Estimating Demand for Utilities in Ghana: An Empirical Analysis

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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JULY, 2016

ABSTRACT

Using a variety of techniques, this doctoral thesis seeks to estimate the demand for key utilities such as electricity and residential water supply in Ghana.

This thesis comprises of four chapters that estimate demand for electricity and residential water supply in Ghana.

Chapter one is a joint paper published in the *Renewable and Sustainable Energy Reviews journal* with Justice Tei Mensah and George Marbuah as co-authors. Although we all worked together from the introduction to the end of the paper; my principal role was writing literature review, sections of the data and discussion. The key idea was to disaggregate the energy sector and individually estimate the demand for each type of energy in Ghana.

Chapter two estimates household demand for electricity in Ghana. We use the Contingent Valuation Method (CVM) to estimate the demand for a 24-hour electricity service among households in Ghana. In response to the current CVM debate, this study investigates critical issues such as hypothetical bias, WTA&WTP convergence/divergence, and scope sensitivity that can easily invalidate our estimates.

Chapter three seeks to estimate demand for piped-water services in urban Ghana. The paper applies three different valuation methods to estimate demand, thus providing validity checks for our estimates using competing methods.

Chapter four is a single authored paper published in *Water Policy Journal*. This chapter seeks to estimate demand for domestic water from an innovative borehole system in rural Ghana using stated and revealed preference approaches. First, the study investigates demand for domestic water supply from an innovative borehole system using the CVM. We further estimate demand for current service of domestic water supply in residences using the Hedonic Pricing Method (HPM). This is achieved through a survey from rural districts in the Greater Accra Region, Ghana. Interval regression and ordinary least squares (OLS) are applied to investigate the determinants of willingness-to-pay (WTP).

The main findings of this thesis may be summarised as follows:

1. Our results show that energy prices, income, urbanization and economic structure are significant demand drivers of the different energy types in Ghana with varying estimated elasticities. We find that there is a high degree

of responsiveness of electricity demand to income changes by mainly the industrial sector relative to households.

2. Households are willing to pay between 7% and 15% of their income to have a 24hour supply of electricity in the GAR of Ghana. However, our cost & benefit analysis show a net cost of GHS567.52million ($146.97million) per annum.
3. The average amount that a household is willing to pay per month for a reliable piped-water services is GHS 44.73 or US$14.27 (HPM), GHS 22.72 or US$7.25 (TCM) and GHS 47.80 or US$15.25 (CVM) respectively. These amounts are equivalent to 3%-8% of households' income. We find evidence of a positive net benefit of GHS 486.78million (US$155,49million) per annum.
4. Finally, regarding water supplied from the innovative borehole system and current improved water services, we find evidence that monthly WTP values are GHS35.90 (US$11.45) and GHS17.59 (US$5.61) in the CVM and HPM, respectively. These values represent approximately 3%-6% of household monthly income which is consistent with earlier studies.

By way of conclusion, the author follows these empirical findings and prescribe several policy recommendations to inform policy direction in the utility sector(s) in Ghana and other developing countries with similar characteristics.

DEDICATION

I dedicate this work to the Almighty God who has given me the inspiration and strength irrespective of the difficult times I have been through.

ACKNOWLEDGEMENTS

Through this tough journey of life, I have come to understand that it takes a little bit of everybody around you to get to your final destination. Several people have contributed immensely to this height and I want to cease this opportunity to appreciate them.

First

I sincerely want to express my profound gratitude to the School of Economics, University of East Anglia for the professional environment and well-suited logistics they made available for me to have the soundness of mind to concentrate and undertake this PhD programme. I also want to thank my employers, Central University, Ghana for granting me study leave to pursue further studies.

Second

A special acknowledgement goes to my supervisors Professor Peter G. Moffatt and Dr. Corrado Di Maria. Your guidance and excellent contribution to my work deserves commendation. Some tasks were so challenging yet, you gradually guided me through to the end. To me, you were like a father, a brother and sometimes a colleague. I couldn't have asked for more!

Also, to all Faculty members especially Prof. Enrique Fatas, Prof. Robert Sugden, Dr. Silvia Ferrini, Dr. Georgios Papadopoulos, Dr. Emiliya Lazarova, Dr. Katerina Karadimitropoulou, Dr. Farasat Bokhari, Dr. Joel Clovis etc. who have contributed to my work in one way or another during my upgrade, internal seminars and personal consultations. I say a big thank you to you all.

For the excellent administrative support and opportunities I got from Gina Neff, Shiona Brereton, David Robson, Thomas Cushan and Jessica Pointer, I say another big thanks to you all.

Again, I appreciate my family at Central University especially Prof. Anthony Panin, Prof. Adusei Jumah, Paragon Pomeyie, Davis Adu Larbi, Daniel Offei, Dr. Deodat Adenutsi, Rev. Godson Ahiabor, Rev. Eddie Carboo, Justice Ampiah, Edmond Kwablah, Juliana Adama and Matilda Wilson.

Third

A very special thanks go to my wife and kids, Sandra Otenewaa Amoah, Anthony Addo-Amoah Jnr. and Richel Adubea Amoah. You guys have been very supportive through these years. You sacrificed all for this height to be attained. I say, I owe you one!

