conduct audits of compliance with licence conditions in an objective manner.

1.3 Importance & Purpose of Study

Given the water scarcity problems facing South Africa, and indeed the world, discussed in this chapter there is clearly an urgent need for water managers to ensure water resources are used in a sustainable way, and that there is sufficient protection against further pollution and degradation of water resources. South Africa has also independently given itself the statutory mandate to provide all citizens with access to basic water and sanitation services at an affordable cost (NWA, 1998). With these multiple objectives, focus can no longer remain on augmenting the supply of water in order to increase water availability, and instead careful water management options will be required. The best option at this point for South Africa is to reduce the overall demand for water. With household water consumption expected to be the largest driver of increased water demand going forward, understanding the factors affecting household water consumption is crucial. This study will hence conduct an in-depth investigation of the factors affecting household water consumption in the City of Mbombela in Mpumalanga, South Africa. The hope is that by developing a better understanding of the key drivers affecting household water consumption, the basis for more effective water management policy will be formed. One notes that South Africa is a mostly semi-arid country and the Northern region of the country, the area in which the Mpumalanga province is located, is regularly affected by droughts and other water availability issues. It is therefore essential to understand what is driving household water consumption in this region in order to prevent ongoing water shortages. Efficient water delivery is essential for socioeconomic development, and thus this paper hopes to contribute towards the formulation and implementation of more effective water management policies in the future. With households accounting for a substantial proportion of total water consumption in most developing countries, understanding the factors affecting household water consumption has become a fundamental concern of policymakers. This paper thus hopes hopes to show which factors are driving household water consumption in Mpumalanga.

1.4 The structure of the dissertation

The remainder of this dissertation will be structured as follows. Chapter 2 will provide an in-depth review of the literature analysing the factors affecting household water demand. Chapter 3 will focus on the the used, presenting a detailed data description and empirical data analysis. The method employed in this study will then be outlined in Chapter 4. Chapter 5 will present the results of the dissertation, which will be followed by the provision of policy recommendations in Chapter 6. Chapter 7 will then present the conclusion of the dissertation.

Chapter 2: Literature Review

As was discussed in Chapter one of this paper, water demand management has become an increasingly important issue for residential water supply authorities throughout the world. Population growth and climate change, coupled with decreasing freshwater supplies and the ever-increasing cost of water infrastructure, have led to a renewed emphasis on water demand management. This has been particularly important at the household level, with households now accounting for a significant proportion of total water supply globally. In response, an extensive body of literature concerning the factors affecting household water consumption has been developed and this chapter aims to provide an in-depth review of this literature, by focussing on research performed in both industrialised and developing countries. The studies reviewed in this chapter have occurred in a multiplicity of contexts, however, they have generally shared a common focus: namely, estimating price and income elasticities of water consumption in order to design better pricing regimes, quantifying the impact of environmental/climatic factors on water consumption and, in more recent times, estimating the effect of socioeconomic factors on household water consumption, as well as the effect of water saving technologies on consumption levels. This literature review will flow in accordance with this general theme and will therefore be broken down into five main sections, each of which will discuss a predominant factor or set of factors affecting household water consumption. The five broad sections will be (1) price, (2) income, (3) climatic factors, (4) socio-economic factors, and lastly (5) behavioural factors, with each section containing more specific sub-sections.

2.2 Price

Under the ideological construct of the alleged supremacy of the market as the instrument to manage and efficiently allocate natural resources (Anderson 1991; Andersen and Sprenger 2000), price represents one of the most predominant tools used to manage the demand for water (Arbués et al, 2004; Corbella and Puyol, 2009; Garcia and Reynaud, 2004; Ghimire et al., 2016). The essential logic here flows from the law of demand, which argues that the demand for water should be inversely related to water price, which would make sense if water were treated as a pure economic good. However, as Savenije (2002) notes, the relationship between water consumption and price is starkly different to that of a normal economic good, and it is in fact a much more complex good to understand, as water is often irreplaceable. Being a commodity with extremely limited substitutes, the price elasticity of demand for water would be expected to be inelastic, implying that a specific percentage change in the price of water would lead to a significantly smaller percentage change in consumption. It is important to be aware that although price represents one of the most important tools used to manage water demand, policymakers need to remain acutely aware that price changes may also lead to socially undesirable distributional effects on households (Hajispyrou et al. 2002; Ščasnýa & Smutnáa, 2019), and hence these outcomes need to be seriously considered before designing and implementing effective policies aimed at altering household water demand. One notes that in situations where there is a single volumetric price for water, demand estimation is relatively straightforward, however difficulty in econometric modelling is found when discontinuous tariff structures exist, something which will be discussed later within this section.

2.1.1 Price Elasticity of Water Demand

Commencing with studies performed in industrialised countries, which have estimated the price elasticity of water demand, Worthington and Hoffman (2008) conducted a synoptic survey of the empirical residential water demand studies conducted between 1980 and 2008. Through their in-depth review, they demonstrated that the price elasticity of water demand varied between −0.25 and −0.75, something which they largely attributed to the fact that water had, and still has, no substitute for basic uses. Upon a review of papers from the same time period, a similar result to that of Worthington and Hoffman was found, with the papers recognizing that domestic water consumption was generally price-inelastic, with price elasticity estimates in these studies generally varying between -0.1 and -0.9 (Arbues et al. 2003; Hoffman et al. 2006; Mazzanti & Montini, 2006; Savenje & van der Zaag, 2002). In a review of 15 studies by Brookshire et al. (2002), similar results were again found, however this time the range of price elasticities was substantially larger with estimates ranging from -0.11 to -1.58, with an average of -0.49. Despite, the majority of studies continuing to report inelastic price elasticities, higher price elasticities have been reported with increased frequency in more recent times, something which, in industrialised countries, has been directly attributed to increased outdoor water use, with estimates now ranging from -1.57 to -3.33 when outdoor uses are considered (Klaiber et al., 2014; Yoo et al., 2014). Although not from an industrialised country, a specific study in this regard conducted in Muscat, Oman, used a two-stage least squares econometric model to estimate a price elasticity of water demand. They found an estimate of -2.10, which the researches explained by the fact that a large proportion of household water use had been for outdoor purposes (Kotagamaa et al., 2017). Looking at the relationship between the price elasticity and specific water uses now, the early consensus amongst scholars revealed that the price elasticity of water demand did vary according to the type of use (Billings & Aghte, 1980; Thomas & Syme, 1988), a consensus which remains to this day (Reynaud, 2018; Dhungel & Fritz Fiedler, 2020). Elaborating upon this statement, Renwick & Green (2000) showed that the more basic and essential the water use was, the closer to zero the price-elasticity of demand would be. These findings were confirmed at the international level by Dalhuisen et al. (2003), reflecting that price mechanisms would not make a substantial difference in the quantity of water demanded for basic uses. In contrast, when dealing with water-related leisure activities such as watering the garden, making use of swimming pools, or other outdoor activities, price-elasticity of the demand increases substantially to values sometimes well in excess of -1 (Klaiber et al., 2014; Yoo et al., 2014; Kotagamaa et al., 2017). This information is critical for policymakers to understand when setting pricing schemes in order to balance equity with efficiency and to achieve the greatest conservation potential in outdoor uses, while not translating the conservation burden to essential water uses (Corbella & Puyol, 2009).

Moving to studies conducted in developing countries now, a comprehensive review of the early literature concerning the price elasticity of domestic water demand in developing countries was conducted by Naughes and Wittington (2010). They demonstrated that despite the heterogeneity in the places and the time periods analysed, scholars generally agreed on the inelasticity of water demand in developing countries. Naughes and Wittington revealed that most of the price elasticity estimates for households in developing countries, with a private water connection, ranged from -0.3 to -0.6. These results were thus similar to the ones found in industrialised countries of that time, as the price elasticity was also generally inelastic. A key difference, however, was that there was a significantly larger effect on water demand at lower price levels in developing countries than in industrialised ones. In their investigation, Naughes and Wittington importantly emphasized that analysing the demand for water in developing countries was much more complex than in industrialised countries due to different household groups using multiple water sources to meet their demand, something which requires careful investigation to draw appropriate policy recommendations. This is a problem which remains to this date, with most water demand research being based on single equation models for a single source of water, something rarely seen in developing country contexts. This approach has led to two fundamental problems, firstly the demand models do not capture the full range of alternatives, so the true economic relationship among the alternatives is obscured. And secondly, economic theory predicts that the demand for a good becomes more price-elastic as the number of close substitutes increases. Thus, if researchers artificially limit the number of alternatives studied to something less than the true number, the price elasticity estimate may be biased downward (Coulibaly et al., 2014). One of the earliest studies addressing this issue was performed by David and Inocencio (1998), with the key difference in their study from others at the time being that they analysed the price elasticity of non-piped water, something which Naughes and Wittington did not consider. Using data from Manila, in the Philippines, they estimated a price elasticity for vended water of -2.1, thus substantially larger than piped water estimates of the time. Two studies then went a step further and analysed the price elasticity of water demand for households with both piped water connections and having access to non-piped water sources. These studies were conducted in Vietnam in 2008 and in Sri Lanka the following year, with both studies finding that households which relied solely on piped water were significantly less sensitive to price changes than households which had both piped water and access to non-piped water, which was usually in the form of a well (Cheesman et al. 2008; Naughes & van den Berg, 2009). One of the most predominant studies addressing the issues mentioned was performed by Coulibaly (2014), in which he accounted for both multiple water sources and multiple demand equations. Coulibaly's results provided price elasticity estimates ranging from -0.62 to -2.33, thus again revealing that the price elasticities of water demand are substantially larger when there are multiple water sources available to households. Turning to South Africa specifically now, one notes that there have been relatively few studies analysing the price elasticity of water demand in the country. The studies which have been conducted though, have produced findings concurrent with the piped-water demand literature abroad, estimating inelastic price elasticities of water demand (Veck & Bill, 2000; Jansen, 2013; Szabo, 2009). The first major South African study was conducted by Veck and Bill (2000) and estimated the price elasticity of demand for water amongst different income groups in two suburbs of Johannesburg, namely Alberton and Thokoza. Their results revealed a price elasticity estimate of -0.17 in both suburbs. A later South African study performed by Jansen (2013) estimated the price elasticity of water demand for households in the city of Cape Town and found water demand to be mostly price inelastic. Therefore, the discussion above has importantly shown that despite the general consensus being that the overall price elasticity of water demand is inelastic, there are numerous scenarios in which these estimates can become significantly elastic, such as in the presence of substantial outdoor water use, as well as when multiple water sources are available to households, something predominant in developing country contexts.

2.1.2 Block-Scheme Water Pricing

Before analysing the literature relating to block-scheme pricing one needs to understand what these schemes in fact are. A block-scheme essentially involves households typically paying fixed service charge for water in addition to a per unit cost. There are three predominant rate structures used to price water in this regard: the uniform rate, increasing block rate, and decreasing block rate structures. Households facing a uniform rate structure pay the same marginal price for all units consumed, while households facing an increasing (decreasing) block rate structure face a constant price over the first units consumed, however they pay a higher (lower) amount over the next units used (Klein et al, 2006). Increasing block rate structures have become increasingly popular because of their ability to promote conservation among individual water users, with early evidence of this is provided by Cavanagh et al.

(2002) who reported that between 1991 and 1997, the number of utilities applying an increasing block rate to price water nearly doubled. For this reason, much of the literature in the early 2000s concerning household demand for water focused on the impact of increasing block rates on demand, and this literature will be discussed below.

Starting with studies conducted in industrialised countries once again, a meta-analysis of the empirical findings regarding the price elasticity of water demand in differing block structures was completed by Dalhuisen et al. (2003), in which he considered 64 studies over the period 1964 to 2001. A crucial finding from this research was that the average price elasticity of demand for water in the case of increasing block rate structures was relatively higher, when compared to flat rate and decreasing block structures, although the estimates remained price inelastic. A similar conclusion was reached by Martínez- Espiñeira and Nauges (2004) when they demonstrated that the water demand function which they modelled for Seville, Spain, presented different price elasticities for different levels of consumption in different price ranges. An early study in the USA, in this regard, compared residential water demand estimates under decreasing and increasing block rates in Texas and found significant elasticity estimates ranging from -0.36 to -0.86 (Nieswiadomy & Molina, 1989). Again, in the USA, Taylor et al (2004) produced similar findings, going on to reveal that when the fixed fee was purged from the data, average price was not significant, however marginal price remained significant. Moving to developing countries now the literature has been relatively sparse, however, a prominent piece of research relating to block-schemes in developing countries was completed by Whittington (2009) in which it was shown that moving from a uniform to an increasing block structure tariff could significantly impact household water consumption. In the paper, Wittington makes the important point that the poor often pay higher average water prices than better-off households and provides two fundamental reasons for this outcome. Firstly, it is stated that households in high-density housing conditions must pay more per unit under the increasing block tariff (IBT) structure than households which share a connection with only a few others. Secondly, Withington provides that many low-income families do not have private connections at all and purchase water from vendors, who thus become caught up in increasing block rates as well, and likely pass them along to the buyer. With respect to studies in South Africa, Szabo (2009) has been the only widely published researcher to analyse price elasticity in differing block-schemes in the country. Szabo used a structural approach to estimate the price elasticity of the demand for water in Pretoria, and found that consumers would choose the block they wanted to consume in, based on all the marginal prices in the pricing schedule and, within a particular block, they would choose the quantity to be consumed based on the marginal price applicable to that specific block (Szabo, 2009).

2.2 Income

For normal goods, the law of demand argues that demand should increase proportionately with income. In the case of water, however, the measurement of income's effect on demand is much more complex because water bills often represent a substantially lower proportion of income for higher-income households than is the case for lower income households. Another thing to note is that in studies based on whole-of-utility data, income is normally presented as per capita or per household, whereas in household-based studies actual household income, or a proxy for household income, can be employed (Worthington & Hoffman, 2008). In addition, because income can approximate wealth, income recorded from taxation, census and survey data can also be used to proxy other normal and luxury goods associated with household water demand where data may not be as easily obtainable, including things such as swimming pools, in-ground garden irrigation systems and dishwashing machines (Worthington & Hoffman, 2008). Studies focusing on water demand across a range of countries, and over a large time period, generally agree that there exists a positive effect of income on water consumption. This means richer households tend to use more water than poorer households, even if the difference is small (Mazzanti & Montini, 2006; Nauges & Thomas, 2000; Jayarathnaa et al., 2017; Ščasnýa & Smutnáa, 2019).

2.2.1 Household Income

Looking at the effect of household income on water consumption in general, the literature covering industrialised countries has empirically demonstrated that domestic water consumption is positively correlated with household income (Agthe & Billings, 1987; Arbués and Villanua, 2006; Hoffman et al. 2006; Renzetti, 2002; Jayarathnaa et al., 2017; Reynaud & Romano, 2018). The explanation here is quite simple, higher income households are associated with higher living standards, which suggests that they own more water-consuming appliances and these households are more likely to have a higher probability of the presence of high-water demanding outdoor uses, such as gardens and swimming pools (Reynaud & Romano, 2018). Elaborating upon this, a recent study conducted by Romano & Salvati (2014) used a linear mixed effects model to estimate the determinants of residential water demand for chief towns of every Italian province. Romano and Salvati's findings show that per capita income, which was used as a proxy for household income, had a positive effect on water consumption levels, a finding in line with the other industrialised country literature mentioned previously. Using GIS modelling to analyse residential water demand in Brisbane, Australia it was revealed that income was again highly significant in predicting household water demand (Jayarathnaa et al., 2017). Looking at studies using proxies for household income now, Fan et al. (2017), using GDP per capita as a proxy, was able to illustrate through conditional inference trees and the random forest method that water consumption was significantly affected by GDP per capita in China. Other reliable proxies for household income, such as monthly expenditure and occupation of household head, were used by Dagnew et al. (2012) to demonstrate that these variables too had a positive and statistically significant effect on water consumption. One notes that studies performed in developing countries investigating the effect of household income on water demand have differed slightly from those of industrialised countries, as they have often simultaneously looked at the effect of household income levels on the choices made by households with regards to accessing improved water sources (Madanat & Humplick, 1993; Hindman, 2002; Basani et al, 2006; Rauf et al, 2015). Despite this difference in technique, the conclusion from these studies has been in line with the results from industrialised countries revealing that income has been positively correlated with water consumption. The extension of these studies has demonstrated that income was also highly correlated with a household's choice of accessing an improved water sources (Hindman, 2002; Rauf et al, 2015). The overall view from both industrialised and developing countries has therefore been that household income is positively related to water consumption levels.

2.2.2 Income Elasticity

Upon reviewing the early literature regarding the income elasticity of water demand, Piper (2003) stated that almost all the demand models had estimated the income elasticity of water demand to be positive and inelastic, with Piper providing that this result had occurred regardless of the region where the study was conducted or the modelling technique used. This statement is in line with the views of Cavanagh et al. (2002) who reported that most income elasticities provided in the studies conducted between 1951 to 1991 had generally fallen within the range of 0.2 to 0.6. These findings have remained consistent in more recent times, with the literature continuing to report positive and inelastic income elasticities of water demand, across widely varying contexts (Hoffman et al, 2006; Romano & Salvati, 2014; Jayarathnaa et al., 2017). Ščasnýa and Smutnáa (2019) attempted to cover a gap in the residential water demand literature by estimating price and income elasticities for countries undergoing economic or political transitions. They did this by looking at water demand in the Czech Republic between 1993-2016, a period when the price of water almost tripled, water consumption decreased by a third, and families became considerably richer. After controlling for price endogeneity, their estimate of income elasticity was about +0.16 and robust across all model specifications (Ščasnýa & Smutnáa, 2019). These findings thus fit in the range found in previous studies, however they are slightly more inelastic than usual, and importantly the research also confirmed that the effect of income decreased with household wealth. Moving specifically to studies in developing countries now, one of the earliest studies performed a cross-sectional analysis of a random sample of 1400 households from a range of developing countries to estimate an income-elasticity of 0 for low-income households and an elasticity of 0.2-0.4 for higher-income households (Katzman, 1977). Later, an in-depth analysis of the literature prior to 2010 in developing countries was performed by Naughes and Wittington (2010), which confirmed these early findings. After considerable analysis they were able to demonstrate that the income elasticity was relatively low in developing countries, most often in the range of 0.1–0.3, and thus significantly less than in industrialised countries (Naughes & Wittington, 2010), a range which fits the estimates of more recent studies (Ahmad et al., 2016; Fan et al., 2013; Akoteyon, 2019; Abdullah et al., 2019). Looking at South Africa now, more specifically Cape Town, Jansen (2013) performed a water demand modelling estimation procedure and found that higher-income households were significantly more sensitive to price changes than lower income households.

Within all of this literature, however, the problem of multicollinearity is a real concern, as household income is likely to be correlated with a variety of housing characteristics such as the number of bathrooms, appliance ownership and plot size (Foster and Beattie, 1979; Martinez-Espineira, 2002; Reynaud & Romano, 2018). One should also note that the income elasticity of residential water demand may be provided as low irrespective of location, however this may be due to sample or specification bias. For instance, the income effects as measured may be mixed up with price effects in poorly specified models. This creates a situation whereby elasticities are only valid in the short term and may be substantially more elastic over the longer term.

2.2.3 Indoor vs Outdoor Water Demand at Differing Income Levels

When investigating the effect of income on water consumption, it is important to note that while low-income households may not respond to price changes because they are using water mostly to fulfil their basic needs, high-income households often fail to respond because the price signal is not strong enough to curb their water demand (Renwick & Archibald, 1998; Dagnew et al., 2012; Reynaud & Romano, 2018). Analysing the factors effecting water consumption of high-income households therefore regularly differs to that of low-income households since they often have considerable outdoor water usage for things such as swimming pools and garden watering. Domene et al. (2005), in fact, emphasized that garden watering reflected to a large extent household income and class. Studies analysing the income elasticity of water demand for indoor versus outdoor uses have thus largely been confined to developed countries (Howe & Linewar, 1967; Loh & Coghlan, 2003; Syme et al, 2004; Mansur & Olmstead, 2006; Vlach, 2016). These papers reveal that indoor water consumption remained relatively stable for households with different income categories, while significantly larger variations appeared when outdoor uses were present. With regards to developing countries, studies analysing the effect of income on water consumption have largely ignored the differences between indoor and outdoor uses, however one early study conducted in Pretoria, South Africa, did distinguish between the two (Veck & Bill, 2000). Veck and Bill showed that the demand for indoor water use was price inelastic for all income group households. For outdoor use, however, they revealed that high-income households were significantly more responsive to price changes.