The praying woman in my life Mrs Mercy Addo and the father of wisdom Mr. Sampson Manukure Addo. Dad and Mum you have been a source of my inspiration and I'm proud to be your child. To my in-laws, Mr & Mrs Ampofo, I appreciate your love and do not take it for granted. To my brothers and sisters: Herbert Amoah, Richard Amoah, Florence Manukure, Joshua Duah, Pastor & Mrs Alamu (UK), Pastor & Mrs Otoo (UK), Mr & Mrs Ntim (UK) , Mr & Mrs Kinful (UK), Mama Grace and family, and all the other wonderful CCBC Becton branch members. Carol Gurajena (UK) thanks for sacrificing your time to read through my work. I count it as a privilege to be associated with you all.

Fourth

These friends of mine have been there for me through thick and thin. They motivated me, challenged me and urged me on even when I felt like giving up. To George Adu, Justice Tei Mensah, George Marbuah, Franklin Amuakwa-Mensah, Edmond Hagan, Joel Kwabena Frimpong and Jerry Seddor, I say Ayekoo! To my right hand man, Rexford Kwaku Awuku Asiama, you have been very supportive any time I needed you. You have been a brother and a colleague. I salute you for your time and sacrifices through the data collection up until this final stage. I owe you one!

Fifth

A healthy competition amongst PhD students is always a delight. I must appreciate all past and present colleagues especially Jack Whybrow, Dr. Mike Brock, Dr. Zoe Bett, Dr. Bing Radoc, Natalia Borzino, Yusuf Kucuk, Carsten Crede, Cameron Belton, Paul Gorny, Richard Havell, Issa Hijazeen, Haifa Al Hamdani, Anwesha Mukherjee, Emike Nasamu, Ioannis Pappous, Lina Restrpo Plaza, Balazs Stadler, Antonios Staras, Mengjie Wang, Lian Xue, Ritchie Woodard, Han Lin etc.

Lastly

For all module convenors who gave me the opportunity to teach, I owe you an appreciation. To the PGR office: Gilly and Fiona, thanks for the support anytime it was needed.

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ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criterion
AMCOW	African Ministers Conference on Water
ARDL	Auto-Regressive Distributed Lag
BDM	Becker-DeGroot-Marschak
BIC	Bayesian Information Criterion
CO_2	Carbon dioxide
CVM	Contingent Valuation Method
CWSA	Community Water and Sanitation Agency
DBDC	Double Bound Dichotomous Choice
DF-GLS	Dickey Fuller-Generalized least square
ECG	Electricity Company of Ghana
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
GAR	Greater Accra Region
GDM	Gravity Driven Membrane
GDP	Gross Domestic Product
GHp	Ghana Pesewas
GHS	Ghana Cedis (¢)
GLSS	Ghana Living Standards Survey
GoG	Government of Ghana
GPRS	Ghana Poverty Reduction Strategy
GSGDA	Ghana Shared Growth and Development Agenda
GSS	Ghana Statistical Service

GWCL	Ghana Water Company Limited
HPM	Hedonic Price Method
IBS	Innovative Borehole System
IEA	International Energy Agency
ISSER	Institute of Statistical, Social and Economic Research
ITCM	Individual Travel Cost Method
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
MIC	Middle Income Country
MICS	Multiple Indicator Cluster Survey
ML	Maximum Likelihood
NED	Northern Electricity Department
NOAA	National Oceanic and Atmospheric Administration
NSRP	National Solar Rooftop Programme
NWP	National Water Policy
OLS	Ordinary Least Squares
PAM	Partial Adjustment Model
RCS	Randomized Card Sorting
RFO	Residual Fuel Oil
RP	Revealed Preference
RQS	Randomized Questionnaire Sorting
SDG	Sustainable Development Goals
SP	Stated Preference
SSA	Sub-Saharan Africa
TC	Travel Cost Method
TIOLI	Take-it-or-leave-it

TOR	Tema Oil Refinery
UNICEF	The United Nations Children's Emergency Fund
UPPF	Unified Petroleum Price Fund
USA	United States of America
VIF	Variance Inflation Factor
VRA	Volta River Authority
WAGP	West African Gas Pipeline
WHO	World Health Organization
WTA	Willingness to Accept
WTP	Willingness To Pay
ZTCM	Zonal Travel Cost Method

GENERAL INTRODUCTION

Under the auspices of the United Nations, countries came together in September 2015 and sanctioned several development goals with the primary aim of ending poverty, protecting the planet and ensuring prosperity for all over the next fifteen years. These goals form the new Sustainable Development Goals (SDGs), a continuum that consolidates the Millennium Development Goals (MDGs), which are all targeted towards improving human welfare.

This thesis contributes to our understanding of the challenges connected with the achievement of SDG 6: Ensure access to water and sanitation for all, and 7: Ensure access to affordable, reliable, sustainable and modern energy for all, and its relevance to human welfare particularly in developing countries.

The role of key utilities such as electricity and water supply is one of the key drivers that can account for differences in human welfare across time and space. In as much as the absence of utilities affect firms' productivity, Barnes et al. (2011) also argues that the absence of such utilities have negative implications on general welfare conditions. By implication, the absence of such key utilities have serious impacts on the overall development of an economy. It is against this background that developed countries ensure that such resources are given some degree of priority to serve as the base to support both firms and households wellbeing.

Ghana is naturally endowed with sizeable amount of resources that can be harnessed to propel its growth and development agenda. However, not much has been achieved with these endowments vis a vis electricity and water supply. This is because dating back to independence until today, such utilities have attracted large subsidies from the government and donor support. Unfortunately, donor funding mostly delay and do not come on schedule. Also, successive governments' inability to honour their financial obligations towards these sectors have left these utility companies with huge debt. Based on these challenges, four key research questions are outlined by this study: what are the key determinants of energy demand particularly electricity in Ghana? If utilities are adequately and reliably supplied, will households in Ghana be willing to pay for reliable services without government support? Do these estimates satisfy internal and external validity requirements? Does the cost benefit analysis from our estimates support private sector involvement in both electricity and water sectors?

To the best of our knowledge, there is a paucity of empirical based evidence on such relevant estimates to influence policy direction. The main purpose of this thesis is to fill this gap. This is achieved by providing a valid empirical evidence that will engender policies in harnessing endowments that can propel growth and development in Ghana and other developing countries with similar characteristics.

The main contributions of this thesis are as follows: first, it is the first study to consider a comprehensive set of disaggregated energy demand sources in a single study to shed light on the key drivers of these energy demand components, especially electricity, at the macro level in a developing country. Second, at the micro level, it provides the first estimates of WTP for electricity within the context of addressing issues such as hypothetical bias, WTP & WTA, and scope sensitivity in a developing country. Third, it provides the first developing country's study to compare three economic valuation methods in a water related study. Lastly, it provides the first study to design and further estimate WTP for water from an innovative borehole system for rural communities in a developing country. In short, this study presents the first cost and benefit analysis study for key utilities in Ghana in a single study to inform policy direction towards addressing a critical problem currently bedevilling the country.

This thesis has four chapters with two main themes. The first theme looks at demand for energy in Ghana. The second theme looks at water supply with an emphasis on urban and rural residential water supply. In chapter one, we disaggregate and model types of energy in Ghana, and estimate their elasticities. This chapter is a macro study which makes use of times series data and applies the Autoregressive Distributed Lags (ARDL) model for the estimation. The study finds that energy prices, income, urbanization and economic structure are significant demand drivers for the different energy types in Ghana with varying estimated elasticities. Specific to electricity, the study finds that income, urbanization and structure of the economy are significant factors behind electricity consumption in Ghana, with all drivers having positive elasticities. Overall, urbanization is shown to have the highest impact followed by income and economic structure. The results are found to be consistent with existing studies.

Following on the estimates from our macro study, we further investigated demand for electricity using a household survey in Ghana. We applied the standard Contingent Valuation Method (CVM) to estimate demand for a 24-hour electricity service. This was conducted in line with topical validity issues such as hypothetical bias, WTP & WTA, and scope sensitivity that can easily invalidate WTP estimates. Our results show that households are willing to pay between 7% and 15% of their income to have a 24hour supply of electricity in the GAR of Ghana. However, our cost & benefit analysis shows a net cost of GHS567.52million ($146.97million) per annum. This suggests that a complete removal of subsidies on electricity tariff in Ghana will hurt household's electricity consumption.

The second part of the thesis addresses household water demand. This section has two chapters (i.e. chapters three and four). The third chapter applies three valuation methods to estimate demand for reliable piped-water services in urban-Ghana. Our goal is to estimate the economic value of reliable piped-water supply, and provide validity checks for our estimates. We survey urban households and find that the average amount that households are willing to pay per month is GHS 44.73 or US$14.27 (Hedonic Price Method), GHS 22.72 or US$7.25 (Travel Cost Method) and GHS 47.80 or US$15.25 (CVM) respectively. These amounts are equivalent to 3%-8% of households' income. This study provides evidence of the economic viability of private sector involvement in the water sector in Ghana. Our estimates will inform both managers and policy makers in their decision-making on reliable piped-water supply.

The last chapter for the thesis investigates demand for domestic water supply from an innovative borehole system using the CVM. We further estimate demand for current service of domestic water supply in residences using the Hedonic Pricing Method (HPM). This is achieved through a survey from rural districts of the GAR, Ghana. Interval regression and ordinary least squares are applied to investigate the determinants of WTP. We find that monthly WTP are GHS35.90 (US$11.45) and GHS17.59 (US$5.61) in the CVM and HPM, respectively. These values constitute approximately 3%-6% of household monthly income which is consistent with existing studies. For policy purposes, the study recommends the adoption of this cost effective technology to help ease the water burden on society.

All in all, the study has shown a positive demand for these key utilities (electricity and water). This is evidenced by their WTP for improvement in these services because of its welfare benefits. This methodology satisfies relevant internal and external validity checks needed to validate our estimates. We argue that a regulated private provision of water supply could be better for the water sector but definitely not an immediate option for the electricity sector if consumers are not going to enjoy their subsidies. For policy purposes, we argue that towards achieving the SDGs government should ensure that the necessary incentives to attract regulated private sector for the water sector is put in place within a due diligence framework. Also, in the absence of the private sector in electricity supply in Ghana, government should provide incentives for private households to use renewable energy. These recommendations are crucial as electricity and water are key drivers to Ghana's growth and development agenda.