2.3 Climatic Factors

This section will analyse the climatic factors affecting household water consumption levels, as climate has been one of the most studied drivers of domestic water demand in the literature. The reason for this is that it is believed that water consumption should vary depending on variables, such as temperature, wind, moisture, seasonality and rainfall, with these variables ultimately influencing the amount and/or frequency of activities that involve water-use, such as personal hygiene practices and garden watering (Romano & Salvati, 2014; Wang et al., 2014; Ashoori et al., 2016). There are numerous climatic variables discussed within the literature, however only the discourse relating to the three most predominant of these will be discussed in this section.

2.3.1 Rainfall

One of the more advanced early studies examining rainfall's effect on water consumption was conducted by Woodward and Horn (1988) in Arizona, USA. They found that precipitation events decreased water demand from one day prior to the precipitation event to several days following it, with the reduction the day before likely being due to weather forecasts. Their results ultimately showed that rainfall explained approximately 27% of the total variation in water demand for their sample of Arizonan Households, and rainfall events that lasted several days had less of an effect on water demand than distinct rainfall events that had dry days in between them (Woodward & Horn, 1988). The paper went even further and illustrated that Monsoon precipitation in the summer months (May - Sept) had much more of an effect on water consumption than winter precipitation, and the number of monsoon precipitation events was a better predictor than the amount of rain that fell within each event (Woodward & Horn, 1988). Continuing with early studies conducted in the USA, Gutzler and Nims' (2005) research in Albuquerque and Rhoades and Walski's (1991) research in Austin, both revealed that rainfall was the most significant climatic variable in explaining daily municipal water consumption. Moving abroad from the US now, Corbello and Puyol (2009) found rainfall to be the most significant climatic variable in determining water demand in their global study of industrialised countries. They, however, demonstrated that rainfall was expected to have a significant effect on water demand for outdoor activities only, principally water used for gardening purposes. Looking at the psychological effect of rainfall on water consumption, it has been demonstrated that the occurrence of rain is significantly more important than the amount of rainfall in effecting consumption, thus confirming the results presented by Woodward and Horn (Arbues et al. 2003). This finding was also in line with results from previous work conducted in Spain in 2002 which pointed out the importance of the recurrence of rain, as opposed to the total amount of rain (Martínez-Espiñeira, 2002). One study finding a contrasting result to those mentioned above, revealed that rainfall in fact had no significant association with water consumption levels, however this may have been due to the relatively small number of observations used in this panel data study of Portuguese communities (Martins and Fortunato, 2007). The more recent literature has confirmed these early findings with precipitation being identified as a highly significant factor in determining household water demand (Wang et al., 2014; Ashoori et al., 2016). With regards to developing countries, the literature has unfortunately been extremely scarce. Nonetheless, two recent studies in China have been conducted to analyse the effect of rainfall on water consumption. The first was in Urumqi City and found that despite domestic water consumption in the city being highly correlated with temperature, it was however only weakly correlated with rainfall (Yan, 2013). The second, in contrast, analysed data from 286 cities across China from 2000-2015 and found that water consumption per capita per day was strongly influenced by precipitation, although the effect was much higher for higher-income households (Fan et al. 2017), something which may point to a reduction in outdoor water use by high-income households following precipitation events.

2.3.2 Temperature

One would expect that increasing temperatures would lead to an increase in water consumption, and this has turned out to be the most common finding in the literature, irrespective of location, with temperature being shown to be highly correlated with household water consumption levels (Gato et al. 2007; Maidment & Miaou, 1986; Yan, 2013; Ashoori et al., 2016). One of earliest and most comprehensive studies in this regard was that of Maidment and Miaou (1986), in which they investigated weekly municipal water use in three cities of three states in the United States – Texas, Florida, and Pennsylvania. The water use levels recorded in each city were then compared it to a heat function, a temperature function, and rainfall events, to analyse the differing effects of these climatic factors, with the results revealing that water consumption had the highest and most significant correlation with temperature. Using their heat function, Maidment and Miaou found that in Texas, water consumption increased when the temperature reached around 21 degrees Celsius and then rose more sharply at about 32 degrees. The authors also found that the water use response from a ‘hot day’, which was typically an increase in water use, would decay such that each successive day had 2/3rds of the response of the previous day (Maidment & Miaou, 1986). Two European studies analysing the effect of temperature on water consumption interestingly produced starkly contrasting results to each other, with the first by Martins and Fortunato (2007) demonstrating that high temperatures increased the demand for water in Portugal, whilst Schleich and Hillenbrand (2009), investigating average per capita demand for water and sewage in over 600 water supply areas in Germany, found no impact of temperature on residential water use. Moving to developing countries now, the literature is unfortunately extremely scarce, however evidence from Yan (2013) revealed that temperature was statistically significant related to water consumption in cities across China – a finding in line with the general results seen in industrialised countries.

2.3.3 Seasonality

In terms of the effect differing seasons have had on water consumption, most papers investigating this phenomenon have been conducted in Spain (Arbués and Villanua, 2006; Domene and Sauri, 2006; García-Valiñas, 2005). Domene and Sauri performed research in the Metropolitan Region of Barcelona and found that water use was higher in summer, a finding in line with García-Valiñas (2005) who also observed significantly higher water demand in summer than in all other seasons. Contrastingly, however, Arbués and Villanua reported an association between high temperatures (summer) and lower water demand within the city of Zaragoza, Spain, something which they suggested was due to water use levels tapering off in the summer due to the outflow of residents to holiday destinations. Moving out of Spain, an early study by Dandy et al (1997) showed that the sensitivity of water use to price in Adelaide, Australia, depends significantly on the season. Meanwhile, using temperature as a proxy for the summer season in Texas, USA, it was shown that increased temperatures (summer) impacted positively on water consumption.The rationale provided being that hotter days brought about increased garden watering, swimming pool use, and personal hygiene (Hoffman et al, 2006). These general results have been found to transcend all contexts, and in the Katarko Village, in Northern Nigeria, seasonal changes were also identified as the key climatic factor influencing water consumption levels (Nyong & Kanaroglou, 2001). These results continue to permeate in more recent work with seasonality being identified as a key determinant of residential water demand in numerous studies (Wang et al., 2014; Clarke et al., 2017; Rathnayaka, 2015). Expanding upon two of these studies, Clarke et al. (2017) used household-level panel data from Tucson, Arizona, to estimate the residential demand for water via a Stone-Geary specification, with the estimated model finding substantial seasonal variation in the price elasticity estimates. Secondly, in a comprehensive analysis performed to examine seasonal variability of residential water end-uses, it was interestingly shown that shower water use was significantly different between winter and summer seasons, in addition to irrigation, evaporative cooler and pool water end-uses, while it was revealed that other water end-uses were not significantly different across seasons (Rathnayaka, 2015).

2.3.4 Climatic Factor Critiques

In concluding this section, it is important to highlight some of the problems and criticisms which have been seen within the studies analysing the effect of climatic factors on water consumption. The first area of concern is that there has been some criticism surrounding the specification of weather parameters, with Maidment and Miaou (1986) first arguing that the linear relationship assumed between the proxy for weather, such as rainfall or temperature, and the focus of measurement often breaks down. Looking at problems relating to rainfall specifically, in their meta-analyses, Espey et al. (1997) and Dalhuisen et al. (2003) argued that the incorporation of rainfall led to reduced valued of the price elasticity of water demand. This suggests that rainfall and prices are positively related, lying at odds with the notion that prices should be set with scarcity in mind (Worthington & Hoffman, 2008).

2.4 Socioeconomic Factors

In order to explore the determinants of water demand further, and to test the robustness of price and income elasticities, it is necessary to include other explanatory factors in water demand modelling, of which socioeconomic factors are crucial (Mazzanti and Montini 2006; Nauges and Thomas, 2000; Renzetti 2002; Abdullah et a, 2019; Garcia et al., 2019). In fact, it has even been shown that increasing water prices are sometimes associated with increases in water use, as opposed to reductions (Corbella and Puyol, 2009). Early on, Baumann et al. (1998) suggested that this occurrence was a result of the failure to recognise that domestic water use may increase/ decrease due to socioeconomic factors such as household size, housing type, age, etc. There has thus been a growing body of literature which includes these socioeconomic variables within their water demand models, and of particular relevance is that much of this literature is concerned with developing countries.

2.4.1 Household Size

When investigating the effect of household size on water consumption, one would expect that the more people there are present within a household, the higher the aggregate household water consumption should be. Despite this expectation, studies from industrialised countries have not indicated significant results with regards to the effect of household size on water consumption, and results from Spain, in fact, suggest that economies of scale regarding the optimization of water use were found to be generally unachievable in small households within the city of Zaragoza (Arbués et al, 2000). Arbues et al. (2003) argued in their research that an optimum household size exists, beyond which economies of scale begin to vanish. Moving forward, in an investigation of water use efficiency, Lux (2008) demonstrated that increasing the number of people within small households in Germany intensified the effect of 'inefficient' water use within these households. One can therefore see that household size has generally not been regarded as one of the most crucial factors affecting water consumption in industrialised countries. With regards to developing countries, however, household size has been shown to have a much more significant effect on overall household water consumption (Cheesman et al. 2008; Abdullah et al, 2019; Garcia et al., 2019). An in-depth analysis of the literature concerning developing countries by Naughes and Wittington (2010) revealed that household size was statistically significant in most cases. The authors also illustrated that when the dependent variable was total household water use, larger households were found to have substantially greater use. On the other hand, when the dependent variable was per capita water use, scale effects were confirmed, implying that per capita consumption decreased with the number of members in the household (Naughes & Wittington, 2010). Continuing with developing countries, in Buon Ma Thuot, Vietnam, it was found that doubling the number of people within a household resulted in a 50% increase in water demand from a piped network (Cheesman et al. 2008). Similarly, in Sri Lanka, household size was again shown to be a significant explanatory variable determining water demand, with the estimated coefficient on household size provided at 0.38, suggesting that an additional household member would increase household water use by 38% (Gunatilake et al, 2000). One of the most recent studies in this regard was performed by Abdullah et al. (2019), in which the projected 50-year water demand of Maiduguri township, North-Eastern Nigeria, from 2006 to 2056 was investigated. Through their research, household size was revealed as the most statistically significant variable in determining household water demand, alongside other socioeconomic variables like gender and income. Household size was also shown to be decidedly significant in determining residential water demand in single-family households in the city of Joinville, Southern Brazil (Garcia et al., 2019)

2.4.2 Gender

A variable which has been largely absent from the literature in the developed world has been that of gender and its effect on domestic water use. Despite this, there has been a notable amount of research on this variable in the developing world, with early papers by Crow (2001) and Zwarteveen (1997) reviewing the relationship between gender, water rights and access to water in developing countries. Elsewhere, the importance of gender analysis when developing water policies was emphasized by Van Koppen (2001) due to the important variation of water use along gender lines. Turning to empirical investigations of the effect of the gender variable on water use, evidence from Ukunda (Kenya) and Dakar (Senegal) revealed that households with more women were less likely to purchase water from vendors (and more likely to rely on water from wells and kiosks), presumably because more people in the household were available to carry water (Mu et al, 1990). In Merawi, Ethiopia, Dagnew et al. (2012) found that gender of the household head impacted negatively on water consumption, suggesting that females used more water than males. This is likely due to water use for household activities such as washing and cleaning. In the previously mentioned study of Maiduguri township, North-Eastern Nigeria, by Abdullah et al. (2019), gender was again reported as highly significant, with similar effects seen to that of Dagnew’s study.

2.4.3 Age

In terms of age's effect on water consumption, two key early investigations stand out - Hanke and de Mare’s (1982) study of Sweden, and Lyman’s (1992) study of Moscow, Idaho. The key finding from Kanke and de Mare was that the elasticity of water demand for adults (0.13) was more than double that of children (0.05). While Hanke and de Mare only distinguished between adults and children, Lyman considered children, teenagers and adults, with teenagers classified as individuals between age 10-20. Findings from Lyman revealed that adding a child to a home increased water consumption by 2.5 times that of an additional teenager and 1.4 times that of an additional adult. A fascinating dynamic of the age variable revolves around the difference in water use levels of individuals who have entered retirement age. In Tucson, Arizona, Billings and Day (1989) found that water use levels increased as individuals transitioned from the 55-64 age range to the ‘post-retirement’ class, a result probably due to an emphasis on work giving way to time at home and on activities such as gardening. In contrast, however, Martinez-Espineira’s (2002) study of cities in northwest Spain demonstrated that cities with a high concentration of people over age 64 had lower water use levels. Nauges and Thomas (2000) argued that water demand in areas with a higher proportion of younger people was likely to be higher due to more frequent laundering and use of water-intensive outdoor leisure activities. However, communities with a higher proportion of older inhabitants were found to be more focused on gardening, hence affecting their water consumption levels.

2.4.4 Education Level

Relatively few studies have investigated the impact of people's education level on water consumption in the developed world. The few studies that exist argue that education level is to be related to environmental consciousness and awareness, as opposed to directly influencing water use trends (Syme et al, 1991; Syme et al, 2000; Dieu-Hang et al., 2017). As such, increased education levels could be translated into the purchase of water-efficient appliances or the planting of water conserving garden species, which ultimately impacts overall water consumption (Vasquez, 2016; Arbues et al., 2016). In the developing world, there has been a relatively substantial amount of literature on the influence of education on water use. The current stock of empirical evidence not only focusses on education's effect on water use levels, and instead focusses on the impact of education levels on water consumption levels, as well as on the choice of particular water sources for households. The general consensus of this literature being that education level was positively related to consumption and the decision to improving diversification in water supply sources (Madanat and Humplick, 1993; Hindman, 2002; Larsen et al. 2006). While numerous socioeconomic variables were found to be significant in determining household water consumption in Nigeria, it was the education's coefficient which was revealed to be the most influential parameter. Garcia et al. (2019) also found education to be a key and significant variable affecting household water consumption in their study of single-family households in Southern Brazil.

2.5 Behavioural Factors

In terms of demand-side management policies for reducing water use, several non-price measures are possible, of which consumer behaviour is widely regarded as the most fundamental. The importance of consumer behaviour as an explanatory factor in household water use has been emphasised throughout, with the most common behavioural factors discussed in the literature being the effect of water restrictions, be they mandatory or voluntary, and, the effect of adopting water saving technologies.

2.5.1 Water Restriction Programmes

The majority of the studies investigating the effect of water restrictions on domestic water use have been conducted in industrialised countries, with studies in the United States of America in the early

2000s accounting for the most substantial portion. Elaborating upon this statement, Kenney et al. (2004) applied a simple ‘before and after’ comparison as well as an ‘expected use’ model to data from Colorado and found that mandatory outdoor watering restrictions reduced municipal water demand by between 13% to 56%. In the same study, it was demonstrated that voluntary restrictions resulted in anywhere from a 12% savings to a 7% increase in water use. Moving to Iowa, in one of the first studies investigating the effect of restrictions, Lee (1981) analysed the effectiveness of various water conservation practices using a multiple regression predictive model. Among the variety of policies reviewed, mandatory restriction was found to be the most effective measure in reducing water use, with voluntary conservation policies also resulting in substantial decreases in water use. Renwick and Green (2000) found that mandatory restrictions, such as prohibitions on washing sidewalks and driveways or bans on landscape watering during peak hours, reduced average water consumption by approximately 30%. Moving abroad from the USA now, a study conducted in Sardina, Italy, concluded that restriction measures often did not have a significant influence on water use after the first year of their implementation, something which was attributed to the fact that users adopted defensive measures when restrictions were in effect such as using water tanks to offset regulations (Statzu and Strazzera, 2009). Contrastingly, yet in line with the US studies, García-Valiñas (2005) demonstrated that restrictions implemented in Seville, Spain, during the drought, seemed to have an important influence in reducing water demanded in the area (Garcia-Valiñas, 2005).

2.5.2 Adoption of Water Saving Technologies

A decade or so ago, literature concerning the effect of water saving technologies and strategies on water consumption was extremely limited, however this trend has changed in more recent time. Despite the lack of early research, this is an area which needs urgent investigation as we move into a world where the focus has now moved to reducing water demand, as opposed to hoping to augment supply. Importantly, it has been shown in the literature that water consumption levels are significantly linked to water use habits and attitudes towards water conservation, which suggests that water saving technologies could be key determinants of households water consumption (Syme et al. 2004; Willis et al. 2011; Hoolohan and Browne 2016). One of the most recent studies falling within this bracket of research was conducted by Manouseli et al. (2019) in which the effectiveness of a water efficiency programme initiated in South East England was evaluated. Analysis from the study revealed that households which had participated in the programme reduced their per capita consumption by approximately 15%, with the paper also importantly pointing to the fact that single resident and relatively poorer households had a higher potential to conserve water than wealthier and larger households (Manouseli et al., 2019). In 2011, a fascinating study was conducted by Tsai et al. (2011)

in four towns within the Ipswich watershed in Massachusetts, USA, to assess the impact of four water conservation strategies - (1) installation of weather-sensitive irrigation controller switches (WSICS) in residences and municipal athletic fields; (2) installation of rainwater harvesting systems in residences; (3) two outreach programs: (a) free home indoor water use audits and water fixture retrofit kits and (b) rebates for low-water-demand toilets and washing machines; and (4) soil amendments to improve soil moisture retention at a municipal athletic field (Tsai et al., 2011). The key results from the study revealed that of the strategies tested, the installation of weather-sensitive irrigation controller switches (WSICS) in residences and municipal athletic fields reduced water consumption, rainwater harvesting provided substantial water savings, and finally the modelling approach showed the potential water savings which could result from soil amendments in ball fields (Tsai et al., 2011). In an interesting paper from 2015, it was concluded that water conservation habits helped reduce water consumption, however, the adoption of efficient water-using technologies led to lower water savings than expected, and, in some cases, resulted in an increase in water consumption (Urdiales, 2015). Most recently, the presence of water-efficient appliances was shown to be a highly significant predictor of household water demand in the city of Joinville, Southern Brazil (Garcia et al., 2019). This ever-growing body of literature provides crucial information on the range and effectiveness of individual water conservation mechanisms, however it is a necessity that further research is conducted to deepen our understanding of the extent to which adoption of water saving technologies could contribute at reducing water consumption levels (Koop et al., 2019).

2.6 Conclusion

This section has provided an in-depth review of the current literature about the factors that drive household water consumption, both from an industrialised and developing country perspective. The review firstly highlighted the importance of price in influencing water consumption levels, hence, revealing it to be an extremely effective tools for managing water scarcity. The review then went on to highlight the substantial affect household income has on water consumption levels, revealing a highly economically and statistically significant relationship between household income and household water consumption levels. This shows that wealthier households were shown to use substantially more water for non-discretionary and outdoor purposes than their poorer counterparts. The effect of various climatic factors was then investigated, with the review highlighting rainfall and temperature to be the key climatic factors affecting household water consumption levels. To note here is that a key limitation of this study is that it does not include any of the climatic variables described. This is because this study uses cross-sectional data from one location and thus including time varying climatic variables was not possible, and similarly there was no climatic variation by regions due the data emanating from one location. A selection of crucial socio-economic factors was then discussed in some detail, with these including household size, age, gender and education level. Household size was shown to have the largest effect on water consumption levels, although education has also been shown to display a significant and positive effect on water consumption. Finally, behavioural factors associated with reactions towards water restrictions and adoption of water saving technologies were discussed. Both water restrictions and adoption of water-saving technologies are shown to promote reduced water consumption.

Chapter 3: Data

This chapter will focusses on the data set used within this study. The chapter will be broken down into two key sections – 1) the Data Description, in which the data set used and the method of data collection will be discussed; and 2) the Preliminary Data Analysis, which provides an analysis of the data set and summary statistics of the variables employed in the empirical specification.