CHAPTER ONE

ENERGY DEMAND IN GHANA: A DISAGGREGATED ANALYSIS

1. Introduction

The role of energy resources in meeting the needs of households, industries, transportation and agricultural sectors among others in any economy cannot be overemphasized. Different types of energy sources are required to meet demand for lighting, cooking, electricity generation among many other uses. Global energy demand is predicted to rise by one-third by 2040, driven higher by growing populations and expanding economies of India, China, Africa, the Middle East and Southeast Asia (IEA, 2015). In Africa, natural gas consumption has seen substantial growth on the back of increased economic activity, new infrastructural investment and domestic price subsidies (Ackah, 2014; Eggoh *et al*., 2011).

Demand for energy in Ghana similar to most developing countries exceeds the available supply. A key challenge to Ghana's energy sector is inadequate access to modern and clean energy services such as liquefied petroleum gas (LPG) and hydro/solar-based electricity. Access to modern energy services in Ghana has been defined as "…communities /households connected to the grid (i.e. electricity access) and the number of households using LPG either as their main fuel for cooking or in combination with other cooking fuels (i.e. access to clean cooking fuels)" (Serwaa Mensah *et al*. 2014). It is estimated that almost 50% of Ghana's population do not have access to grid-electricity and that about 90% of those who do not have access to LPG for cooking rely on biomass (i.e. firewood and charcoal) as alternatives (Kemausuor *et al*. 2011). Lack of access to these modern and cleaner energy sources has been attributed to factors including but not limited to income and supply-side constraints (Mensah and Adu, 2013). This implies that most households depend heavily on traditional energy sources such as biomass (mainly charcoal and wood fuel) to meet their energy demand. The impact of continual exploitation of forest lands and burning of wood fuel by households and industries on environmental degradation (i.e. deforestation and climate change) continues to engage decision-makers at the local, national, regional and international levels. Carbon dioxide (CO_2) emissions from primary fuel consumption by the residential sector accounted for about 18% of global CO_2 emissions in 2008 (OECD and IEA, 2010). It is estimated that about 80% of Ghanaian households depend heavily on wood fuels for cooking and heating water (Energy Commission, 2003). The overreliance on biomass as a key energy source by Ghanaian households is among the main drivers of the rapid depletion of Ghana's forest cover which stands at about 2% loss per annum. Incessant depletion of the forest to meet primary energy consumption is likely to derail efforts at ensuring environmental sustainability and inhibit Ghana's attainment of Millennium Development (MDG) Goal 7 (Mensah and Adu, 2013). According to a recent Ghana Multiple Indicator Cluster Survey (MICS) report, more than 3 billion people worldwide rely on solid fuels (i.e. biomass and coal) for their basic energy needs (including cooking and heating). Cooking and heating with solid fuels often generates high levels of indoor smoke, a complex mix of health-damaging pollutants. The main problem with the use of solid fuels is products of incomplete combustion, including carbon monoxide, sulphur dioxide, and other toxic elements. This increases the risk of acute respiratory illness, pneumonia, chronic obstructive lung disease, cancer, and possibly tuberculosis, low birth weight, cataracts, and asthma among others (Ghana Statistical Service, 2011).

It is in recognition of the debilitating impact of continued use of primary energy sources such as biomass on health and climate change that the United Nations has been advocating for intensification of programs/policy initiatives that encourages a switch from traditional energy sources to an enhanced access and utilization of modern and cleaner ones like LPG (Mensah and Adu, 2013). The Government of Ghana therefore launched a National LPG Programme in 1990 to promote LPG use as an alternate energy source to charcoal and firewood. Urban households, public institutions and the informal commercial sector requiring mass catering facilities were targeted through extensive promotional and educational campaigns (UNDP Ghana, 2004). The results of these promotional efforts bore some significant fruit with LPG consumption doubling in 1992 and by 2004, total LPG consumption was over 50,000 tonnes per annum which is about ten times more than pre-promotional consumption levels (UNDP Ghana, 2004). Promotion of LPG use among rural households was also initiated through the Unified Petroleum Price Fund (UPPF). The idea of this policy was to compensate oil marketing companies that transport petroleum products like LPG to rural and distant locations outside a radius of 200km from the Tema Oil Refinery[1] to cover transportation cost (UNDP Ghana, 2004). Despite these efforts, LPG consumption levels remained low in even urban areas with high demand for wood fuel. The key mitigating factor identified at the initial stages of the LPG campaign was the relatively high upfront cost of the LPG cylinder compared to that of wood fuel. Financial support was given by the UNDP under its

[1] Tema Oil Refinery (TOR) is the only oil refinery in Ghana.

Rural LPG Challenge in 2004 to support government relaunch of the LPG campaign in rural areas and especially in the Northern regions of Ghana which were lagging other regions in terms of access to LPG services (Kemausuor *et al*., 2011). Another complementary effort was the completion of the West African Gas Pipeline (WAGP) project in 2006 under which natural gas is transported from Nigeria to other West African states[2] through to Ghana. This was to provide reliable and adequate supply of gas for electricity generation in Ghana (Mensah and Adu, 2013). Access to electricity in Ghana since the establishment of the Volta River Authority (VRA[3]) has seen significant improvement over the years. Consumption grew by 9.4% between 1990 and 2001. Access rate of electricity in Ghana was estimated to be about 54% in 2007 (Kemausuor *et al*., 2011). However, frequent power crises since 2006 has almost rolled back most of the gains made in terms of supply for domestic and industrial use. The high dependence of Ghana on natural gas supply from Nigeria through the WAGP which is erratic, coupled with inadequate gas storage infrastructure (due to low investment) and a crippling TOR is among some of the reasons for the rampant LPG shortages and frequent power outages in Ghana. The recent discovery and exploitation of oil deposits in Ghana is expected to reduce importation of crude oil and gas from Nigeria following completion of a gas infrastructure project (Ghana Gas Company) which is expected to improve access to various sources of modern energy, especially LPG.

The literature on energy demand has grown rapidly over the years. While some studies looked at aggregate energy demand drivers (see e.g. Bentzen and Engsted 1993 and Gately and Huntington 2001), others estimate disaggregated or sectoral determinants of demand for energy (see e.g. Gately and Streifel, 1997; Akinboade *et al*., 2008; Pedregal *et al*., 2009; Sa'ad, 2009; Boshoff, 2010). The results from most of these studies are often mixed and conflicting. Recent evidence on energy demand in Ghana includes Adom (2011) who modelled causality between electricity consumption and economic growth. The evidence was that it is economic growth that causes electricity demand and not the other way round. Adom *et al*. (2012) also find that the main drivers of electricity demand in Ghana are real income per capita, industrial efficiency, degree of urbanization and structural changes in the economy. Policy regime changes have also been modelled in the demand for electricity in Ghana (Adom and Bekoe, 2013). In a more recent study, Ackah (2014) modelled aggregate, residential and industrial demand for natural gas in Ghana. The study revealed that demand for natural gas is significantly driven by income, population,

[2] WAGP is a 678km offshore pipeline carrying natural gas from Nigeria through Benin to Togo and Ghana.

[3] The VRA is a state agency responsible for generating Ghana's electricity from installed hydro power and thermal plants.

real price of natural gas, and industrial share of output. Ackah's study differs from Mensah (2014) who estimated factors influencing demand for only aggregate LPG in Ghana. Similar to Ackah (2014), Mensah (2014) identified income and price as main demand drivers of LPG in addition to rapid urbanization.

The goal of this study therefore is to provide a comprehensive analysis of the drivers of disaggregated energy demand in Ghana to offer guidance on energy policy prescriptions towards achieving the overarching aim of becoming an "energy sufficient economy" to propel the engines of economic growth and development. To realise this goal, we consider a comprehensive set of disaggregated energy demand sources – gasoline, diesel, LPG, kerosene, solid biomass, residual fuel oil and electricity – in a single study to shed light on the key drivers of these energy demand components. We use the autoregressive distributed lag model approach of Pesaran *et al*., (2001) to estimate short and long run disaggregated energy demand determinants. This is important for purposes of policy planning and implementation since the estimated coefficients could inform energy demand management as well as the supply side. Critical policy and sensitive issues such as petroleum price subsidization, urban planning as well as the need for further investment in energy infrastructure could benefit from our results.

The rest of the paper is organized as follows. Section 2 gives a brief overview of energy demand trends in Ghana. A discussion and summary of selected empirical literature on energy demand is presented in Section 3. Section 4 highlights methodological and data issues and the empirical results are analysed in Section 5. We conclude the paper in Section 6 with a discussion of appropriate policy implications from our results.

2. Energy Demand Trends in Ghana

Successive governments in Ghana have over the last two to three decades implemented various policies aimed at boosting economic growth and poverty reduction. Policies implemented include *inter alia* the Economic Recovery Programme (ERP) and Structural Adjustment Programme (SAP) in the 1980s and early 1990s, Ghana Poverty Reduction Strategy (GPRS I, 2003-2006), Growth and Poverty Reduction Strategy (GPRS II, 2006-2009) and recently the Ghana Shared Growth and Development Agenda (GSGDA, 2010-2013). The last three medium-term policies sought to pursue pro-poor policies to reduce high poverty incidence in the country, implement programmes and projects that would ensure attainment of middle income country (MIC) status by 2015 and accelerate attainment of the MDGs ahead of the 2015 deadline. The energy sector was duly given priority in these development policies including actions to ensure sustainable energy use to reduce the impact on the environment, improve access to modern energy sources such as LPG and making energy products for most Ghanaians affordable. Ghana has however managed to reach MIC status ahead of the 2015 target year. By 2007, per capita GDP crossed the income threshold mark of US$1,000 to qualify for MIC status. As at 2013, GDP per capita for Ghana was US$1,850 (World Bank, 2014). Further, overall real GDP has posted positive growth rates since 1984 (8.6%) reaching an all-time high of 14.05% in 2011 with a corresponding per capita income growth of 12% in the same year.