3.1 Data Description

The data used within this study comprises of a cross-sectional household level data set from Mpumalanga, South Africa. The data set corresponds to 526 households from the City of Mbombela in Mpumalanga and was collected in late 2019 by a team of field workers who went door to door conducting a household survey for willing households. More details regarding the questionnaire used will be discussed further below, however at this point one notes the importance of the data set to the study. Household-level data is highly preferable for estimating the determinants of residential water demand and the availability of this newly collected household level data is of huge benefit to this study. The most crucial data collected within this survey was that of the household monthly water bill and the household monthly water consumption levels for the three months prior to the date of data collection. Coupled with this, was vital data on numerous socio-economic characteristics of the households sampled. Previously, accurate data combining water consumption, pricing and socio-economic characteristics has been hard to come by. Making this data set even more valuable is the additional data relating to households' attitudes towards water saving technologies, as well as information regarding households' adoption of water saving technologies and the constraints they face to the adoption of these technologies. The value of this new data set is of great significance to the quality of the results seen in this paper.

With regards to the data collection process, a stratified random sampling technique was used to obtain a representative sample. As was mentioned, surveying of the households was conducted in late 2019, using a structured questionnaire prepared in the native language. The survey questionnaire included an introductory section which briefly described the background and purpose of the survey to the household in question. Following this, willing households were asked a set of approximately 40 short questions which were divided into 6 distinct sections. The 6 distinct sections included – 1) household identification, 2) general information on household water consumption, 3) socioeconomic variables of households, 4) household water saving strategies and technologies, 5) household attitudes towards water conservation, and 6) household constrains to the adoption of water saving technologies. These broad sections were broken down into several important questions which allowed for comprehensive, and specific, data on each household to be collected. (See Annexure 1 for full survey questionnaire).

Looking at some of the crucial variables used within this study and how they were calculated, one begins with the independent variable used – average monthly household tap water consumption. This variable was calculated by averaging the three-monthly household water consumption levels recorded from the questionnaire. This figure was then logged to fit the appropriate functional form of the model, a process which also allows for the easy estimation of the price and income elasticities of water demand, which are crucial estimates to be calculated in this study. Moving to the key explanatory variables used - price and income – to calculate the tap water price variable used in this study, the fixed fee of R118 which was applicable to all households was first removed from the average monthly tap water bill for each household, since this amount was paid by all households regardless. This new figure for the water bill was then divided by the average monthly tap water consumption level, with both of these figures having been recorded within the survey for the three months prior to data collection. This new tap water price variable was then logged to ensure normality of the variable and to allow for the estimation of price elasticities within the regression estimation section. Regarding the tap water price variable, there are two key issues related to price when analysing water demand facing a nonlinear pricing scheme, as is seen in this study. Firstly, one must decide between using marginal or average price. With households in the study generally indicating they did not have good price knowledge, one notes that these households would likely be more sensitive to changes in average price than in marginal price, and thus average price is used in this study. The second issue, as commented above, relates to the price endogeneity generated by the simultaneous determination of price and the block of consumption, and this issue was addressed using an instrumental variable approach which will be discussed in more detail within the methodology section of this chapter (section 3). The other crucial explanatory variable of household income used in this study was calculated by summing together 6 forms of household income identified within the survey. These included employment income, remittances and government transfers, business income, pension, and finally other income. The newly calculated household income variable was then logged to allow for elasticity estimates within the regression section to be calculated, with this functional form also performing best in the model testing phase. The table below provides definitions of all the key variables used in the econometric specification employed in this study, with the inclusion of these variable based upon the crucial variables highlighted in the literature review from Chapter 2.

Table 6: Definitions of Key Variables:

Variable	**Definition**
Average Monthly Consumption (L)	Average monthly tap water consumption in litres
Average Tap Water Bill	Average monthly tap water bill in Rands
HH Income (R)	Household income (Rands)
Water Scarcity	Water scarcity rating by households
No of Interruptions	No. of water interruptions in the last 12 months
Water Quality	Water qaulity rating by household
Age	Age of household head
Gender (% Male)	Gender of household head (% male)
HH Head Years of Educ	Household head's years of education attained
Spouse Years of Educ	Spouse's years of education attained
No. of Employed HH Members	Number of members in the household who are employed
HH Size	Household Size
Children Under 5	No. of children under 5 years of age
Groundwater Access (%)	Implies a household has groundwater access (borehole or well)
Owns Lawn (%)	Household owns lawn
Owns Swimming Pool (%)	Household owns swimming pool
Aware of WS Strategies (%)	Household is aware of water saving strategies
Prioritise Conservation (%)	Household believes water conservation is a priority
Installed Water Saving Tech (%)	Household installed water saving technology
Used Greywater (%)	Household uses greywater technology
Used Rainwater (%)	Household uses rainwater technology
Price Block	The tap water consumption block in which a household consumes

3.2 Data Analysis

The data generated from the questionnaires was analysed and simplified using Microsoft Excel and the Stata 14 statistical package. The data was first cleaned, coded, and labelled, before a preliminary data analysis was conducted which produced the series of figures and tables seen within the remainder of this section. The aim of this section is to provide more context of the households studied. The empirical figures have been divided into 6 separate sub-sections; namely, 1) Household Sample Breakdown, 2) Household Tap Water Consumption and PricingPrice 3) Socio-Economic Characteristics of Households, 4) Water Service and Use Characteristics of Households, and 5) Water Saving Strategies and Technologies used by Households. The intention is that this break down will allow for specific and in-depth discussions on the variables used within the study. The empirical analysis will end with the provision of important summary statistics on all the variables used in the regression section.

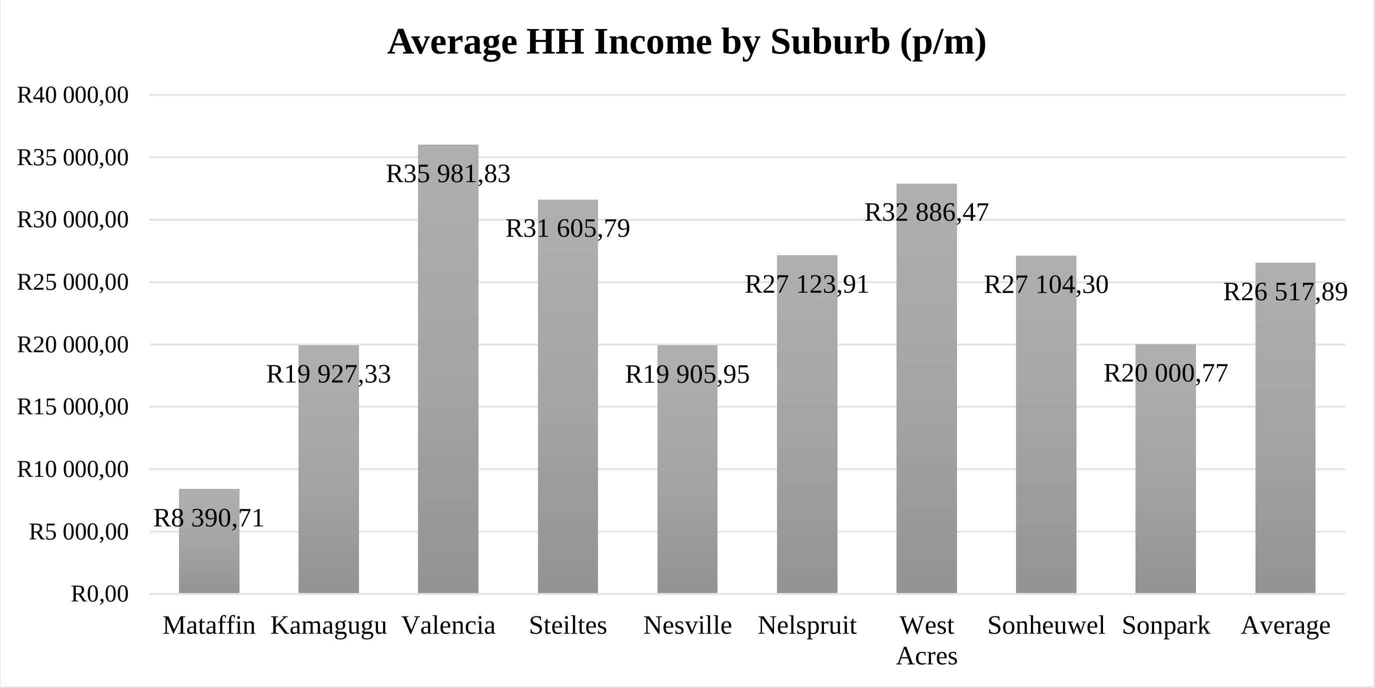
3.2.1 Household Sample Breakdown

Table 7: Study Sample Breakdown by Suburb

Households Sampled by Suburb		
Suburb	**Count**	**% of Sample**
Mataffin	42	8%
Kamagugu	60	12%
Valencia	60	12%
Steiltes	53	10%
Nesville	43	8%
Nelspruit	86	17%
West Acres	94	18%
Sonheuwel	64	12%
Sonpark	13	3%
Total	**515**	100%

The table 7 above provides a break-down of the households sampled in the study, broken down by the suburb in which the household was located. One notes here that all the households were located in the Mbombela Municipality of Mpumalanga, South Africa, with variation only seen in terms of the suburb location. The table 7 shows that the sampled households were relatively evenly distributed amongst the suburbs listed, with percentages corresponding to each suburb generally ranging from 8-18% of total sampled households. The clear exception here being Sonpark which accounted for only 3% of the sampled households. The suburbs which were represented the most were Nelspruit and West Acres, with 17% and 18% of the sample, respectively. Something to be aware of, is that in the previous section it was mentioned that the data set corresponded to 526 households, however the table above provides a total of only 515 households. The reason for this is that 11 households were dropped from the data set due to data recording errors during the data cleaning process. An important feauture to note about these suburbs is that they are middle income households in Mpumalanga and do not reflect the general income patterns of households in Mpumalanga, which are generally significantly poorer. The average household income is shown in the figure below, with mean household income being R26 517 per month, and the median was R22 400. As was mentioned these are extremely high figures in comparison to the national and provincial averages. To contextualise, the median income in Mpumalanga in 2016 was R29 400 per anum (All Community Survey 2016), thus only slightly larger than the monthly average reported for the sampled households. The median income in South Africa per month is currently R3300, which equates to a yearly average of R39 600, around a sixth of the income earned by sampled households (SALDRU, 2016).

Figure 4: Average Household Income by Suburb (p/m)



3.2.2 Household Tap Water Consumption, HH Tap Water Bill and Tap Water Price

This will be a crucial sub-section in terms of preliminary statistics as it will include information concerning household tap water consumption levels, the independent variable used in the regression section of this study, as well as data on household tap water bills and hence the tap water price calculated within the study. The table below reveals an average tap water consumption level of 2188L per household per month, with significant variation by seen across suburbs. The suburb in which consumption levels were the highest was Valencia where households consumed an average of 5431L per month, substantially higher than the next two highest recorded levels of 3720L and 2190L respectively. Mataffin had the lowest consumption level of 1061L per household, however there were four other suburbs which recorded also consumption levels that are lower than 1500L per month, suggesting the average of 2188L was highly influenced by the consumption levels in Valencia. One notes that this is an extremely low water consumption level overall. For comparison, during the 2017 Cape Town drought households were restricted to using approximately 6000l of water per month, thus nearly three times as much as the average reported in our sample. Data collected for this study was collected during a severe drought in Mpumalanga which explains some of the extremely low figure reported, however one must be aware that the study average represents tap water consumption only, and thus overall water consumption is likely substantially higher. The low average tap water consumption for sampled households thus suggests that households are using other water sources to meet their overall water demand, and not just tap water, something which requires careful attention and will be addressed throughout this section. The columns to the right of the Table 8 present the average monthly water bills for households, by suburb. There is clearly a strong correlation between tap water consumption levels and tap water bills, with Valencia paying the most for tap water, on average R2336 per month. This water bill figure is over 5 times the size of the average water bill in Mataffin of R497, with the overall average tap water bill for sampled households being R894. Interestingly, one sees that households in Nelspruit consumed more water than those in Sonheuwel on average, however their average water bills were lower than in Sonheuwel. This trend is seen again when looking at Kamagugu and West Acres. With Kamagugu this time consuming considerably more water per household yet having a lower average water bill.

Table 8: Household Tap Water Consumption vs Tap Water Bill - by Suburb

	HH Tap Water Consumption (l)				**Household Tap Water Bill (R)**			
Suburb	**Month 1**	**Month 2**	**Month 3**	**Average**	**Month 1**	**Month 2**	**Month 3**	**Average**
Mataffin	990	1001	1191	**1061**	R528	R407	R554	**R497**
Kamagugu	2213	2273	2351	**2279**	R702	R730	R764	**R732**
Valencia	5724	5085	5565	**5431**	R2 452	R2 089	R2 499	**R2 336**
Steiltes	1959	2215	2394	**2190**	R547	R596	R701	**R615**
Nesville	3875	3844	3442	**3720**	R1 066	R1 173	R1 168	**R1 136**
Nelspruit	1254	1336	1415	**1335**	R508	R521	R552	**R527**
West Acres	1348	1457	1469	**1425**	R749	R753	R790	**R764**
Sonheuwel	1151	1210	1330	**1230**	R650	R667	R738	**R685**
Sonpark	979	1210	1488	**1226**	R876	R992	R1 192	**R1 020**
Average	**2154**	**2158**	**2254**	**2188**	**R880**	**R853**	**R950**	**R894**

**Comparable Stats Source: Department of Water and Sanitation, 2018*

The average tap water price used in this study was calculated by dividing the total household tap water consumption level with the household tap water bill to give a price per litre. An important thing to note here is that a fixed water fee of R118 was applicable and charged to all households, and thus this fixed charge was subtracted from the water bill before average price was calculated (City of Mbombela Tariff Schedule, 2018). Specific price blocks were also identified in which households paid different average prices for tap water and the results are seen in Table 9. The table 9 shows 4 different price blocks corresponding to different consumption levels of households. The average price per litre of tap water increases with consumption up to a point, that point being 3000l, with price increasing from R0.35 per litre to R0.54 per litre from block one to three. Interestingly, the average price per litre then decreases substantially for the households consuming more than 3000L to only R0.27 per litre. The overall average price per litre for the sampled households was recorded as R0.41 per litre.

Table 9: Average Water Price P/L - by Price Block

Average Water Price p/l - by Price Block		
Price Block	Consumption Bracket	**Price p/l (Rands)**
1	Less than 1000L	0,35
2	1000 - 2000L	0,47
3	2000-3000L	0,54
4	More than 3000L	0,27
	Study Sample Average	0,41

3.2.3 Socio-Economic Characteristics of Households

Table 10, below, provides information on extremely vital variables to household water consumption levels, that being information on some of the key socio-economic characteristics of households. Various socioeconomic characteristics are provided in table 10. Beginning with household size, one sees that the average household size in this study was 3.95 per household members. This figure is slightly higher than both the national average household size of 3.3, as well as the Mpumalanga provincial average of 3.5 (Stats SA, 2016). Analysing this variable further one sees that 16% of the households in the study had more than 6 household members present. Moving to the gender variable, one notes that this variable only represents the gender of the household head. Table 10 shows that 32% of household heads were female, with the other 68% being male. This percentage is relatively low in comparison to provincial and national standards, which report that 39% and 41% of households are headed by females, respectively (All Community Survey 2016; Stats SA, 2016). The next variable reported in Table 10 is the age of the household head, and one sees an age range of 22-93 years, with the mean age reported as 53 years of age. 78% of household heads in the sample were considered to be in the working age range, 18-65 years old, while the remaining 22% were classified as in retirement age, meaning over the age of 65. In terms of education, the households sampled were relatively educated in comparison to the province and the nation, with the average years of education attained by the household heads being 14.6 years, thus significantly larger than both the national average of 10.4 and the provincial average of 10.3 years of education attained (All Community Survey 2016; Stats SA, 2016). Continuing with education, the table illustrates that 62% of household heads in the sample had completed tertiary education, 23% secondary education and the remaining 5% had completed primary education. The final socioeconomic variable reported is that of the employment status of the households. The first thing one sees is that 81% of household heads were employed, which is quite high in comparison to the South African and Mpumalanga's provincial employment rates which are reported at 51% and 42%, respectively. The 81% reported, however, is just the employment status of the household head and thus does not reflect the true employment status of all working age members of the households. A more comparable figure to the national and provincial statistics may thus be the 51% of spouses who were reported as employed within the sampled households.

Table 10: Socio-Economic Variables of Sampled Households

Household Size	
Average HH Size	3,95
No. of HH with 6+ member	81 (16%)
Mpumalanga	3,5
SA	3,3
Gender of HH Head	
Male	68%
Female	32%
Mpumalanga (Female HH Head %)	39%
SA (Female HH Head %)	41%
Age of HH Head	
Average	53
Minimum	22
Maximum	97
Working Age (18-65)	390 (78%)
Retirement Age (65+)	112 (22%)
Education Level of HH Head	
Education Level Attained of HH Head	
Primary	5%
Secondary	23%
Tertiary	62%
Average years of educ.	14,6
Mpumalanga	10,3
South Africa	10,4
HH Employment Figures	
Employment Rate of HH Head (%)	81%
Employment Rate of Spouse (%)	53%
Employment Rate in Mpumalanga (%)	51%
Employment Rate in South Africa (%)	42,4%
Average number of Employed HH members	1,4

**Comparison data sources: All Community Survey 2016, Stats SA 2016

3.2.4 Water Saving Strategies & Technologies used by Households

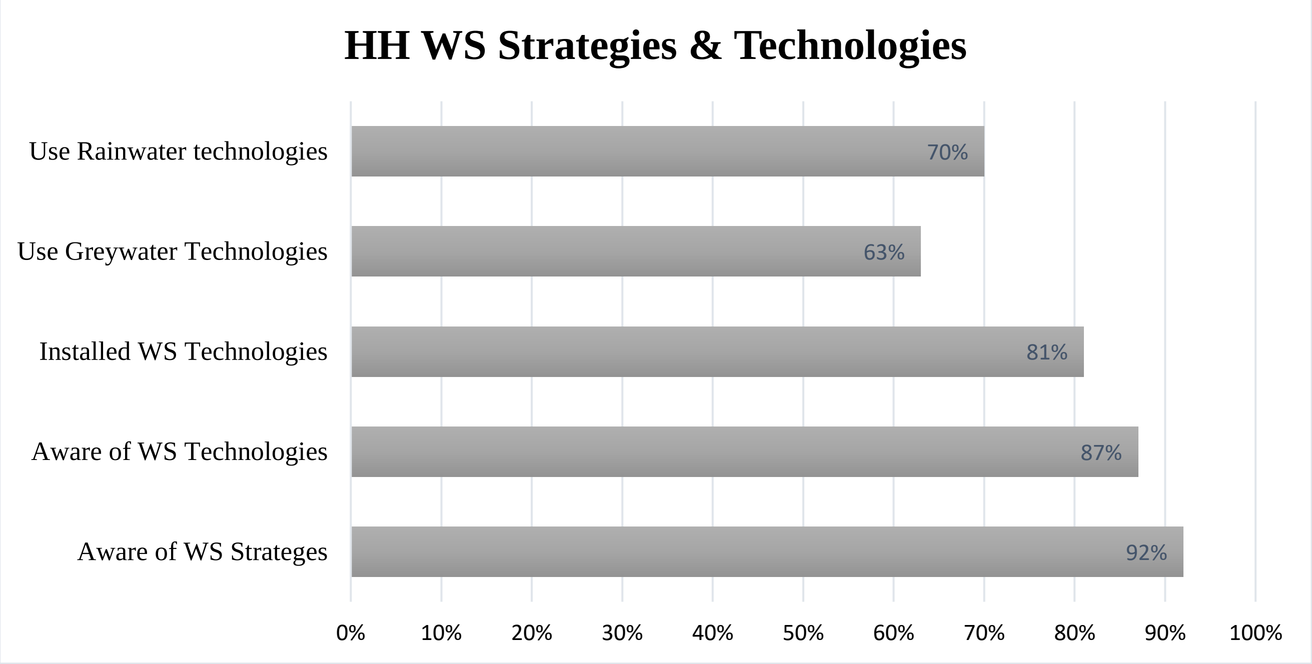
The next two figures presented will provide evidence of households' attitudes towards water saving strategies and technologies, as well as illustrate households' adoption of these water saving strategies and technologies. Looking at table 13, one first sees that there is a strong tendency to prioritise water conservation with 92% of sampled households stating people in their area should prioritise water conservation. Looking at household views on rainwater use, 91% of households believe they should be allowed to harvest and use rainwater, despite 70% believing it may be associated with environmental or health hazards. The belief that one should be able to use rainwater is thus likely driven by the fact that 88% of households believe rainwater can reduce one's water bill. Turning to greywater, 72% of sampled households believe it can reduce one's water bill, with 77% believing households should be able to use and harvest greywater. Interestingly, more than half of the respondent households believed water was priced to high, 56%, while the sampled households were also willing to spend an average of R277 for improved water services and quality in their area.