Structurally, the economy has undergone rapid transformation over the last three decades. Agriculture, which hitherto commanded a greater share of total output, has seen its contribution slump over the years. From about 65% of total GDP with industry and services sectors accounting for 12.9% and 22% respectively in 1978, the agricultural sector's share as at 2013 stood at 22%. The services sector now leads with 49.5% and industry follows accounting for the remaining 28.6%. It is noteworthy that this structural change came to light on the back of a rebasing exercise carried out on Ghana's national accounts in 2006. The implication of the sustained economic growth over the years and the changing structure of the economy is that energy demand is likely go up as more firms expand their plant sizes, households on average are becoming richer and all sectors particularly the emerging petroleum subsector's energy requirements surge. As noted by Duku *et al*. (2011), Ghana's energy demand in recent years has increased significantly due to population increase (average growth rate of 2% per annum) and rapid urban growth (average growth of 4% for the period 1980-2013). Unfortunately, this increasing demand for energy is much more pronounced in the consumption of wood fuel, with wood charcoal the main choice (Duku *et al*., 2011).

Fig. 1.1 shows the dynamic changes in different energy mix between 2000 and 2012. Clearly, in 2000, the distribution shows a heavy dependence on energy from biomass (59%) with electricity the second largest source of total energy consumption (32%). In terms of petroleum products, consumption of diesel and gas oil mostly for transportation and industrial purposes leads the energy demand ladder with aviation fuel (ATK), kerosene and residual fuel oil (RFO), LPG and premix fuel (mostly used to power outboard motors for fishing) follow in that order. What is worrying though is the rather low utilization of LPG which is cleaner, portable, and efficient with multiple uses. As discussed in the earlier section, this could be due to the relatively high cost of gas cylinders and refilling as well as frequent shortages on the market which leaves very little option for households and small scale enterprises than to fall on primary sources such as biomass to meet their energy needs. The trend however, is changing with deliberate government efforts aimed at reducing heavy reliance on biomass use.

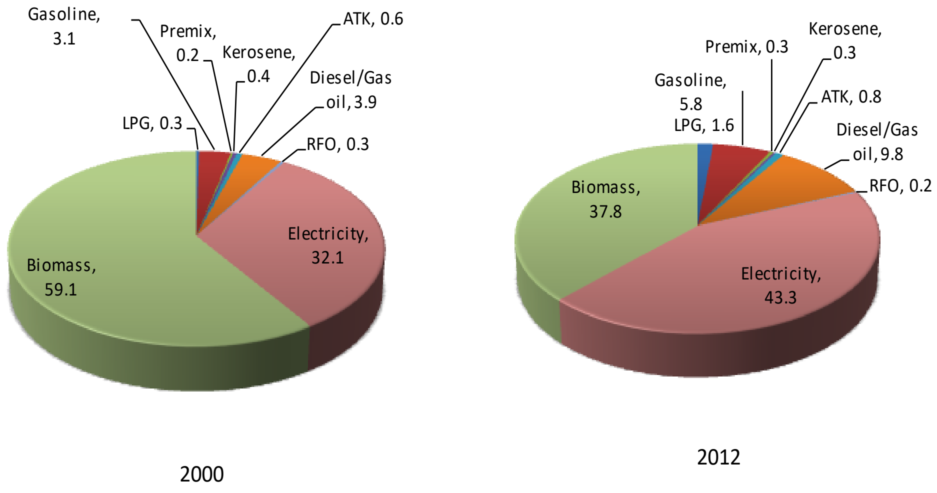

Fig. 1.1: Energy Demand Shares by Type (2000 & 2012)

By 2012, the share of biomass to total energy had declined significantly to about 38% while electricity access increased by 11 percentage points over the thirteen year period. This is very significant and could be explained by the investment in thermal plants and participation of the private sector in electricity generation (e.g. Asogli Power Plant) in the last few years. Also, the continued national electrification project to get the rest of the country that are not connected to the national grid seems to be bearing some fruits. What is encouraging though is that LPG utilization seems to be picking up albeit from a low base. From a low of 0.3% in 2000, LPG share of total energy consumption as at 2012 was 1.6%. We believe this figure could have been much higher but for the erratic supply of the gas on the market coupled with the high cost of LPG which most poor households cannot afford in both rural and urban areas.

As already discussed, petroleum products constitute a significant source of Ghana's energy consumption requirement. The different components of oil products consumed are depicted in the first panel of Fig. 1.2. The second panel shows sectoral demand of oil products. The trend shows that since the early 1970s, the most consumption has come from diesel and gasoline and the trend seems to have been following an upward trajectory since 1983. LPG though starting from a very base shows promise of increased usage peaking around 2009 but the upward trend picked up after a decline in 2010. Expectedly, the transport sector consumes much of the petroleum products followed by industry. Transportation, especially importation of heavy duty and luxury vehicles as well as taxis and minibuses has increased considerably in Ghana in recent years. The residential sector (households) continues to consume more of petroleum products. It is instructive to note that many households in the urban areas in recent times have been switching to the use of LPG and kerosene stoves with further decline in use of electric cookers.

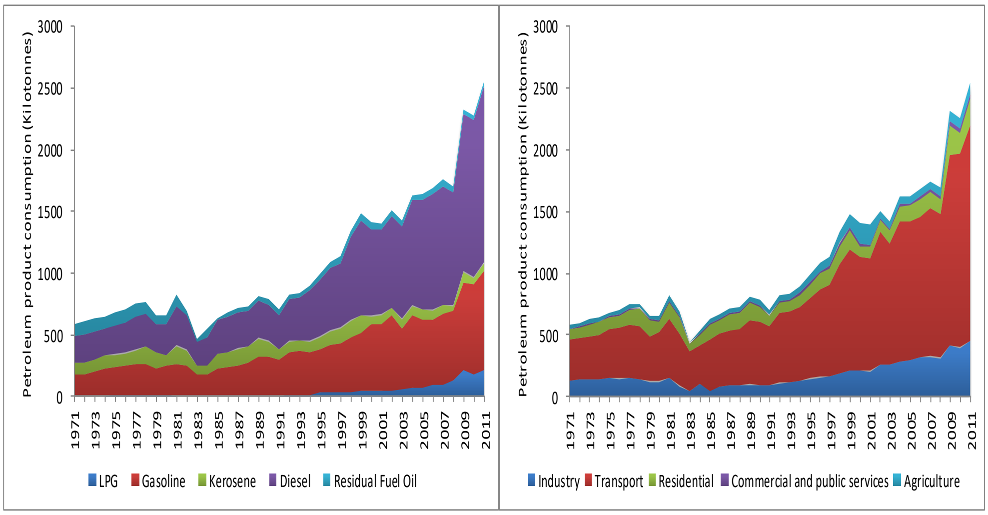

Fig. 1.2: Consumption of Oil Product Type and Sectoral Demand

3. Empirical Literature

In this section, we present a review of the literature on the determinants of energy demand. As demonstrated in various empirical studies and for simplicity in our presentation, we categorise these determinants under economic and non-economic determinates of energy demand.

Economic determinants of energy demand dates back to the 50s which saw the pioneering work of Houthakker (1951) in a cross-sectional study that focused on domestic tariffs. Under the assumption of a stable demand function, he first considered the relevant theoretically justified variables (such as income, price and price of related goods) that should enter the demand function for electricity. In addition, he used the generalized least squares to analyze forty-two British provincial cities for the years 1938/9 and concluded that demand for electricity was sensitive to changes in both price and income. Several other studies which include Dahl, (1991, 1993, 1994, 2012); Bentzen and Engsted, (2001); Pesaran et al., (2001); Gately and Huntington, (2001, 2002); Alves and Bueno, (2003); Akinboade et al. (2008); Webster et al. (2008); Brons et al. (2008); Havránek et al. (2012); Havránek, and Ondřej (2013); Mensah, (2014), Arzaghi and Squalli (2015), Havranek and Kokes (2015) have followed this conventional approach in estimating the various elasticities of their respective demand functions.

Non-economic (macro and micro) determinants include but not limited to preferences or taste, technical progress, environmental pressures and regulations, energy efficiency standards, economic structure, age, education, substitution of labour or capital or raw materials for energy inputs, gender, leisure time, size of the household, lifestyles, effects of values and norms. Some of the aforementioned factors have been included in studies such as Hunt et al. (2003); Heltberg (2004, 2005); Ouedraogo (2006); Ackah (2014) and Karimu (2013, 2015). In the most recent study, Karimu (2015), the study investigated both economic and non-economic (hybrid) factors influencing the choice of cooking fuels in Ghana. The dataset used for the study was the fifth round of the Ghana living standards survey (GLSS 5, 2005/06) conducted in the year 2005/06. This consisted of 8,687 households of which 8,262 contain information regarding household energy use. The multinomial probit model was estimated and he found that, both economic and non-economic factors influenced household choice for the various fuels.

In addition, some studies especially most recent ones have also looked at demand-side challenges and management of energy (see Strbac, 2008; Sorrell, 2015; Wu et al., 2015. Zhou and Yang, 2015; Ming et al., 2015; Ogunjuyigbe et al., 2015). However, it is important to acknowledge that for policy purposes the issue of energy demand management can be well addressed if demand for energy is disaggregated and holistically analysed. Furthermore, most energy demand studies have focused on Asia (see Iwayemi et al., 2015), with a paucity of such studies on hybrid disaggregated energy demand in Africa. This study also contributes to the literature by providing empirical evidence on disaggregated energy-demand in an African context.

Overall, literature on energy demand provides a broad empirical evidence of aggregated and disaggregated energy demand analysis respectively, with papers mainly differing in the data coverage as regards countries and time periods, variables selection, the estimation methods and output. These diversities observed in the literature have had their primary objective of obtaining estimates for price and income elasticities and these are summarized in table 1.1 below.