Table 11: Household Attitudes Toward Water Saving

Household Attitudes Toward Water Saving - Question Responses	
Survey Question	**Response**
Should households in your area prioritize water conservation?	92%
Should households be allowed to use and harvest rainwater?	91%
Should households be allowed to use and harvest wastewater?	77%
Do you think rainwater is associated with environmental/ health hazards?	70%
Do you think grey water is associated with environmental/ health hazards?	64%
Do you think the use of rainwater helps save tap water?	89%
Do you think the use of grey water helps save tap water?	77%
Do you think rainwater can help reduce your water bill?	88%
Do you think grey water can help reduce your water bill?	72%
Is water priced too high?	56%
What Would you be willing to pay to enjoy improved water services and qaulity in your city?	**R277**

With regards to awareness and adoption of water saving strategies and technologies, the Figure 5 shows that a substantial 92% of households were aware of water saving strategies, such as showering and not bathing, with a similarly impressive 87% aware of water saving technologies, such as efficient shower heads (See section E of Annexure 1 for more details on these strategies and technologies). In terms of using alternative water sources to tap water, rainwater and greywater technologies were widely used by the sampled households, with adoption rates of 70% and 63%, respectively, with households commonly using both. The widespread use of these alternative water sources, particularly rainwater, likely explains a portion of the low average tap water consumption figure reported in table 8. This is because households which used these other sources were able to have substantially larger overall water consumption. Lastly, from the figure 5, one sees an impressive 81% of households had installed water saving technologies - which covered technologies such as efficient shower heads, toilet flushing systems and efficient washing machines.

Figure 5: Awareness and Adoption of Water Saving Technologies



3.2.5 Groundwater Use of Households

With regards to groundwater use, the Table 12 below provides statistics relating to household access to, and use of, boreholes and wells. The table shows that 18% of sampled household owned a borehole, while only 1.75% owned a well. To measure the amount of borehole water used by sampled households, the repsondents were asked to indicate the amount of water which was extracted from these sources daily. The average number of litres taken from boreholes per day was 281L, while it was 232L for wells. This equates to monthly groundwater water consumption levels of 8430L for boreholes and 6960L for wells. One can therefore see that households with groundwater access were able to consume roughly 3-4 times as much water as those without it (2188L), which shows that tap water consists of only a small portion of total water consumption for households who have access to groundwater sources. For those households, this explains the extremely low levels of tap water consumption seen earlier in Table 8.

Table 12: Household Groundwater Statistics

Groundwater Statistics	
% of HH's with Borehole	18%
Average no. of litres extracted per Borehole per day	281L
% of HH’s with Well	1.75%
Average no. of litres extracted per Well per day	232L

3.3 Overall Summary Statistics

This sub-section provides the summary statistics on all the variables used in the econometric specification employed in this paper. The tables provide a substantial amount of information on numerous variables and thus a discussion on all of these would not be appropriate, particularly because most of these variables were already explained in the previous sub-sections. A selection of key takeaways and statistics from the tables will thus be highlighted instead. Table 14, below, provides the summary statistics of each variable overall, and by income level, with household groupings on either side of the median income level (R22 400) used. Looking at average monthly tap water consumption, wealthier households are shown to use approximately 17%, or 345 litres, more tap water than poorer households. Average income levels for the wealthier households were significantly larger than those in the poorer group, with households above the median wage earning an average of R39 879 per month in comparison to R13 172 for their counterparts. A fascinating statistic from the table reveals that 75% of wealthier households were headed my males, in comparison to only 61% for households below the median income cut-off, something which could point to the gender pay gap existing in South Africa. Education levels of the households were significantly higher in the wealthier group, particularly with regards to the spouse’s years of education attained, with a difference of over 4 years between the two groups reported. As one would expect, there was significantly larger percentage of households owning lawns and swimming pools in the wealthier group, with these households too having a considerably larger household size. With regards to water saving technologies and strategies the key statistic from the table is that wealthier households were 12% more likely to have installed water saving technologies.

Table 13: Summary Statistics – by HH Income Level

	Statistics by HH Income Level		
	Overall	**< Median Inc.**	**> Median Inc.**
Variables			
Observations	*515*	*257*	*257*
Average Monthly Tap Water Consumption (L)	2187	2014	2359
Average Water Bill	R894	R732	R1056
HH Income (R)	R26 517	R13 172	R39 879
Water Scarcity	8,60	8,76	8,43
No of Interruptions	1,71	1,46	1,96
Water Quality	8,81	9,01	8,61
Age	53,08	52,33	53,74
Gender (% Male)	0,68	0,61	0,75
HH Head Years of Educ	14,62	13,55	15,71
Spouse Years of Educ	9,84	7,63	11,93
No. of Employed HH Members	1,43	1,12	1,75
HH Size	3,95	3,57	4,32
Children Under 5	0,40	0,35	0,45
Groundwater Access (%)	19%	19%	19%
Owns Lawn (%)	60%	53%	67%
Owns Swimming Pool (%)	22%	15%	30%
Aware of WS Strategies (%)	92%	91%	93%
Prioritise Conservation (%)	92%	92%	93%
Installed Water Saving Tech (%)	79%	73%	85%
Used Greywater (%)	63%	62%	65%
Used Rainwater (%)	70%	70%	70%

Table 15, below, provides statistics on the same variables as the previous table, however, this time households have been broken down according to the sources of water they use, as opposed to by income levels. One sees a wide range in average monthly tap water consumption levels, with households accessing groundwater using 3751L of tap water, while those using rainwater as well as tap water, have tap water consumption levels of 1452L per month. Fascinatingly, households using only tap water, have the second lowest consumption levels, implying their overall water consumption is substantially lower than households using both tap water and another source of water to meet their overall demand. Looking at the water bill, one sees that households using rainwater have the lowest water bills, which thus could be something driving the use of rainwater collection technology. Income is revealed to vary widely by household group, with households using tap water only, having the lowest income levels by some distance. Financial constraints faced by these households thus likely explain why they have not accessed other water sources as of yet. Households using tap water only were also clearly the households with the lowest education levels, with education levels equivalent to only about 60% of other households. This will end the empirical data analysis, more in-depth information on each variable can be extracted from the tables. The study will move onto discussing the methodology used next.

Table 14: Summary Statistics –by HH Water Consumption Method

	Statistics - By HH Water Consumption Method					
	Overall	**Tap Only**	**Tap & Other**			
Variables			**Overall**	**Tap & Bottled**	**Tap & Rain**	**Tap & Ground**
Observations	*512*	*36*	*475*	*154*	*208*	*97*
Average Monthly Tap Water Consumption (L)	2187	1618	2229	2073	1452	3751
Average Water Bill	R894	R773	R908	R906	R715	R1252
HH Income (R)	R26 517	R15 552	R27 305	R25 109	R28 662	R26 250
Water Scarcity	8,60	8,59	8,59	8,95	8,03	9,06
No of Interruptions	1,71	2,08	1,69	1,23	2,14	1,61
Water Quality	8,81	9,11	8,81	9,17	8,48	8,96
Age	53,08	52,76	53,23	52,84	54,50	52,88
Gender (% Male)	0,68	0,68	0,68	0,69	0,69	0,66
HH Head Years of Educ	14,62	10,19	14,97	14,62	15,12	15,38
Spouse Years of Educ	9,84	7,22	10,01	9,17	10,82	9,67
No. of Employed HH Members	1,43	1,03	1,46	1,22	1,74	1,23
HH Size	3,95	3,86	3,97	3,90	4,04	4,10
Children Under 5	0,40	0,58	0,39	0,50	0,25	0,52
Groundwater Access (%)	19%		20%			100%
Owns Lawn (%)	60%	38%	61%	54%	66%	66%
Owns Swimming Pool (%)	22%	11%	23%	28%	13%	42%
Aware of WS Strategies (%)	92%	81%	93%	82%	100%	96%
Prioritise Conservation (%)	92%	80%	94%	88%	97%	97%
Installed Water Saving Tech (%)	79%	70%	80%	73%	85%	89%
Used Greywater (%)	63%		66%	53%	77%	65%
Used Rainwater (%)	70%		72%	51%	100%	54%

Chapter 4: Methodology

Both household water demand model specification, and the econometric techniques used to estimate these demand functions, have gone through several phases of development, with many approaches having been taken. This paper will follow the 'economics approach' and attempt to model household demand for water as a behavioural phenomenon. In this approach, household demand for water is modelled as a final good for consumption similar to that of any other good, with the decision to consume more or less being based on a variety of factors such as price, weather, income, etc. Traditionally, researchers using the 'economics approach' have relied on regression analysis as the primary tool for estimating household water demand, and this literature will be touched on more within the next sub-section. The existing literature covering the estimation of household water demand models involves numerous econometric techniques. For cross-sectional data, however, the data type used in this study, the predominant empirical techniques employed include OLS, generalized least squares (GLS), two-and three-stage least squares (2SLS and 3SLS), logit modelling, and various instrumental variable (IV) methods. The remainder of this methodology section will be broken down into two sub-sections. The first will provide a brief review of the methodologies followed in previous household water demand studies, while focussing of water demand estimation literature following regression methods. The second will provide a detailed description of the methodology followed within this study.

4.1 Review of Water Demand Modelling Methods – A Focus on Regression Methods

As was mentioned previously, researchers using the 'economics approach' have generally relied on regression analysis as the primary tool for estimating household water demand. In regression analysis an equation relating total water consumption, the independent variable, to multiple demand-related variables is estimated. This process allows one to isolate the effect of, for example, a change in price on quantity of water demanded, while controlling for other variables that factor into the consumer's decision process. Most previous studies have used conventional regression methods such as ordinary least squares (OLS), 2- and 3-stage least squares (2SLS & 3SLS), and time series analysis to estimate the price and income elasticities of residential water demand (Billings and Agthe, 1980; Kenney et al. 2008; Ghimire et al., 2016; Pérez-Urdiales et al., 2016). The use of these different methods has changed significantly over time, however, and the reasons for this change will now be elaborated upon.

OLS regression methods dominated the early water demand literature (Billings and Agthe, 1980; Chicoine et al., 1986; Hewitt and Hanemann, 1995; Higgs and Worthington, 2001; Martinez-Espineira, 2003), however aspects of water markets would later complicate the choice of estimation method, the most predominant of these problems being block rate pricing schemes (Dalhuisen et al. 2003; Martínez- Espiñeira and Nauges, 2004). When using data with block rate pricing, the first major problem which occurs is simultaneity: that is, when consumers select the quantity of water to be demanded, they also select the price (Ghimire et al., 2016). Because the price of water both determines and is determined by consumption levels, OLS estimations of block rate pricing models often yield biased and inconsistent estimates due to the price endogeneity generated (Olmstead, 2009; Pérez-Urdiales et al., 2016). Commencing from the mid-late 2000s studies would begin accounting for this endogeneity problem using various methods. Olmstead (2009) details the two most predominant approaches used to address the price endogeneity problem: reduced-form approaches, such as instrumental variable (IV) methods, and structural approaches, such as discrete/continuous choice models (DCC). The instrumental variable approach has often been undertaken along with fully parametric or semiparametric methodologies such as 2SLS regression or Generalized Method of Moments (GMM) (Kenney et al. 2008; Olmstead, 2009; Klaiber et al., 2012; Ahmad et al. 2016). In the first stage of this method, the endogenous variable, which is water price in these studies, is regressed against a set of variables which are not correlated with the error term, but are highly correlated with the endogenous variable itself (Ghimire et al., 2016; Ahmad et al. 2016). The 'new' water price calculated is then regressed against all the explanatory variables and instrumental variables in the second stage.

The next sub-section, which details the methodology followed in this study, will expand upon the discussion above. Before that, however, one notes that the analysis of household water demand in developing countries is much more complex than in industrialised ones as highlighted by Naughes and Wittington, (2010). This is largely due to the fact that households in developing countries have access to, and may use, more than one of several types of water sources, something in stark contrast to most industrialised countries. This complexity in analysis has led to a relative lack of literature emerging from developing countries which estimates household water demand, and this paper hopes to begin bridging this gap.

4.2 Methodology Followed

4.2.1. Methodology Description

In line with most of the previous water demand literature, this paper uses regression techniques to estimate household water consumption levels. The independent variable, monthly household tap water consumption, is therefore regressed on a set of predictor variables, the two most important of which identified in the literature being price and income. Concerning the price variable, one notes there are two crucial issues related to price when analysing household water demand facing a nonlinear pricing scheme, as seen in this study. Firstly, one needs to decide between using marginal or average price, and secondly, the simultaneous determination of price and the block of consumption generates a price endogeneity problem (Pérez-Urdiales et al., 2016).

In deciding between using average and marginal price first, early studies revealed that researchers used either average price (Gaudin et al. 2001; Kenney et al. 2008; Michelsen et al. 1999) or marginal price (Nieswiadomy and Molina, 1989) when analysing the effect of price on household water demand, and there was little consensus over the appropriate variable choice. Later, however, an extensive discussion was undertaken in the water demand literature on the appropriate pricing structure to use (Nataraj and Hanemann 2011; Schleich and Hillenbrand 2009), and whether consumers respond to marginal prices or average water price. This discussion, combined with more recent literature, has shown that an informed consumer may respond to the marginal price, while consumers with incomplete information tend to respond to the average price (Ghimire et al., 2016; Pérez-Urdiales et al., 2016). In this study, households revealed that they were not well informed about the water pricing structure, suggesting sampled households were more sensitive to changes in average price than in marginal price, and hence average price is used in this study.

Moving towards the second issue mentioned of price endogeneity, one notes a basic condition for unbiased and consistent parameter estimation under ordinary least squares (OLS) regression is that there is no correlation between the error term and any of the explanatory variables (Ghimire et al., 2016). Use of the average water price in the water pricing model for demand estimation, however, leads to a simultaneity problem as average price is determined by the consumed quantity of water and marginal price. Average tap water price will thus be correlated with the error term and therefore an OLS regression estimation leads to biased and inconsistent results. The first step taken in this study was to estimate an OLS regression, however as has just been discussed this was not the appropriate model to use due to price endogeneity, a problem which could be solved with the introduction of some instrumental variables, which are variables correlated with average tap price but uncorrelated with the error term. Therefore, a two-stage least-squares (2SLS) modelling technique was applied with the use of instrumental variables, as has been seen in previous studies (Kenney et al. 2008; Ahmad et al. 2016; Ghimire et al., 2016). As the name suggests, this method is conducted in two stages. Firstly, the endogenous variable, average water price in our case, was regressed against the chosen instrumental variables. The new predicted average water price from the first stage was then regressed on the set of predictor variables and the instruments in the second stage. This method provides for consistency in the limit, with the ultimate goal of the instruments being to provide an accurate proxy for the endogenous variable. Before performing the 2SLS regression analysis, there is the crucial step of identifying appropriate instrumental variables for the first stage of the regression, which is a relatively complex process. Several possible instrumental variables have been used in previous water demand studies that have used cross-sectional data, with these including locality, water scarcity, water quality, fuel cost, and a few more (Olmstead, 2009; Binet et al., 2014; Pérez-Urdiales et al., 2016; Ghimire et al., 2016; Ahmad et al., 2016). All those IVs mentioned and several more possible IVs (See Annexure 2 for full list) were tested, and after much testing two appropriate instrumental variables were identified for the study, those being: 1) water quality, and 2) average water price with the fixed fee included. Elaboration of the reasons for the choice of these instruments will follow, with a detailed description of instrumental variables too being provided below.

A good instrument (Z) must satisfy two crucial conditions. Firstly, $Cov(Xi,Zi)\neq 0$, with X_i being the matrix of endogenous dependent variables, meaning that the instrument must be correlated with the endogenous variable, implying that a first stage exists. Secondly, $Cov(Zi,\eta i)=0$, where ηi is the compound/unknown error, meaning that the instrument is not correlated with the outcome or any other unobserved determinant of it such that the effect of Z on Y only goes through the endogenous variable X. Putting this in less mathematical terms, an instrumental variable must satisfy the following conditions: 1) Z must have a causal effect on Y, 2) Z may affect the outcome variable Y only through X, implying that Z does not have a direct influence on Y, which is referred to as the exclusion restriction, and 3) there is no confounding for the effect of Z on Y (Newhouse and McClellan, 1998; Martens et al., 2006; Wunsch et al., 2006). The instruments used in this study, water quality and average price with the fixed fee included, must therefore meet all these requirements, and hence each variable's appropriateness as an instrumental variable is to be discussed and tested next.

Water quality has been used as an instrumental variable in previous water demand studies, proving its appropriateness as in instrument (Ahmad et al., 2016). Ahmad et al. (2016) discuss the suitability of water quality as an instrumental variable for water price, however they use water leakages as a proxy for water quality in their study, due to lack of data on water quality specifically. In this study, we have data on water quality itself which strengthens the variable appropriateness as an instrumental variable, which is confirmed through theoretical and formal testing to be seen within this section. Discussion will thus focus on the proposed instrumental variable of average water price with the fixed fee included. Before commencing with testing, one notes that the exclusion restriction, which provides that the instrument Z has no effect on Y except through X, and that there are no common causes between Z and Y, cannot be formally tested. One is unable to test the exclusion restriction for the same reason one looking for an instrument in the first place: that is the relationship between X and Y is confounded by some error or unobservable factors, ηi. Therefore, any test of conditional independence between Z and Y, controlling for X, would be confounded by the same error or unobservable factors. The question then becomes – how does one make an argument for an instrument? This requires, what David Freedman calls 'Shoe leather', which describes intimate knowledge of the subject matter to develop meticulous research designs and eliminate rival explanations (Freedman, 1991).

The first stage of the 2SLS IV regression, contrastingly, is easily testable and is generally referred to as the inclusion restriction. The test performed here essentially asks whether the instrument (Z) affects the endogenous variable (X), which is testable with an F-test. Both water quality and average price with the fixed fee included, the two proposed instruments, pass this test well (with elaboration on tests results seen in the next paragraph and in Annexures 3 and 4). Moving onto arguing the exclusion restriction condition now, one begins with noting that the average price per litre of tap water when the fixed fee is included, the proposed instrument (Z), only affects household tap water consumption (Y) though its effect on average price with the fixed fee removed (X), as the fixed fee is paid by all households regardless. Expanding upon this, one observes that the water price being responded to by households, is the price which excludes the fixed fee chardged to all households, as this is treated as a sunk cost by households. Thus, the average price per litre of water with the fixed fee removed (X) is the water price which households respond to, the endogenous variable in our study. The price with the fixed fee included (Z) therefore passes the exclusion restriction as its effect on household tap water consumption (Y) is only felt through the effect of the average price with the fixed fee removed (X). Water quality has already been used in previous studies as an IV suggesting it also passes this test (Ahmad et al., 2016), and thus both proposed instrumental variables are shown to be theoretically good instruments.

There are two distinct problems with instruments which require further testing, however. The first relates to the inconsistency of instrumental variable methods when more than one instrument is used, and hence overidentification must be tested. Secondly, and often related, is the problem of having weak instruments. The first test performed, however, before even testing the instrumental variables, is to test for endogeneity present within the price variable in order to confirm which regression technique is appropriate. The Hausman test for endogeneity was hence carried out, returning an F-stat of 442.57 and a p-value of 0.0000, which revealed that the price variable was indeed endogenous. This was confirmed by the Durbin test score of 237.6, with a corresponding p-value of 0.000. There was thus clearly price endogeneity present and hence a 2SLS model was the more appropriate model to use in this study, as opposed to an OLS model. This test must importantly be carried out before instrumental variables are tested as if there was no endogeneity present, OLS regression would perform better, negating the need for IVs in the first place. Moving to statistically testing the chosen instrumental variables fit for the model now, a first thing to check is the instrumental variables' strength. After conducting the appropriate first stage test, one sees that the instruments are jointly significant and different from zero, with a p=value of 0.0000. The F-statistic provided from the test was 769.61, which is extremely good, as generally an F statistic over 10 is required to suggest instruments are sufficiently strong. The minimum eigen value statistic from this test was 769.62, with the corresponding critical value for the 5% Wald test being 19.93. This too provides evidence of significantly strong instruments. One must also ensure the IVs are not overidentified and the appropriate test to perform in this regard is the Sargan and Basman Test. Results from this test showed that we should accept the overidentifying restrictions and conclude that the instruments were indeed valid. The Hansen test of over identifying restrictions (OIR) also indicated that the chosen instruments were valid, confirming this finding. (See Annexures 3 and 4 for the full test results mentioned in this paragraph)

With appropriate instrumental variables identified, a 2SLS regression was run with household tap water consumption used as the independent variable. A large set of possible variables, over 30, which had been recorded in the survey process were initially tested in an OLS regression, which allowed for the number of variables to be reduced significantly following this testing. Once the most crucial variables affecting tap water consumption levels were identified from the data set, and with the inclusion of those recommended in the literature, the initial 2SLS regressions were run. The best performing models, which included the appropriate variables required by household water demand studies, were then identified and results of these are seen in Chapter 4. One notes that a fundamental problem which affects household water demand estimation functions is the presence of unobserved individual heterogeneity, implying a common demand function is unlikely to represent the behaviour of all households (Pérez-Urdiales et al., 2016). To address this issue, we identify different groups of households and provide individual demand functions for each group, as well as for sampled households overall. To show the difference in factors affecting water consumption between households of different income levels, households were firstly grouped into two groups, with one consisting of households with income levels below the median level (R22 400), while the other group had income levels above this threshold. Households were also grouped according to the water sources they used to meet their overall demand to isolate the key factors affecting these specific subgroups. Households were therefore classified as using either: 1) tap water only, 2) tap and rainwater, 3) tap and bottled water, or 4) tap and groundwater. This approach allows one to distinguish between several different response patterns to changes in the factors affecting household water consumption, including different price elasticities. Results seen in the next chapter should thus be especially interesting policymakers dealing with heterogenous users

4.2.2 Econometric Specification of Model

Based on the description of the method followed above, this sub-section will now provide the econometric specification of both the OLS and 2SLS models used within this study. Conventionally, the water demand function of a representative household is specified as $Q = f(P,X)$. Where Q represents the household water consumption level, P symbolizes the price of water, and X represents a vector of other exogenous variables such as household income, gender, location, etc. The linear estimation form can therefore best be described as:

$$Qi = Xi\,\beta + Pi\alpha + \varepsilon i \qquad (1)$$

Where:

- Qi is the quantity of water demanded
- Xi represents exogenous variables
- Pi is the price of water
- β & α are vectors of respective parameters of exogenous vectors and price
- εi represents the error term

The OLS estimation used in this study is similar to previous studies in assuming that household water consumption is a function of price, climate, and household characteristics such as income and household size, however it also includes newer factors to the literature relating to household use of water saving technologies and strategies. Building upon equation 1, the OLS demand specification used in this study was hence:

$$Ln(Q) = \beta_0 + \beta_1 Ln(P) + \beta_2 Ln(Inc) + \beta_3 HHsize + \beta_4 Gender + \beta_5 HHEduc + \beta_6 Swimpool + \beta_7 Raintank + \beta_8 Rainsystem + \beta 9 Efficwashmach + \varepsilon_i \qquad (2)$$

Where:

- Ln(Q) equals the log of the average household tap water consumption
- Ln(P) represents the log of the average tap water price per household
- Ln(Inc) is the log of household income
- HHsize refers to the number of household members in each specific household
- Gender is a dummy variable portraying the gender of the household head
- HHEduc equals the number of years of education attained by the household head
- Swimpool refers to whether a household owns a swimming pool
- Raintank symbolizes that a household uses rain tanks
- Rainsystem refers to whether a household uses a rainwater system
- Efficwashmach indicates whether a household is in possession of an efficient washing machine
- β_0 represent the constant term, whereas β_0- β_9 represents the respective parameters of the dependent variables
- εi is the error term

However, as was noted in the description of the methodology, the tap water price P in this case is correlated with the error term εi such that $E(Pi\ \varepsilon i) \neq 0$. Therefore, a 2SLS modelling estimation procedure was performed with the use of instrumental variables as the correlation mentioned causes biased and inconsistent OLS estimates. In the first stage of the regression tap water price, P, was regressed against numerous possible IVs (see annexure 2 for full list), with the two IVs passing the critical tests being average water price with the fixed fee included and water scarcity. The regression performed to estimate the new average tap water price P* with instrumental variables was thus:

$$Ln(P) = \beta_0 + \beta_1 WaterScarc + \beta_2 AvPff + \varepsilon_i \qquad (3)$$

Where

- P = average tap water price per litre
- WaterScarc represents the water scarcity level
- AvPff is the average tap water price per litre with the fixed fee included
- εi is the error term

In stage two of the 2SLS estimation procedure, the new tap water price P* estimated in stage one was then regressed against all the exogenous variables and the instrumental variables. The final 2SLS model used was hence:

$$Ln(Q) = \beta_0 + \beta_1 Ln(P^*) + \beta_2 Ln(Inc) + \beta_3 HHsize + \beta_4 Gender + \beta_5 HHEduc + \beta_6 Swimpool + \beta_7 Raintank + \beta_8 Rainsystem + \beta_9 Efficwashmach + \varepsilon_i \qquad (4)$$

IV’s = WaterScarc & AvPff

Where

- Q equals average household tap water consumption

- P^* represents the new average tap water price per household
- Inc is the monthly household income level
- HHsize refers to the number of household members in each specific household
- Gender is a dummy variable portraying the gender of the household head
- HHEduc equals the number of years of education attained by the household head
- Swimpool refers to whether a household owns a swimming pool
- Raintank symbolizes that a household uses rain tanks
- Rainsystem refers to whether a household uses a rainwater system
- Efficwashmach indicates whether a household is in possession of an efficient washing machine
- β_0 represent the constant term, whereas β_0- β_9 represents the respective parameters of the dependent variables
- WaterScarc represents the water scarcity level
- AvPff is the average tap water price per litre with the fixed fee included
- εi is the error term

With the methodology followed in this study theoretically described in section 3.3.2.1, and now the econometric specification of the model detailed, the paper will move onto to analysing the results produced in Chapter 4.

Chapter 5: Regression Results and Discussion

This presents the econometric findings of this study , which were produced following the methodology discussed within chapter 4. The chapter will discuss these results in some detail, with the discussion ultimately being broken down into two sub-sections: 1) OLS and 2SLS Regression Results, and 2) 2SLS Regression Results - by HH Water Consumption Method. As has been mentioned, the average tap water price in this study was endogenous, thus violating the orthogonality conditions due to price being corelated with the error term. This, as has too been discussed, results in biased and inconsistent OLS estimates of the price elasticities. This issue was addressed using a 2SLS regression estimation procedure with instrumental variables. Those IVs being water scarcity and the average tap water price with the fixed fee included. We initially estimate the OLS regression with its results presented in table 16 , however, one notes that the key column to be looking at when analysing the results is the overall 2SLS regression column, in which the price endogeneity problem has been addressed, and not the OLS column. Whilst running the 2SLS regressions, we run a further four 2SLS sub-regressions identifying specific household sub-groups, to show the different behavioural response patterns of these heterogenous households. Households here are firstly broken down according to income level and then according to water consumption sources. Within the consumption break down of households, it is revealed that over 90% of households use more than just tap water to meet their overall water demand, and hence the second sub-section of these results then elaborates upon this fascinating finding.

5.1 Regression Results & Discussion

5.1.1 OLS & 2SLS Regression Results

The table below provides the OLS and 2SLS regression results estimated in this study. Due to endogeneity present within the price variable, the OLS estimates are biased and inconsistent. Therefore, the correct results to be analysing here are the 2SLS results, with the key column to look at below being the overall 2SLS column. The columns to the right are also important as they highlight the different behavioural response patterns of the specific household sub-groups. Discussion of the variables will commence after this table, with some variables being individually described, and others grouped together. Standard errors are reported in parenthesis.

Table 15: OLS & 2SLS Regression Results

	OLS	**2SLS**	**2SLS - by HH Income Level**		**2SLS - by HH Water Consumption Method**	
Variables	**Overall**	**Overall**	**< Median HH Inc.**	**> Median HH Inc.**	**Tap Only**	**Tap and Other**
Price	**-0.115*****	**-0.353*****	**-0.433*****	**-0.251*****	**-0.879*****	**-0.325*****
	(0.0315)	(0.0338)	(0.0500)	(0.0453)	(0.261)	(0.0335)
HH Income	**0.198*****	**0.238*****	**0.186****	**0.297****	**0.628***	**0.201*****
	(0.0587)	(0.0542)	(0.0935)	(0.125)	(0.327)	(0.0552)
HH Size	0.0149	**0.0493****	0.0150	**0.0772****	**0.269****	0.0322
	(0.0247)	(0.0236)	(0.0334)	(0.0330)	(0.111)	(0.0241)
Gender	0.0312	0.00681	-0.0894	0.0530	-0.387	0.0400
	(0.0769)	(0.0788)	(0.115)	(0.109)	(0.385)	(0.0802)
HH Head Years of Educ	0.0113	0.00855	0.0200	-0.000504	-0.0142	0.00796
	(0.00778)	(0.00891)	(0.0128)	(0.0125)	(0.0362)	(0.00942)
Swimming Pool	0.111	0.101	-0.0374	0.170	-0.125	0.113
	(0.0792)	(0.0910)	(0.158)	(0.107)	(0.535)	(0.0918)
Rainwater Tank	**-0.232*****	**-0.283*****	-0.189	**-0.306*****	-	**-0.252*****
	(0.0697)	(0.0716)	(0.131)	(0.0833)		(0.0825)
Rainwater System	**-0.380*****	**-0.424*****	**-0.313***	**-0.434*****	-	**-0.425*****
	(0.103)	(0.108)	(0.167)	(0.139)		(0.108)
Efficient Washing Machine	**-0.292*****	**-0.332*****	**-0.404*****	**-0.258*****	-0.101	**-0.349*****
	(0.0668)	(0.0779)	(0.126)	(0.0981)	(0.437)	(0.0799)
Constant	**5.169*****	**4.428*****	**4.809*****	**3.900*****	-0.328	**4.896*****
	(0.534)	(0.482)	(0.818)	(1.270)	(2.740)	(0.500)
Observations	500	499	245	253	36	460
Wald chi2(7)		166.27	103.24	64.54	16.41	147.54
Prob > chi2		0.0000	0.0000	0.0000	0.0216	0.0000
***** p<0.01, ** p<0.05, * p<0.1**						

5.1.1.1 Price

When analysing the effect of price on water demand, the conventional approach is to estimate the price elasticity of water demand. This estimate describes the change in the quantity demanded of water in response to a change in price, with all other variables held constant. Both tap water consumption and tap water price were estimated in a log-log form allowing one to directly infer price elasticity estimates.

As was mentioned at the beginning of this chapter, the 2SLS model was the appropriate model for our data set with the best performing estimates, and thus they key results column to look at when discussing the price elasticity estimates, and indeed all dependent variable estimates, is the overall 2SLS column. The elasticity estimate reported in this column is -0.353 and it is shown to be statistically significant at the 1% level. This implies that a 1% increase in water price would lead to a 0.353% decrease in the quantity of water demanded. This low price elasticity estimate is in line with a large portion of the literature (Brookshire et al., 2002; Mazzanti and Montini, 2006; Worthington and Hoffman, 2008; Naughes and Wittington 2010), with the strong inelasticity predicted suggesting that pricing policies will not have much of an effect in altering tap water demand in the region. One notes that this estimate was still substantially more elastic the OLS estimate of -0.115. Looking at the remaining 2SLS columns, in which the households were further broken down by both income and water consumption methods, one sees that price was reported as inelastic and statistically significant at the 1% level across all household sub-groups. With regards to the difference between wealthier and poorer households, the table shows that households below the median income level, poorer households, had price elasticity estimates almost twice the size of the wealthier households, -0.433 and -.0251 respectively. This implies that poorer households were substantially more sensitive to price changes than wealthier ones, which makes sense as price changes would be expected to impact poorer households more severely. The last two columns in the table, which break households down by consumption sources, present a fascinating finding, revealing that households which consumed tap water only had price elasticities estimated at -0.879 which was nearly three times higher than households which consumed both tap water and water from another source, which record a price elasticity estimate of -0.325. This suggests that households which were consuming tap water only were much more sensitive to changes in price than their counterparts, likely due to the fact that these households still have the opportunity to begin using other water sources to meet their overall demand. One notes that the Wald Chi score was relatively low for the ‘Tap Only’ regression model, with the corresponding p-value of 0.0216 indicating significance at the 5% level only. Elaboration upon the ‘Tap and Other’ consumption sources column is provided in table 17 and will be discussed later within this section as it covers over 90% of sampled households.

5.1.1.2 Income

Similar to price, the conventional approach when estimating income’s effect on household water demand has been to estimate the income elasticity, meaning the percentage change in quantity of water demanded in response to a change in income, with all other variables held constant. The income variable used in this study was estimated in log form which thus allows for one to directly infer the income elasticity. Looking at the overall 2SLS column, one sees an income elasticity of 0.238, thus slightly higher than the OLS estimate of 0.198, a finding which is in line with much of the literature (Cavanagh et al. 2002; Naughes & Wittington, 2010; Romano & Salvati, 2014; Jayarathnaa et al., 2017; Abdullah et al., 2019). Income is revealed to be statistically significant at 1% level in the overall 2SLS column, remaining statistically significant at either the 5% or 10% level across all household sub-groups. The income effect for wealthier households is substantially larger than for poorer households, with the estimate of 0.297 implying a 10% increase in income would lead to a 2.97% increase in tap water demanded. This is in line with the findings from the very limited developing country literature on the topic, where poorer households are shown to have more inelastic estimates (Katzman, 1977; Naughes & Wittington, 2010). Looking at households consuming tap water only, one sees an extremely high income elasticity estimate of 0.628, suggesting a substantial increase in tap water demand corresponding to increased household income levels. One notes though that this figure is only statistically significant at the 10% level, however. For households using both tap water and another water source to meet their overall demand, the results provide that a 10% increase in household income would cause a 2.1% increase in tap water consumption.

5.1.1.3 Socioeconomic Factors

As has been discussed in this paper, household water demand is also expected to vary depending on numerous socioeconomic characteristics, and the crucial variables to the performance of our model in this regard were household size, gender, education level of household head, and finally whether or not the household owned a swimming pool. Looking at household size first, one sees that the variable is statistically significant in the overall 2SLS model at the 5% level. The coefficient of household size here was reported at 0.0493, which suggests that adding an additional household member results in a 4.93% increase in household water consumption, a relatively low amount. The largest effect of household size is seen in households consuming tap water only, with the figure reported in table 16 suggesting that adding an additional household member would lead to a 26.9% increase in water consumed, with this estimate significant at the 5% level. This higher estimate is more in line with the literature from other developing countries, where household size has been identified as a key determinant of household water demand (Cheesman et al. 2008; Abdullah et al, 2019; Garcia et al., 2019). Moving to the other socioeconomic variables of gender, education level and swimming pool ownership, although these variables were not statistically significant at the 10% level in any of the sub-groups or overall, they were crucial to the model performance and thus needed to be included to support the accuracy of the results.

5.1.1.4 Water Saving Technologies

Beyond price, income, and socioeconomic factors, there are further factors which have been shown to have a considerable effect on residential water demand, most notably climatic factors and the use of water saving technologies. Although we did not have data on climatic factors in this study, there was in-depth data collected on numerous water saving technologies and strategies used by households, which added great value to the results provided in this paper. Ultimately, three water saving technologies were identified to be fundamental to our model, and these were whether households used: 1) rainwater tanks, 2) a rainwater system, and 3) whether households had installed water efficient washing machines. Commencing with the effect of rainwater tanks, the coefficient from the overall 2SLS model shows that rainwater tanks reduced tap water consumption by a substantial 28.3%, with this variable shown to be significant at the 1% level. The statistically, and economically, significant impact of rainwater tanks was also shown throughout the other household sub-groups, with the exception being households below the median income threshold. Rainwater systems too were revealed to have an impressively large impact on water consumption levels, with the variable seen to be significant across all sub-groups. Looking at the overall 2SLS model, one sees that a rainwater system was predicted to reduce tap water consumption by 42.4%, with the range of tap water reductions estimated across sub-groups varying from 31%-43%, thus highlighting its effectiveness in reducing household tap water consumption. The last key water saving technology concerned whether a household had installed a water efficient washing machine, with the table 16 showing this variable to be the most statistically significant of all predictor variables across the sub-groups, apart from price. Overall, the results show that efficient washing machines are estimated to reduce tap water consumption by 33.2%, and with regards to the sub-groups, the variable is most significant for households below the median income level, with a predicted reduction in tap water consumption of over 40%. This represents a crucial finding for policymakers going forward. The water saving technologies discussed are therefore fundamental variables in determining household tap water consumption levels, with extremely large predicted water reductions estimated with the use of these technologies, ranging from 28.3% to 43.4%.

5.2.1 2SLS Regression Results - by HH Water Consumption Method

The last two columns of the table 16 provided the 2SLS regression results of two household sub-groups – households using tap water only, and those using both tap water and another source of water to meet their overall demand. The use of multiple water sources to meet overall water demand is something prevalent amongst households in many developing countries and thus elaboration upon the ‘Tap and

Other' column is necessary given the context of this study, and its lack of attention in the literature. The first thing to notice is that only around 7% of households sampled in the study use tap water only, thus again highlighting the importance of looking at the various household sub-groups provided in table 17, below. As was done in the previous results discussion section, the variables will be discussed individually or in the same grouping fashion as previously, however, in this section it will be done in paragraph form as opposed to individual sub-sections due to its shorter length. The results discussion commences after table 17, below, which provides the 2SLS regression results by household water consumption method.

Table 16: 2SLS Regression Results - by HH Water Consumption Method

Variables	**Tap Only**	**Tap and Other**			
		Overall	**Tap & Bottled**	**Tap & Rain**	**Tap & Ground**
Price	**-0.879*****	**-0.325*****	**-0.411*****	**-0.140*****	**-0.489*****
	(0.261)	(0.0335)	(0.0630)	(0.0422)	(0.0808)
HH Income	**0.628***	**0.201*****	**0.172****	**0.297*****	**0.383****
	(0.327)	(0.0552)	(0.0820)	(0.0712)	(0.181)
HH Size	**0.269****	0.0322	0.0556	-0.0116	-0.0169
	(0.111)	(0.0241)	(0.0369)	(0.0364)	(0.0443)
Gender	-0.387	0.0400	-0.0949	-0.0394	**0.405****
	(0.385)	(0.0802)	(0.122)	(0.104)	(0.188)
HH Head Years of Educ	-0.0142	0.00796	0.0212	-0.0135	**0.0514****
	(0.0362)	(0.00942)	(0.0148)	(0.0119)	(0.0251)
Swimming Pool	-0.125	0.113	0.242*	-0.0918	0.0842
	(0.535)	(0.0918)	(0.139)	(0.148)	(0.191)
Rainwater Tank	-	**-0.252*****	-	0.355	-
		(0.0825)		(0.266)	
Rainwater System	-	**-0.425*****	-	0.155	-
		(0.108)		(0.255)	
Efficient Washing Machine	-0.101	**-0.349*****	**-0.272****	-0.159	-0.338
	(0.437)	(0.0799)	(0.126)	(0.101)	(0.229)
Constant	-0.328	**4.896*****	**4.699*****	**4.030*****	2.472
	(2.740)	(0.500)	(0.791)	(0.682)	(1.718)
Observations	36	460	150	230	77
Wald chi2(7)	16.41	147.54	60.43	37.85	66.23
Prob > chi2	0.0216	0.0000	0.0000	0.0000	0.0000
***** p<0.01, ** p<0.05, * p<0.1**					

Tap water price is once again shown to be statistically significant at 1% level across all household sub-groups, and elasticity estimates are inelastic as one would expect. Despite all being inelastic, there is substantial variation in the estimates, with households consuming tap water only shown to be the most sensitive to price, with an elasticity estimate of -0.879. This would be expected as these households still have the possibility to switch to using other water sources, which provides them with the opportunity to reduce tap water consumption substantially, should they use another source. Looking at the ‘Tap and Other’ sub-groups, one sees that households using tap and rainwater have the most inelastic price elasticity estimate of -0.140, implying a 10% increase in water price would only lead to a 1.4% decrease in tap water consumption. The two other sub-groups also had relatively highly inelastic price elasticity estimates, ranging from -0.411 to -0.489. These results show that pricing policies would have a substantially smaller effect in reducing household tap water demand for household using more than one water source than for households using tap water only.

Moving the income variable now, household income is revealed to be statistically significant across all sub-groups once again, with the significance ranging between 1% and 10% level. Income is most significant for households using tap and rainwater, with the result showing that a 10% increase in household income would lead to a 2.97% increase in tap water consumption. For households using tap and bottled water, the income elasticity estimate of 0.172 was less than half that of households using tap and groundwater, which was estimated at 0.383, with both estimates revealed to be significant at the 5% level. These income elasticities pale in comparison to the 0.628 reported for households using tap water only, one noting again however that this figure was only significant at the 10% level.

In terms of socioeconomic variables, one notes that gender and education have been shown to be crucial socioeconomic variables in determining household water demand in developing countries. It was thus fascinating that these variable were not significant at even the 10% level in any of the models provided in table 16. Interestingly, gender and education were both statistically significant at the 5% level for households using tap and groundwater in table 17. The coefficient on gender here implying that male headed households used just over 40% more water than female headed households, a rather alarming statistic. The coefficient on education reveals that for this sub-group, an additional year of education attained by the household head would lead to a 5.14% increase in tap water consumption for the household. One remembers here that the relatively low Wald Chi score of 16.41, and the p-value of 0.0216, for this regression may be explaining some of the outlying nature of estimated results for this particular model.

Moving to water saving technologies, one notes the effect of two of these technologies - rainwater tanks and rainwater systems - should only be looked at by referring to the overall 2SLS column, which has already been discussed, as these variables were omitted from the sub-group regressions in table 17 to avoid a collinearity problem. Interestingly, the highly statistically significant variable indicating whether a household had installed an efficient washing machine was only significant in one of the ‘Tap and Other’ sub-groups, despite continuing the have the expected sign and values. The installation of an efficient washing machine was shown to reduce water consumption for households using tap and bottled water by 27.2%. The reason for the lack of significance in the other two sub-groups may be due to the fact that these households are either using rainwater or groundwater in their washing machines already, as opposed to tap water.

5.3 Results Section Conclusion

The findings revealed and discussed within this chapter have investigated the key factors affecting household water consumption levels in the City of Mbombela in Mpumalanga, South Africa. Overall, the findings were generally in line with the literature from comparable contexts, with only a few exceptions. Price elasticity estimates were shown to be highly inelastic in the overall 2SLS model, as well as within most household sub-groups, with elasticity estimates ranging from -0.140 to -0.879. These results therefore implying that pricing policies will not have much effect on altering water consumption in the region. Within the price elasticity estimate results, poorer households were shown to be substantially more sensitive to price changes than wealthier ones. Moving to the effect of income on household water consumption, the income elasticity estimates reported in this chapter also fell in line with the comparable literature, with the overall 2SLS model’s income elasticity estimated at 0.201, implying a 10% increase in income would lead to a 2% increase in tap water consumption. Results from the income section also showed that income had a larger effect for wealthier households than poorer ones. With regards to socioeconomic variables, household size was revealed as the key factor affecting household tap water demand in this study, a common finding in most developing countries. One of the most crucial findings from this chapter was that water saving technologies were shown to reduce household tap water consumption levels by between 28.3% and 43.4%, with these variables being highly statistically significant, a crucial finding for policymakers going forward as we move into a world attempting to alter water demand, as opposed to augmenting the supply of water. The policy implications of these results will be discussed in chapter 5, next.

Chapter 6: Policy Implications and Recommendations

South Africa’s water infrastructure is unfortunately based on the outdated notion that there is sufficient water for all uses, and this has resulted in a fundamental structural problem – our water systems assume there is enough sustainable water to continue functioning in a business as usual fashion (EMG, 2019). As has been discussed in the introduction, however, South Africa is fast approaching physical and economic water scarcity, and without a swift combination of investment in more water-wise infrastructures and major consumer behavioural changes to reduce the increasing demand for water, a major water crisis looms on the horizon. To avoid water shortages having a directly negative impact on South Africa’s economic development and sustainability, swift and drastic policy measures will need to be implemented to reduce the demand for water. This chapter presents policy implications and recommendations to achieve this based on the findings produced in this dissertation. The chapter will commence by providing a background of water policy in South Africa in order to provide the policy context for the discussion. Following this, detailed policy implications and recommendations will be discussed in three specific sub-sections related to: 1) Price, 2) Water Saving Technologies, and 3) Mining. The chapter will then culminate in a brief policy conclusion.

6.1 Background to Water Policy in South Africa

South Africa is well-renowned for its ground-breaking water legislation which emphasizes the importance of the entire water cycle and grants the environment and people the basic right to water (WWF-SA, 2016). South Africa was also one of the first countries to promulgate and enact law which specifically allocates water for use by the environment, with the aim of ensuring our water systems have sufficient water to sustain them going forward. Looking at the specific legislation which governs our water, South Africa’s water is governed by the Water Services Act of 1997 and the National Water Act (NWA) of 1998. The National Water act is based upon the principles that all water forms part of a unitary, interdependent water cycle, and hence should be governed under consistent rules (NWA, 1998). Within this act are comprehensive provisions for the protection, use, development, conservation, management, and control of South African water resources, with the specific strategic objectives now stipulated within the National Water Resource Strategy (NWRS; DWAF, 2013). The Mpumalanga Province's legislation is an amalgam of national and regional legislation promulgated before the establishment of the province on 27 April 1994 and legislation which it has itself promulgated since it came into existence. The foundational water policies governing the province are the same as those for the nation collectively, with more specific provincial water policies documented within the Mpumalanga Spatial Development Frameworks, published by the provincial government every second year. Despite the ground-breaking water legislation in South Africa, policy implementation has been severely lacking, a common problem in South Africa, and inadequate, ever-more compromised water resources are compounding the problem. As we progress into the 21st century, these water security problems will intensify, and hence improved water policy legislation and implementation will be essential for the socioeconomic development of South Africa

6.2 Policy Implications and Recommendations

6.2.1 Water Pricing: Policy Implications and Recommendations

Water tariffs are used to both generate government revenue and as a mechanism to modify water use, with the theory being that the more expensive water is, the less one will use. In south Africa this creates a serious problem because for the vast majority of the population water is expensive, however for the top 10% it is extremely cheap (EMG, 2019). It is a highly complex task to price water ‘correctly’ in such an unequal society, especially when the supply of water is restricted due to shortage, which leads to low volumes of use, decreasing possible long term revenue that may have been used to invest in water supply infrastructures. South Africa also explicitly recognises that not having access to adequate water puts vulnerable households under enormous pressure, which in turn places a further burden on the state due to the additional demand on health and welfare services. South Africa has therefore ensured a minimum amount of water, 6000l per household per month, is provided to households for free and legislation in fact provides for this (EMG, 2019). The problem with the provision of free water is that it is essentially non-revenue water, as the government earns no money by providing it, and although non-revenue water levels in South Africa are on par with the global average, they are substantially higher than other water stressed countries (Mpumalanga Spatial Development Framework, 2018). Australia, another water stressed country, for example, has limited non-revenue water to 10% (AWA, 2017), and if South Africa were to do a similar thing, one notes that estimates predict water withdrawals could drop by as much as 1.1 km^3 (Mpumalanga Spatial Development Framework, 2018). The current pricing model which entails that municipalities must provide a basic amount of free water to all households may actually lead to some downsides, as there is a need for sufficient revenue from water to be generated to cover the costs of maintaining the required water infrastructure. This situation has led, and will continue to lead, to perverse incentives being offered by municipalities in order to generate revenue such as selling water rights to mining or agricultural companies, which often negates the attempted positive effect of providing households with free basic water in the first place. We hence suggest that South Africa must price water more deliberately, with water demand management being the most important element within these pricing schemes. In so doing, one must account for the legacy of Apartheid and the extreme structural inequality present in the country, something which requires a delicate and more nuanced water pricing approach.

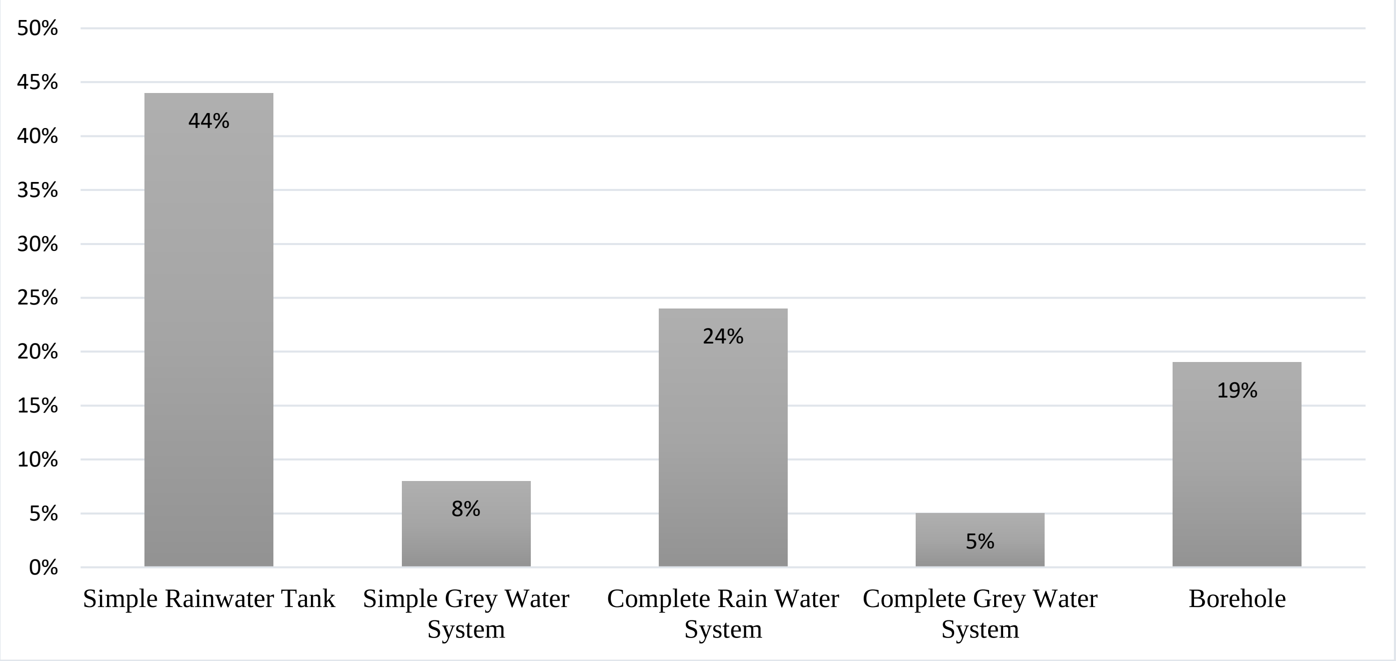
Looking at the results from this paper, price elasticity estimates were reported to range from -0.140 to -0.879, with one noting that the model reporting the -0.879 estimate was only significant at 5% level. Thus, if referring to the highly statistically significant models only, elasticity estimates range from -0.140 to -0.489. These are highly inelastic estimates which suggest that pricing policies will in fact not have much effect on reducing overall household water demand in the region. One notes here, that in the empirical data analysis, it was shown that the average price of water increased with consumption up to a point, that point being 3000l, after which average tap water price then decreased substantially (see Table 9). Research suggests that increasing block-rate pricing structures provides strong incentives for water conservation (Choy, 2015: Donnenfeld et al., 2018), and thus we recommend that the increasing block rate approach is used throughout consumption levels, particularly after the 3000l threshold mentioned, as opposed to only for the initial consumption blocks. Thus, the finding that price decreases after 3000l suggests that an increasing block rate would be an effective policy in this scenario to alter consumption of high consuming households. Although price is generally regarded as one of the most important tools used to manage water demand, it is crucial that policymakers are acutely aware of the socially undesirable distributional effects pricing policies may have on households. We thus ultimately suggest that water is priced more deliberately in Mpumalanga, with a steep increasing block rate approach. We acknowledge also that the relatively low price elasticities reported in this study suggest that pricing policies may not be the most effective instrument that drives reduction of water demand in the region. We move to discussing the policy implications of water saving technologies next.

6.2.2 Water Saving Technologies: Policy Implications and Recommendations

One of the most crucial findings from the results chapter was that water saving technologies, those being rainwater tanks, rainwater systems and efficient washing machines, were shown to reduce household tap water consumption levels by a massive 28.3% to 43.4%. As we progress into a world attempting to alter the demand for water, as opposed to augmenting the supply of water, the significance of this finding cannot be overstated. We therefore recommend these technologies are incorporated into future residential water policy design as the potential water savings could be massive.

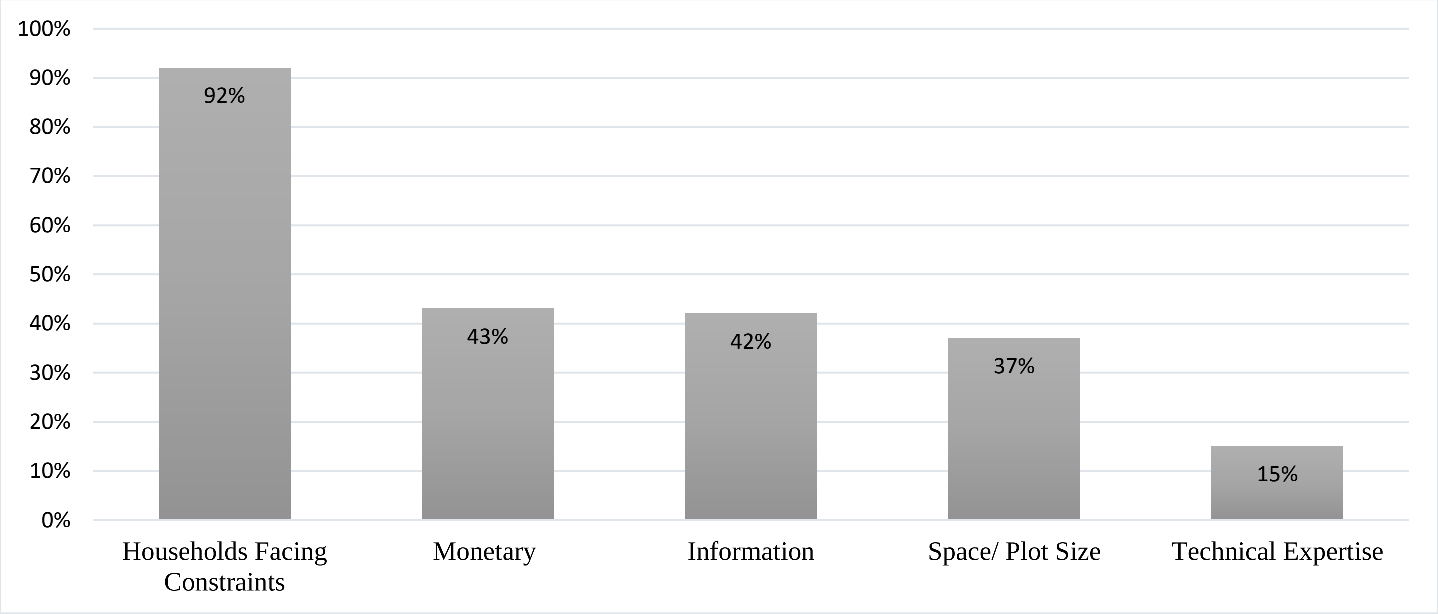
Within the data collection process of this investigation, households were asked which water saving technologies they would prefer, and the Figure 6 below illustrates the households' responses. Crucially, the two technologies mostly preferred by households were those which were also shown to be highly statistically and economically significant in the results section, those being simple rainwater tanks and complete rainwater systems. Although not seen in the table below, the installation of efficient washing machines, which was shown to reduce household tap water consumption by over 30%, was also widely used by households. These technologies are often regarded as highly expensive and households are also often unaware of the massive potential water saving potential of these technologies. We hence discuss the constraints to the adoption of these technologies next as this is crucial information for policymakers.

Figure 6: Water Saving Technologies Preferred by Households



With water saving technologies shown to be so effective in reducing household water consumption levels, it is important to understand the constraints households face to the adoption of these technologies and the figure 8 below provides information on this. The figure shows that nearly all households sampled faced constraints to the adoption of water saving technologies, 92% to be exact, with the most common constraint faced by households being monetary constraints, 43%. Informational and space/plot size constraints were also reported to be faced by many households, 42% and 37% respectively, with only 15% of households reporting to be constrained by technical expertise. We therefore recommend that policymakers attempt to relieve these constraints in order to promote the adoption of water saving technologies, and hence alter the overall demand for water. With monetary constraints being the most common constraint faced by households, we recommend government provide households with cheap and cost-effective water saving technologies like efficient shower heads and rainwater buckets, while subsidising households which install more complex and expensive water saving technologies like rainwater systems and efficient washing machines. We believe that this will undoubtedly promote a reduction in household water consumption levels. We recommend also educational campaigns, to raise awaereness, and the wide-scale promotion of these water saving technologies to the public. This is recommended as over 40% of households revealed information was a key constraint for them. One notes that technical expertise is often a serious constraint for policymakers to overcome, and fortunately in this case only 15% of households report technical expertise as a major constraint to the adoption of water saving technologies. As these technologies become increasingly affordable, their potential impact on household water demand levels may be felt sooner rather than later.

Figure 8: Household Constraints to the Adoption of Water Saving Technologies



6.2.3 Threat of Mining: Water Policy Implications Recommendations

Within the introductory chapter of this paper, the massive threat which mining is having on Mpumalanga’s water resources was discussed, and we believe the policy implications related to this are hence crucial to understand. To highlight the threat of mining, we allude to a 2019 report by the Centre for Environmental Rights (CER) on the compliance of 8 large coal mining operations in Mpumalanga. The report revealed the complete failure by the Department of Water and Sanitation (DWS) to monitor compliance with water use licences for the eight coal mines in question and to take enforcement actions where patently obvious violations had occurred, painting a picture of a broken national department unable to fulfil its statutory mandate of water resource protection (CER, 2019). This has occurred, despite the fact that the Upper Olifants Catchment, where the eight coal mines are located, had been identified by the DWS as one of South Africa's most stressed catchment areas in relation to both water quantity and quality. In terms of consumption, the report revealed that 6 of the 8 mining companies investigated used around 8 million m^3 of water per year, around 4000 Olympic swimming pools. Coupled with this massive water consumption, coal mining is particularly harmful to the quality of water resources, with severe water pollution caused by acid mine drainage. The complete failure to monitor water use licences has essentially created a massive loophole for the companies to operate in., with the report ultimately showing the shocking disregard with which both the state and industry treat our water resources. We therefore call on policymakers, and indeed all corners of society, to take immediate actions to reform the current crisis. We argue that water policy in Mpumalanga will not be effective unless this problem is first solved. Only once there is improved regulation on the use and degradation of water by these mining companies, will residential water demand policy become effective in altering overall water demand.

6.3 Policy Conclusion

Despite water rationing being imminent in South Africa, this reality has not led to a re-think of macroeconomic policies in the country. This delayed reaction and ill-founded complacency has blurred policymakers' vision from the reality that there is an urgent need for proactive water demand management strategies. Natural resources, especially water, will increasingly become the limiting factor to economic development and policymakers must take cognisance of this fact. Providing recommendations for a fundamental rethink of water policy in South Africa is far beyond the scope of this study , however this chapter has provided some important recommendations based on the findings from this investigation to help reduce water demand. For a society undergoing rapid change with many moving dynamics, like South Africa, the management of water for socioeconomic development becomes significantly trickier. It will thus take a concerted effort from all corners of society in the country for new water policies to be effective and sustained.

Chapter 7: Conclusion and Limitations

7.1 Study Limitations and Suggestions for Future Work

With regards to the limitations of this study, there were a couple of minor problems which initially hindered this investigation; however, these were largely overcome. From a contributory perspective, though, two key limitations stand out, both of which relate to the data set used. Firstly, there was no inclusion of any climatic variables in the data set, and one notes these variables have previously been shown to be highly significant factors in determining household water demand levels. The absence of data on these variables therefore limits the results produced in this paper. The second key limitation of this study is concerned with the use of cross-sectional household level data. Data on specific households over a range of time has been shown to be extremely useful in water demand analysis as more effects are able to be captured, and behavioural changes of households can be seen. As we use cross-sectional data from one time-period, we note that this thus limits the findings revealed within this paper.

Moving to suggestions for future work now, we recommend similar studies are carried out in more developing country contexts, as we attempt to build a substantial knowledge base from developing countries on this important topic. Further, we recommend the households sampled in this study are surveyed again in a year or two in order to pick up behavioural changes over time, and hence address the second study limitation mentioned. This second round of data collection will also allow one to investigate the same question answered in this study with data collected during a period in which households are not suffering from severe drought conditions, which undoubtedly has a significant effect on household water consumption patterns, as was the case when data was collected for use in this study.

With water saving technologies shown to reduce water consumption levels so substantially in this study paper, we suggest further work is done in order to investigate the factors driving the adoption of these technologies, as this will provide crucial information for policymakers going forward. One notes that households in this study were revealed to have the unique characteristic of having access to multiple sources of water and we recommend future studies of a similar nature account for this possibility as it results in highly varying price elasticities, and it is in fact a common occurrence in developing country contexts. Our final recommendation builds upon this, and is a suggestion for future research work which investigates the factors driving households' choice to use these multiple water sources, as the use of other water sources will ultimately have a substantial effect on overall municipal tap water demand levels.

7.2 Conclusion

Water is a crucial resource in the functioning of almost all economic activities, and it is also essential for the survival of all living organisms. Concerns about the supply of freshwater, and about the impact of water shortages on economic activity, have therefore placed sustainable water management at the top of the global agenda. With the predicted future scarcity of water for consumption uses in the 21st century, there is an urgent need for in-depth economic analysis on these issues. Recently, these concerns have been growing in developing countries, and there has been wide-spread debate regarding water policy design and implementation in these countries. Residential water consumption now accounts for a substantial, and growing, proportion of total water consumption in most developing economies, and thus residential water demand has become a principal concern of policymakers. This dissertation thus analysed the factors affecting household water consumption levels in the Mbombela Municipality in Mpumalanga, South Africa. This research is of particular importance to South Africa, and indeed many developing and emerging countries, as the country is regarded as a highly water scarce country and hence will need to carefully manage its water resources from a socioeconomic perspective in the future.

The first chapter of this dissertation, the introductory chapter, elaborated upon what has been stated above in attempt to provide the context for this study and highlight the research questions. This introductory chapter revealed South Africa, and indeed the Mpumalanga region, to be semi-arid with highly variable rainfall, a growing demand for water and an ever-dwindling supply of usable water. The country was shown to be fast approaching both physical and economic water scarcity, and it was revealed that unless a solution is found soon, South Africa will be unable to support economic transformation and inclusive growth. Ultimately, a fundamental rethink of South Africa's water sector and water's place within the economy was hence shown to be required. Although recommendations for this entire policy reconsideration falls beyond the scope of this study, the dissertation then reveals that it will contribute to the policy debate by investigating the factors affecting residential water demand in Mpumalanga. An in-depth look at literature which investigated the factors affecting household water consumption, both from an industrialised and developing country perspective, was then conducted in order to review the results and methodologies used prior to this study. This literature review was broken down into 5 key sections, each consisting of a specific factor or set of factors affecting household water consumption, those sections being: Price, Income, Climatic Factors, Socioeconomic Factors and Behavioural Factors. The review highlighted the key takeaways from the literature regarding the factors mentioned, with this providing context for the results found within this research (A summary of the findings from the literature review is seen in section 2.6 – please check for consistency since the numbering has been modified throughout). Before moving to the results section, the dissertation then first provided an extensive preliminary data analysis of the households studied, which was followed by the crucial discussion of the methodology. Within the methodology discussion, a price endogeneity problem caused by the simultaneous determination of price and the block of consumption by households was mentioned, which leads to biased and inconsistent OLS estimates. To deal with this problem, and instrumental variable technique was used and a 2SLS regression model was run. This model ultimately performed extremely well and hence the results produced in this study were based upon this methodology. One notes that households in the study were further broken down into heterogenous income groups, as well as by household water consumption types as households in the study area had the unique characteristic seen in many developing countries of having access to several sources of water, such as tap, ground and rainwater, implying the possibility of substitution. We ultimately ran various estimation strategies ranging from OLS, 2SLS and instrumental variable approaches to identify the factors that influence urban water demand, with the full set of results seen in chapter four.

Overall, the results produced in this study were in line with the findings from research conducted in comparable contexts. The price elasticity estimates were reported to be highly inelastic in the overall 2SLS model, as well as within most household sub-groups, with elasticity estimates ranging from -0.140 to -0.879. In terms of income, the income elasticity estimate in the overall 2SLS model was highly significant and estimated at 0.201, with income results also revealing that income had a larger effect for wealthier households than poorer ones. Households size was shown to be the most significant socioeconomic variable affecting household water demand, a common finding in developing country contexts. The most crucial finding in this research was the revelation that water saving technologies reduced household water consumption levels by between 28.3% to 43.4%, with these variables being highly statistically significant too. Based upon these findings, and within the policy chapter, some policy recommendations were then provided, which will be touched on now. As inelastic price elasticities were reported, we acknowledged that pricing policies may not be the most effective in altering water demand in the region. Due to problems relating to the provision of free basic water by municipalities and the revelation that a decreasing average price per litre of water existed after a certain consumption point, 3000l, we also suggested that water is priced more deliberately in Mpumalanga, recommending a steep increasing block rate pricing structure. With water saving technologies shown to be so effective in reducing household water consumption levels, we emphasized their importance within future residential water demand policy and strategies. Accounting for the constraints faced by households in the study when adopting these technologies, we then recommended that government provides households with cheap and cost-effective water saving technologies like efficient shower heads and rainwater buckets, whilst subsidising households which install more complex and expensive water saving technologies like rainwater systems and efficient washing machines. As information was also widely regarded as major constraint to the adoption of water saving technologies, we recommended also educational campaigns and the wide-scale promotion of these water saving technologies to the public.

Beyond the econometric findings, this dissertation highlighted also the massive threat mining is having on water resources in Mpumalanga, and we therefore called on policymakers, and indeed all corners of society, to take immediate action to reform the current crisis. Finally, we note that water is essential for all life, socioeconomic development, and indeed all economic activity, and despite water rationing being imminent in South Africa, this reality has not led to a re-think of macroeconomic policies in the country. This delayed reaction and ill-founded complacency has blurred policymakers' vision from the reality that there is an urgent need for proactive water demand management strategies. Natural resources, especially water, will increasingly become the limiting factor to economic development and policymakers must take cognisance of this fact. This dissertation has hence provided crucial information on the factors affecting household water consumption in Mpumalanga, with the recommendations based on these findings hoping to alter household water demand levels in the region.

Reference List

Abdullah, A., Ibn Abubakar, B. S. U., Jones, A. N. 2019. Pattern of Residential Water Demand Analysis for Maiduguri Metropolis, North-Eastern Nigeria. Arid Zone Journal of Engineering Technology and Environment. 15(2), 292-303.

Aghte, D.E. & Billings, R.B. 1987. Equity, price elasticity, and household income under increasing block rates for water. American Journal of Economics and Sociology. 46(3), 273-286.

Ahmad, S., Mirza, M., Ali, S., Lotia, H. 2016. Analysing household water demand in urban areas: Empirical evidence from Faisalabad, the industrial city of Pakistan. International Growth Centre, London.

Akoteyon, I. 2019. Factors affecting household access to water supply in residential areas in parts of Lagos metropolis, Nigeria. Bulletin of Geography. Socio-economic Series. Volume 43: Issue 43.

Aprile, M. C., Fiorillo, D. 2017. Water conservation behaviour and environmental concerns: evidence from a representative sample of Italian individuals. Prod.159, 119–129.

Arbues, F. & Villanua, I. 2006. Potential for pricing policies in water resource management: Estimation of urban residential water demand in Zaragoza, Spain. Urban Studies. 43, 2421-2442.

Arbués, F., Bolsa, M.A., Villanúa, I. 2015. Which factors determine water saving behaviour? Evidence from Spanish households. Urban Water J. 13, 511–520.

Arbues, F.; Garcia-Valinaz, M.A.; Martinez- Espineira. 2003. Estimation of residential water demand: a state-of-the-art review. The Journal of Socio- Economics, 32:81-102.

Arbués, F.; Villanùa, I. 2006. Potential for pricing policies in water resource management: Estimation of urban residential water demand in Zaragoza, Spain. Urban Stud. 43, 2421–2442.

Ashoori, N., Dzombak, D.A. & Small, M.J. 2016. Modelling the Effects of Conservation, Demographics, Price, and Climate on Urban Water Demand in Los Angeles, California. Water Resource Manage 30, 5247–5262.

Ashour EK., Al-Najar, A. 2013. The impact of climate change and soil salinity in irrigation water demand on the Gaza Strip. Journal of Water Climate Change. 4(2):118–130.

Barbara G.; Schreiner, E.; Mungatana, D.; Baleta, H. 2018. Impacts of Drought Induced Water Shortages in South Africa: Sector Policy Briefs. Pegasys Institute. WRC Report No. 2604/2/18. ISBN 978-0-6392-0056-9

Basani, M.; Isham, J.; & Reilly, B. 2008. The determinants of water connection and water consumption: empirical evidence from a Cambodian household survey. World Development. 36(5), 953-968.

Billings, R.B. & Day, W.M. 1989. Demand Management Factors in Residential Water Use: The Southern Arizona Experience. Journal AWWA 81(3):58-64.

Binet, M., Carlevaro, F. Paul, M. 2014. Estimation of Residential Water Demand with Imperfect Price Perception. Environ Resource Econ (2014) 59:561–581.

Blignaut, J. & van Heerden, J. 2009. The impact of water scarcity on economic development initiatives. Department of Economics, University of Pretoria, ISSN 0378-4738 = Water SA Vol. 35 No. 4.

Carden, K. 2013. Assessing urban water sustainability in South Africa - not just performance measurement. Department of Civil Engineering, University of Cape Town. ISSN 1816-7950 (On-line) = Water SA Vol. 39 No 3 WISA 2012 Special Edition 2013.

Centre for Environmental Rights (CER). 2019. Full Disclosure Report. The Truth about Water Use Licence Compliance at Mpumalanga Coal Mines.

Cheesman, J.; Bennett, J.; Son, T.V.H. 2008. Estimating Household Water Demand Using Revealed And Contingent Behaviors: Evidence from Viet Nam. Water Resources Research 44, W11428, doi:10.1029/2007WR006265.

Clarke, AJ., Colby, BG., Thompson, GD. 2017. Household Water Demand Seasonal Elasticities: A Stone-Geary Model under an Increasing Block Rate Structure Land Economics.

Corbella, H.M. & Pujol, D.S. 2009. What lies behind domestic water use? A review essay on the drivers of domestic water consumption.

Cubillo Gonzalez, F. & Ibanez Carranza. 2003. Manual de Abastecimiento del Canal de Isabel II. Madrid, Canal de Isabel II.

Dagnew, D.; Nicholson, C.; Collick, A.; Tilahun, S.; & Steenhuis, T. 2013. Factors affecting access to piped water services in peri-urban town of Ethiopia; the case of Merawi.

Dalhuisen, J.M.; Florax, R.J.G.M.; de Groot, H.L.F.; Nijkamp, P. 2003. Price and income elasticities of residential water demand: A meta-analysis. Land Econ. 79, 292–308.

Dandy, G.; Nguyen, T.; Davies, C. 1997. Estimating Residential Water Demand in the Presence of Free Allowances. Land Economics. 73, 125-139.

Data World Pty. Limited. 2018. Mpumalanga Spatial Development Framework. Spatial Challenges and Opportunities Report.

David, C.C. & A.B. Inocencio. 1998. Understanding Household Demand for Water: The Metro Manila Case. Research Report, EEPSEA, Economy and Environment Program for South East Asia.

Deller, S., Chicoine, D., Ramamurthy, G. 1986. Instrumental Variables Approach to Rural Water Service Demand. Southern Economic Journal, Vol. 53, No. 2. pp. 333-346.

Department of Water Affairs (DWA). 2010. National Water Services Regulation Strategy. Department of Water Affairs, Pretoria, South Africa.

Dhungel, R., Fiedler, F. 2020. Price Elasticity of Water Demand in a Small College Town: An Inclusion of System Dynamics Approach for Water Demand Forecast. Air, Soil and Water Research, 7(1).

Dieu-Hang, T., Grafton, RQ., Martínez-Espiñeira, R., Garcia-Valiñas M. 2017. Household adoption of energy and water-efficient appliances: An analysis of attitudes, labelling and complementary green behaviours in selected OECD countries. J Environ Manage.197:140-150.

Domene, E.; Saurí, D. 2006. Urbanization and water consumption: Influencing factors in the Metropolitan Region of Barcelona. Urban Stud. 43, 1605–1623.

Donnenfeld, Z.; Crookes, C.; Hedden, S. 2018. A delicate balance: Water scarcity in South Africa. South African Report 13. Institute for Security Studies.

Ellon, M.K. 2011. Evalusation of the Impact of Scarcity of Water in the bushbuckridge Local Municipality in the Mpumalanga Province: A case study of Islington and Clare B villages. Masters in Development. University of Limpopo.

Environmental & Resource Economics. Springer; European Association of Environmental and Resource Economists, vol. 63(1), pages 167-191.

Fan, L.; Gai, L.; Tong, Y.W. & Li, R. 2017. Urban water consumption and its influencing factors in China: Evidence from 286 cities.

Fielding, K.S.; Spinks, A.; Russell, S.; McCrea, R.; Stewart, R.; Gardner, J. 2013. An experimental test of voluntary strategies to promote urban water demand management. J. Environ. Manag. 114, 343–351.

Forrest, K.; & Loate, L. 2017. Coal, water and mining flowing badly. Society, Work & Development Institute.

Garcia, J., Salfer , L R., Kalbusch , A., Henning, E. 2019. Identifying the Drivers of Water Consumption in Single-Family Households in Joinville, Southern Brazil. DOI: 10.3390/w11101990.

García-Valiñas, M.A. 2005. Efficiency and equity in natural resources pricing: A proposal for urban water distribution service. Environ. Resour. Econ. 2005, 32, 183–204.

Garrone, P., Grilli, L., Marzano, R. 2019. Price elasticity of water demand considering scarcity and attitudes. Utilities Policy. Elsevier, vol. 59(C). pp 1-1.

Gato, S.; Jayasuriya, N.; Roberts, P. 2007. Forecasting residential water demand: case study. Journal of Water Resources Planning and Management. 133, 309-319.

Ghimire, M., Boyer, T. A., Chung, C., and Moss, J. Q. 2015. Estimation of residential water demand under uniform volumetric water pricing. J. Water Resource Planning. Management.

Gilg, A. & Barr, S. 2006. Behavioural attitudes towards water saving? Evidence from a study of environmental actions. Ecological Economics. 57(3), 400-414.

Gunatilake, H.; Gopalakrishnan, C.; Chandrasena, I. 2001. The Economics of Household Demand for Water: The Case of Kandy Municipality, Sri Lanka. Water Resources Development. 17 (3), 277-288.

Gutzler, D.S. & Nims, J.S. 2005. Interannual variability of water demand and summer climate in Albuquerque, New Mexico. Journal of Applied Meteorology 44:1777-1787.

Hanke, S.H. & de Mare, L. 1982. Residential water demand: a pooled time-series cross-section study of Malmo, Sweden. Water Resources Bulletin. 18(4):621-625.

Hansen, L. 1996. Water and energy price impacts on residential water demand in Copenaghen. Land Econ. 72, 66–79.

Hoffman, M.; Worthington, A.; Higgs, H. 2006. Urban water demand with fixed volumetric charging in a large municipality: the case of Brisbane, Australia. The Australian Journal of Agricultural and Resource Economics. 50(3), 347-359.

Howarth, D. & Butler, S. 2004. Communicating water conservation. How can the public be engaged? Water Supply. 4, 33-34.

Howe, C. & Linaweaver, F. 1967. The Impact of Price on Residential Water Demand and its Relation to System Design and Price Structure. Water Resources Research, 3 (1), 13- 32.

Jansen, I. 2012. Aspects of the Economics of Water Management in Urban Settings in South Africa, with a focus on Cape Town. PHD Thesis.

Katz, D. 2015. Water consumption and economic growth: Reassessing the Environmental Kuznets Curve Relationship. J. Clean. Prod. 88, 205–213.

Katzman, M. 1977. Income and price elasticities of demand for water in developing countries. Water Resources Bulletin. 13:47–55.

King, N. 2002. Responding to a City's Water Prices: The case of Tshwane. Masters of Commerce Thesis. University of Pretoria.

Koop, S.; Van Dorssen, A. J.; Bouwer, S. 2019. Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics.

Kotagama, H., Zekri, S., Al Harthi, R., Boughanmi. 2017. Demand function estimate for residential water in Oman, International Journal of Water Resources Development, 33:6, 907-916, DOI: 10.1080/07900627.2016.1238342

Larson, B. & Razafindralambo, R. 2006. Unravelling the Linkages between the Millennium Development Goals for Poverty, Education, Access to Water and Household Water Use in Developing countries: Evidence from Madagascar. Journal of Development Studies 42(1): 22–40.

Loh, M. & Coghlan, P. 2003. Domestic water use study: Perth, Western Australia 1998–2021. Water Corporations, Perth, Western Australia.

Lux, A. 2008. Shrinking Cities and Water Supply» in Population Dynamics and Supply Systems (Hummel, D., ed.). Frankfurt am Main: Campus, 161-179.

Lyman, R.A. 1992. Peak and Off-Peak Residential Water Demand. Water Resources Research 28(9):2159-2167.

Madanat, S. & Humplick, F. 1993. A Model of Household Choice of Water Supply Systems in Developing countries. Water Resources Research 29:1353–8.

Manouseli, D.; Kayaga, S.M.; Kalawsky, R. 2019. Evaluating the Effectiveness of Residential Water Efficiency Initiatives in England: Influencing Factors and Policy Implications. Water Resource Manage. 33, 2219–2238.

Mansur, E. & Olmstead, S. 2006. The Value of Scarce Water: Measuring the Inefficiency of Municipal Regulations. Working Paper 06-01. Washington D.C: AEI-Brookings Joint Centre for Regulatory Studies.

Martens, E.P., Pestman, W.R., de Boer, A., Belitser, S.V., Klungel, O.H. 2006. Instrumental Variables: Application and Limitations. Epidemiology, 17(3), 260-267.

Martinez-Espineira, R. 2002. Residential Water Demand in the Northwest of Spain. Environmental and Resource Economics 21:161–187.

Martins, R. & Fortunato, A. 2007. Residential water demand under block rates-a Portuguese case study. Water Policy. 9, 217–230.

McCarthy TS.; Humphries MS. 2012. Contamination of the water supply to the town of Carolina, Mpumalanga. S Afr J Sci. 2013;109(9/10), Art. #2012-0112.

Miaou, S.P. 1990. A class of time-series urban water demand models nonlinear climatic effects. Water Resources Research. 26, 169-178.

Mu, X.; Whittington, D.; Briscoe, J. 1990. Modeling Village Water Demand Behavior: A Discrete Choice Approach. Water Resources Research 26(4):521–9.

Muller, M. et al. 2009. Water security in South Africa. Development Planning Division. Working Paper Series No.12.

Musolesi, M. & Nosvelli, M. 2007. Dynamics of residential water consumption in a panel of Italian municipalities. Appl. Econ. Lett. 14, 441–444.

Nauges, C. & C. van den Berg. 2009. Demand for Piped and Non-piped Water Supply Services: Evidence from Southwest Sri Lanka. Environmental and Resource Economics 42(4):535–49.

Nauges, C. & Strand, J. 2007. Estimation of non-tap water demand in Central American cities. Resource and Energy Economics, 29(3), 165-182.

Nauges, C. & Van Den Berg, C. 2009. Demand for piped and non-piped water supply services: Evidence from Southwest Sri Lanka. Environmental and Resource Economics. 42(4), 535-549.

Nauges, C. & Whittington, D. 2010. Estimation of water demand in developing countries: An overview. The World Bank Research Observer, 25(2), 263-294.

Newhouse, J.P., McClellan, M. 1998. Econometrics in Outcomes Research: The Use of Instrumental Variables. Annual Review of Public Health, 19, 17-24.

Nieswiadomy, M. L. & Molina, D. J. 1989. Comparing residential water demand estimates under decreasing and increasing block rates using household data. Land Economics, 280-289.

Ochieng, G.; Seanego, E.; Nkwonta.; O. 2010. Impacts of mining on water resources in South Africa: A review. Scientific Research and Essays Vol. 5(22), pp. 3351-3357, 18. Available online at http://www.academicjournals.org/SRE. ISSN 1992-2248.

Olmstead, S.M. 2009. Reduced form vs. Structural Models of Water Demand Under Nonlinear Prices. Journal of Business and Economic Statistics 87, 84–94.

Olmstead, S.W., Stavins, R.N. 2009. Comparing price and non-price approaches to urban water conservation. Water Resources Research, Vol. 45, doi:10.1029/2008WR007227.

Otieno, F. & Ochieng, G. 2007. Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025. Faculty of Engineering, Tshwane University of Technology, ISSN 0378-4738 = Water SA Vol. 30 No. 5.

Pérez-Urdiales, M., García-Valiñas, María. 2016. Efficient water-using technologies and habits: A disaggregated analysis in the water sector. Ecological Economics, Elsevier, vol. 128(C), pages 117-129.

Pérez-Urdiales, M., García-Valiñas, María., Martínez-Espiñeira, R. 2016. Responses to Changes in Domestic Water Tariff Structures: A Latent Class Analysis on Household-Level Data from Granada, Spain.

Peters, R.; & Woodhouse, P. 2019. Reform and regression: Discourses of water reallocation in Mpumalanga, South Africa. Water Alternatives 12(3): 853-868.

Piper, S. 2003. Impact of water quality on municipal water price and residential water demand and implications for water supply benefits. Water Resources Research 39(5): 1127.

Rathnayaka, K. 2015. Seasonal Demand Dynamics of Residential Water End-Uses. Water 7(1):202-216. DOI: 10.3390/w7010202.

Rauf, S., Bakhsh, K., Hassan, S., Nadeem, A. M., Kamran, M. A. 2015. Determinants of a Household’s Choice of Drinking Water Source in Punjab, Pakistan. Polish Journal of Environmental Studies, 24(6), 2751-2754.

Renwick, M.E. & Archibald, S.O. 1998. Demand side management policies for residential water use: Who bears the conservation burden? Land Economics. 74, 343-359.

Renwick, M.E.& Green, R.D. 2000. Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies. Journal of Environmental Economics and Management. 40:37-55.

Renzetti, S. 2002. The economics of water demands. Boston. Kluwer Academic Publishers.

Republic of South Africa (RSA). 1998. National Water Act, Act No. 36 of 1998. Government Printer, Pretoria, South Africa.

Rietveld, P.; Rouwendal, J; Zwart, B. 2000. Block Rate Pricing of Water in Indonesia: An Analysis of Welfare Effects. Bulletin of Indonesian Economic Studies 36(3):73–92.

Rizaiza, O. 1991. Residential water usage: A case study of the major cities of the western region of Saudi Arabia. Water Resources Research. 27(5).

Rock, M. 2000. The dewatering of economic growth. J. Ind. Ecol. 4, 57–73. doi:10.1162/108819800569294.

Romano, G. & Salvati, N. 2014. Estimating the Determinants of Residential Water Demand in Italy. MPDI Water Journal, 6, 2929-2945. ISSN 2073-4441. doi:10.3390/w6102929

Ščasný, M., Smutná, S. 2019. Estimation of Price and Income Elasticity of Residential Water Demand in the Czech Republic over Three Decades. Working Papers IES.

Schreiner, B.; Pegram, G.; Von Der Heyden, C. 2009. Reality check on water resources management: Are we doing the right things in the best possible way? Development Planning Division Working Paper Series No. 11. Development Bank of Southern Africa, DBSA.

Sershen et al. 2016. Water security in South Africa: perceptions on public expectations and municipal obligations, governance and water re-use. School of Life Sciences, University of KwaZulu-Natal. ISSN 1816-7950 (Online) = Water SA Vol. 42 No. 3.

Shamim, MA., Panhwar, IA., Iftikhar, SF. 2019. Water Consumption Behavior: A Review with Global Perspective and Special Reference to Developing Country. Global Management Journal for Academic & Corporate Studies 9 (1), 146-162.

Shaw, D.T. & Maidment, D.R. 1987. Intervention Analysis of Water Use Restrictions, Austin, Texas. Water Resources Bulletin 23(6):1037-1046.

Statzu, V. & Strazzera, E. 2009. Water demand for residential uses in a Mediterranean region: Econometric analysis and policy implications. Available online: http://www.cide.info/conf/2009/iceee2009_submission_88.pdf

Syme, G.J.; Shao, Q.; Po, M.; Cambell, E. 2004. Predicting and understanding home garden water use, Landscape and Urban Planning. 68, pp. 121–128.

Szabo, A. 2009. The Value of Free Water: Analyzing South Africa's Free Basic Water Policy. Available: http://www.econ.umn.edu/~szabo/jmpszabo_nov22.pdf [13 September 2010].

Tolles, J., Meurer, W. 2016. Logistic Regression Relating Patient Characteristics to Outcomes. JAMA. 316 (5): 533–4. doi:10.1001/jama.2016.7653. ISSN 0098-7484. OCLC 6823603312. PMID 27483067.

Tsai, Y.; Cohen, S.; Vogel, R.M. 2011. The Impacts of Water Conservation Strategies on Water Use: Four Case Studies. Water Resource Assoc. 47(4):687-701.

UNESCO .2014. Water in the post-2015 development agenda and sustainable development goals, Discussion Paper, UNESCO International Hydrological Programme.

Van den Berg, C. & Nauges, C. 2012. The willingness to pay for access to piped water: a hedonic analysis of house prices in Southeast Sri Lanka. Letters in Spatial and Resource Sciences, 5(3), 151-166.

Van Koppen, B. 2001. Gender in integrated water management: an analysis of variation». Natural Resources Forum. 25(4), 299-312.

Veck, G. & Bill, M. 2000. Estimation of the Residential Price Elasticity of Demand for Water by means of a Contingent Valuation Approach. WRC Report No. 790/1/00. Pretoria, South Africa: Water Research Commission.

Vlach, T. 2016. Income Elasticity of Water Demand: A Meta-Analysis. Univerzita Karlova, Fakulta sociálních věd.

Wang, X., Zhang, J., Shahid, S. 2016. Adaptation to climate change impacts on water demand. Mitigation Adaption Strategies Global Change. 21, 81–99.

Woodard, G.C. & Horn, C. 1988. Effects of Weather and Climate on Municipal Water Demand in Arizona. Report prepared for Arizona Department of Water Resources and Tucson Water.

World Wildlife Fund – South Africa (WWF-SA). 2016. Water: Facts and Futures. Rethinking South Africa's Water Future.

Worthington, A.C.; Hoffmann, M. 2008. An empirical survey of residential water demand modelling. J. Econ. Surv. 22, 842–871.

Wunsch, H., Linde-Zwirble, W.T., Derek, C.A. 2006. Methods to adjust for bias and confounding in critical care health services research involving observational data. Journal of Critical Care, 21, 1-7.

WWF-SA. & Council for Scientific & Industrial Research (CSIR). 2013. An introduction to South Africa 's Water Source Areas.

Yan, D. 2013. Urban domestic water consumption response to climate change in Urumqi city. In: International Conference on Earth Science and Environmental Protection. vol. 189, pp. 897e904.

Zhang, D.; Ni, G.; Cong, Z.; Chen, T.; Zhang, T. 2013. Statistical interpretation of the daily variation of urban water consumption in Beijing, China. Hydrol. Sci. J. 59 (1), 181e192.

Zwarteveen, M.Z. 1997. Water: From basic need to commodity: A discussion on gender and water rights in the context of irrigation. World Development. 25(8), 1335-1349.

Articles

Boccaletti, G.; Stuchtey, M.; van Olst, M. 2010. Confronting South Africa's water challenge. Available: https://www.mckinsey.com/business-functions/sustainability/our-insights/confronting-south-africas-water-challenge#

de Jager, E. 2016. SA rainfall in 2015 the lowest on record – SAWS, Available: www.politicsweb.co.za/politics/sa-rainfall-in-2015- the-lowest-on-record--saws

Donnely, L. 2012. South Africa's water crisis just got expensive. Available: https://mg.co.za/article/2012-04-16-sas-water-crisis-just-got-expensive

Environment Monitoring Group. 2019. A perfect storm is gathering: South Africa's perpetual water crisis. Available: https://www.dailymaverick.co.za/article/2019-09-12-a-perfect-storm-is-gathering-south-africas-perpetual-water-crisis/

Frankson, L. 2015. Mpumalanga residents threaten strike after water shortage. Available: https://infrastructurenews.co.za/2015/01/19/mpumalanga-residents-threaten-strike-after-water-shortage/
https://www.iol.co.za/news/south-africa/mpumalanga/mpumalanga-coal-mines-threaten-sas-water-resources-ngo-28581975

IOL. 2016. Mpumalanga residents forced to buy water. Available: https://www.iol.co.za/news/south-africa/mpumalanga/mpumalanga-residents-forced-to-buy-water-2077561

IOL. 2019. Mpumalanga coal mines threaten SA's water resources – NGO. Available:
Machogo, T. 2019. Water rationing might lead to job cuts in Mpumalanga. Available: http://www.sabcnews.com/sabcnews/water-rationing-might-lead-to-job-cuts-in-mpumalanga/

Manyana, N. 2019. Mpumalanga residents urged to intensify water saving efforts. Available: https://infrastructurenews.co.za/2019/08/16/mpumalanga-residents-urged-intensify-water-saving-efforts/

McKay, D. 2019. SA coal miners polluting Mpumalanga province water on "egregious" scale. Available: https://www.miningmx.com/news/energy/37488-sa-coal-miners-polluting-mpumalanga-province-water-on-egregious-scale-cer/

News24. 2018. Guptas suck Mpumalanga mining town dry. Available: https://www.news24.com/SouthAfrica/News/guptas-suck-hendrina-dry-20180217

SA Gov. 2019. Minister Lindiwe Sisulu: Response to drought. Available: https://www.gov.za/speeches/response-drought-3-dec-2019-0000

SA News. 2019. Mpumalanga residents urged to do more to save water. Available: https://www.thesouthafrican.com/news/mpumalanga-residents-urged-to-do-more-to-save-water/

SA News. 2019. R18m allocated for Mpumalanga water shortages. Available. https://www.sanews.gov.za/south-africa/r18m-allocated-mpumalanga-water-shortages

Staff Writer, 2019. The average salaries in 10 major cities across South Africa. Available: https://businesstech.co.za/news/property/318888/rent-vs-salary-in-south-africas-biggest-cities/

Staff Writer, 2019. Rent vs salary in South Africa's biggest cities. Available: https://businesstech.co.za/news/property/318888/rent-vs-salary-in-south-africas-biggest-cities/

The Citizen. 2019. Water crisis in Mpumalanga town of Hendrina. Available: https://citizen.co.za/news/south-africa/1970795/water-crisis-in-mpumalanga-town-of-hendrina/

Tonisi, L. 2019. Water scarcity in South Africa and the precarious road ahead. Available: https://www.dailymaverick.co.za/article/2019-10-18-water-scarcity-in-south-africa-and-the-precarious-road-ahead/

Viljoen, B. 2019. 'All we can do now is pray for rain' - Water crisis hits Barberton Available: https://www.news24.com/SouthAfrica/News/all-we-can-do-now-is-pray-for-rain-water-crisis-hits-barberton-20191022

Watson, A. 2019. Water quality, supply in crisis while polluting mines go unchecked. Available: https://citizen.co.za/news/south-africa/environment/2150362/water-quality-supply-in-crisis-while-polluting-mines-go-unchecked/

Appendices

Appendix 1: Survey Questionnaire Used

QUESTIONNAIRE

Introduction

Good morning/afternoon/evening. My name is **XXXX**, and I am part of a research team collecting data in Cape Town and Mpumalanga. The data collection is part of collaboration between the Sultan Qaboos University in Oman and the University of Cape Town in South Africa. The project's main objective is to understand the challenges faced by water users. From this city, a small sample of households has been selected and I am now in the process of discussing with people like you to get information about water management behaviour in your community. This information is **confidential** and will only be used for the purposes of this study, which will not make reference by name to any one respondent. I will be grateful if you could assist me in filling out this questionnaire in as honest as possible. The interview will take about 40 minutes of your time and participation is voluntary. Your responses will help the City of Cape Town to design better water policy measures.

Section A: Identification		**Code**
A1	Questionnaire number	
A2	Date	
A3	Suburb	
A4	Enumerator	
A5	GPS coordinates	

Section B: General information on household water consumption				**Code**
B1	Over the past 3 months, what was the household's tap water consumption?	Current month		
		Previous month 1		
		Previous month 2		
B2	Over the past 3 months, what was the household's monthly tap water bill?	Current month		
		Previous month 1		
		Previous month 2		
B3	Do you know how water is being priced in your city?		0=no 1=yes	
B4	Does household drink tap water?		0=no 1=yes	
B5	a) In your opinion, how critical do you think the water situation in the city is?		Please rate 1 to 10	
	b) Number of times household experienced water interruption past 12 months			
B6	Please rate your tap water quality using a scale from 1 to 10			
B7	Does household buy bottled water for drinking purposes?		0=no 1=yes	
B8	a) Does household own a borehole?		0=no 1=yes	
	b) How much water can be taken from the borehole per day in litters?			
	c) Does household own a well point?		0=no 1=yes	
	d) How much water can be taken from the well point per day in litters?			
B9	Does household use tap water for irrigation on the property?		0=no 1=yes	
B10	Does household own a lawn?		0=no 1=yes	
B11	Does household own trees?		0=no 1=yes	
B12	Does household own a flower garden?		0=no 1=yes	
B13	Does household own a vegetable garden?		0=no 1=yes	

Section C: Socioeconomic Variables			**Code**
C1	Age of household head		
C2	Gender of household head	0=Female 1=Male 2=Not disclosed	
C3	a) Education level of household head	0=None 1 = Primary 2=Secondary 3=Tertiary	
	b) Number of years in school for the household head		
	c) Education level of spouse	0=None 1 = Primary 2=Secondary 3=Tertiary	
	d) Number of years in school for the spouse		
C4	a) Is household head employed?	0=no 1=yes	
	b) Is spouse employed?	0=no 1=yes	
	c) Number of employed household members		
C6	a) Employment income of household head (Rand)		
	b) Employment income of other household members (Rand)		
	b) Income from business (Rand)		
	c) Remittances (Rand)		
	d) Pension		
	e) Government transfers		
	e) Income from other sources (Rand)		
C7	Household size		
C8	Number of children under five		
C9	Does household own a car?	0=no 1=yes	
	Number of cars owned		
C10	Does household own a swimming pool?	0=no 1=yes	
	How big is the swimming pool in litters		

Section D: Household water saving strategies and technologies				**Code**
D1	Is household aware of any water saving strategies?		0=no 1=yes	
D2	a) Use shower rather than the bath tab		0=no 1=yes	
	b) Turning off the tap when soaping up in the shower		0=no 1=yes	
	c) Turning off the tap when washing dishes		0=no 1=yes	
	d) Reducing the number of baths/shower		0=no 1=yes	
	e) Reducing the length of baths/shower		0=no 1=yes	
	f) Reducing toilet flushes		0=no 1=yes	
	g) Use bucket for bathing		0=no 1=yes	
	h) Turn off the tap when cleaning teeth		0=no 1=yes	
	i) Use bucket for watering the garden rather than horse pipe		0=no 1=yes	
	j) Use bucket for washing car(s) rather than horse pipe		0=no 1=yes	
D3	Is household aware of any water saving technologies?		0=no 1=yes	
D4	Has household installed water saving technologies?		0=no 1=yes	
	Type of water saving technology	1. Efficient shower head	0=no 1=yes	
		2. Toilet flushing system	0=no 1=yes	
		3. Efficient washing machine	0=no 1=yes	
D5	Does household use greywater technologies?		0=no 1=yes	
D6	Type of greywater technology	1. bucket	0=no 1=yes	
		2. simple greywater tank	0=no 1=yes	
		3. greywater system installed	0=no 1=yes	
		4. pond	0=no 1=yes	
D7	Does household use rainwater technologies?		0=no 1=yes	
D8	Type of rainwater technology	1. bucket	0=no 1=yes	

		2. simple rainwater tank 0=no 1=yes	
		3. rainwater system installed 0=no 1=yes	
		4. pond 0=no 1=yes	

Section E: Household attitudes towards water conservation			**Code**
E1	Do you think households in your area should prioritize water conservation? 0=no 1=yes		
E2	Should household be allowed to harvest and use rainwater? 0=no 1=yes		
E3	Should household be allowed to harvest and use waste water? 0=no 1=yes		
E4	Do you think rainwater is associated with environmental/health hazards? 0=no 1=yes		
E5	Do you think greywater is associated with environmental/health hazards? 0=no 1=yes		
E6	Do you think the use of rain helps to save tap water? 0=no 1=yes		
E7	Do you think the use of greywater helps to save tap water? 0=no 1=yes		
E8	Do you think rain can help to reduce your water bill? 0=no 1=yes		
E9	Do you think greywater can help to reduce your water bill? 0=no 1=yes		
E10	Do you think tap water is correctly priced by city authorities?	1. Too low 0=no 1=yes	
		2. Correctly priced 0=no 1=yes	
		3. Too high 0=no 1=yes	
E11	How much are you willing to pay to enjoy improved water services and quality in your city?		

Section F: Constrains to adoption of water saving technologies			**Code**
F1	Do you think household is facing any constrains that limit the adoption of WCT? 0=no 1=yes		
F2	What type of constraints does household face?	1. Monetary 0=no 1=yes	
		2. Information 0=no 1=yes	
		3. Space/plot size 0=no 1=yes	
		4. Technical expertise 0=no 1=yes	
		5. Other (____________________________)	
F3	Which technology would you have preferred?	1. Simple rainwater tank 0=no 1=yes	
		2. Simple greywater tank 0=no 1=yes	
		3. Complete rainwater system 0=no 1=yes	
		4. Complete greywater system 0=no 1=yes	
		5. Borehole	
		6. Well point	
		7. Pond 0=no 1=yes	

Thank you for participating in this survey

Appendix 2: List of instrumental Variables Proposed and Tested

Instrumental Variables Tested
Locality
Water Scarcity
Number of Interruptions
Average tap water price with fixed fee included
Fixed fee as a proportion of water bill
Price Block
Water Quality
CPI
Fuel Cost

Appendix 3: Results of Price Endogeneity Tests

Tests of Price Endogeneity			
Ho: variables are exogenous			
Durbin (score) chi2(1)	=	237.601	(p=0.0000)
Wu-Hausman F (1,488)	=	443.574	(p=0.0000)

Appendix 4: Instrumental Variable Test Results

4.1 Tests of Overidentifying Restrictions			
Sargan (score) chi2(1) =	=	1.14328	(p=0.2850)
Basmann chi2(1) =	=	1.12065	(p=0.2898)

4.2 First-stage regression summary statistics (IV Strength Tests)					
Variable	R-sq	Adjusted R-sq	Partial R-sq	F-stat	Prob>F
Average Price	0.7738	0.7692	0.7593	769.615	0.0000
Minimum eigenvalue statistic	=	769.615			
Critical Values	# of endogenous regressors			=	1
Ho: Instruments are weak	# of excluded instruments			=	2
		10%	15%	20%	25%
2SLS Size of nominal 5% Wald test		19.93	11.59	8.75	7.25
LIML Size of nominal 5% Wald test		8.68	5.33	4.42	3.92