Table 1.1: Disaggregated Demand for Energy

Reference	**Focus/Data**	**Method/Model**	**Results** (*Price/Income Elasticities)*	
Arzaghi and Squalli (2015)	Demand for gasoline for 32 countries over the 1998-2010 period	Random Effects	Gasoline	SR-0.05/0.16
				LR-0.25/0.81
Havranek and Kokes (2015)	Income elasticity of Gasoline demand using Dahl's (2012) dataset	Meta-Analysis	Gasoline	SR na/0.1 to 0.28
				LR na/0.23 to 0.66
Mensah (2014)	LPG demand in Ghana from 1992-2012	ARDL	LPG	SR -0.03/0.06
				LR -0.28/0.45
Boshoff (2010)	Demand for petroleum product in South Africa from 1998Q1-2008Q4	ARDL	Diesel	LR -0.13/1.51
Bhattacharyya and Blake (2009)	Petroleum product demand in Middle East and North African	Log-linear	Gasoline	SR -0.079/0.267
			Diesel	SR -0.026/0.135
			Kerosene	SR -0.019/0.123
			Fuel oil	SR -/0.179/0.445
Atakhanova and Howie (2007)	Residential Energy Demand in Kazakhstan from 1994-2006	Dynamic Panel Techniques (two-steps GMM estimation)	Electricity	SR -0.22/0.12
				LR -1.1/0.59
De Vita et al. (2005)	Energy Demand in Namibia from 1980Q1-2002Q4	ARDL	Electricity	LR -0.298/0.589
			Petrol	LR -0.858/1.081
			Diesel	LR -0.109/2.075
Liu, G. (2004)	Energy Demand for OECD Countries from 1978-1999	Dynamic Panel Techniques (One-step GMM estimation with Strictly exogenous income)	Electricity	SR -0.030/0.058
				LR -0.157/0.303
			Natural Gas	SR -0.102/0.137 LR -0.364/0.303
			Hard Coal	SR 0.000/-1.148 LR -0.001/-2.243
			Gas Oil	SR -0.143/0.030 LR -0.318/0.066
			Motor Gas	SR -0.191/0.196 LR -0.600/0.614
Lundmark et al. (2001)	Energy Demand in Namibia from 1980-1996	OLS	Electricity	LR -0.863/-0.512
Hunt et al. (2000)	Energy Demand for Honduras from 1973-1995	Cointegration Technique	Electricity	LR na/0.79
			Petroleum	LR -0.24/1.58
Espey (1998)	Gasoline Demand from 1929-1993	Meta-Analysis (Linear model reported)	Gasoline	SR -0.000/0.010 LR -0.110/-0.025
Silk and Joutz (1997)	Residential Electricity Demand in US. Data from 1949-1993	Cointegration Technique	Electricity	SR -0.62/0.38 LR -0.6/0.82

*SR and LR denote short-run and long-run elasticity estimates respectively.

4. Model Specification, Data and Methodology

4.1. Model specification and data

Energy is a key ingredient in the demand basket of economic agents in every sector of the economy due to its important role in production and consumption (Mensah, 2014). Thus, the underlying framework behind demand for energy services stems from standard economic theory of demand which stipulates demand as a function of income, prices and a vector of other demand drivers. This can be expressed as

$$Q_t^E = f(P_t, Y_t, X_t) \tag{1.1}$$

where Q_t^E represents the quantity of energy services consumed, while Y_t and P_t represents income and a vector of price of the own price and price of related commodities, respectively. X_t on the other hand is a vector of demand drivers such as economic structure, degree of urbanization, etc. However, the exact functional form of energy demand equations has been the subject of debate in the empirical literature ranging from the traditional log-linear to demand systems.

Nonetheless, in this study we follow the traditional log-linearized approach as implemented by De Vita et al. (2006), Zuresh and Peter (2007), Adom *et al*., (2012) and Mensah (2014). We specify the disaggregated energy demand functions as:

Gasoline

$$lnGS_t = \alpha_0 + \alpha_1 lnPS_t + \alpha_2 lnPD_t + \alpha_3 lnPLPG_t + \alpha_4 lnY_t + \alpha_5 lnU_t + \varepsilon_t \tag{1.2}$$

Diesel

$$lnD_t = \beta_0 + \beta_1 lnPS_t + \beta_2 lnPD_t + \beta_3 lnPLPG_t + \beta_4 lnY_t + \beta_5 lnU_t + \eta_t \tag{1.3}$$

Liquefied Petroleum Gas (LPG)

$$lnLPG_t = \theta_0 + \theta_1 lnPS_t + \theta_2 lnPD_t + \theta_3 lnPLPG_{tt} + \theta_4 lnY_t + \theta_5 lnU_t + \zeta_t \tag{1.4}$$

Kerosene

$$lnK_t = \phi_0 + \phi_1 lnPK_t + \phi_2 lnPLPG_t + \phi_3 lnY_t + \phi_5 lnU_t + \upsilon_t \tag{1.5}$$

Solid biomass

$$lnBE_t = \varphi_0 + \varphi_1 lnPK_t + \varphi_2 lnPLPG_t + \varphi_3 lnY_t + \varphi_4 lnU_t + \nu_t \quad (1.6)$$

Residual Fuel Oil (RFO)

$$lnRFO_t = \lambda_0 + \lambda_1 lnPRFO_t + \lambda_2 lnY_t + \lambda_3 lnU_t + \vartheta_t \quad (1.7)$$

Electricity

$$lnEC_t = \delta_0 + \delta_1 lnY_t + \delta_2 lnU_t + \delta_2 LnES_t + \xi_t \quad (1.8)$$

where $lnGS$ is the log of gasoline consumption; $lnDE$ is the log of diesel consumption; $lnLPG$ is the log of LPG consumption; lnK is the log of kerosene consumption; $lnBE$ is the log of biomass energy consumption; $lnRFO$ is the log of RFO consumption; $lnEC$ is the log of electricity consumption. Also; $lnPS$, $lnPD$, $lnPLPG$, $lnPK$, $lnPRFO$, lnY, lnU and $lnES$ represent respectively the logs of: real price of gasoline, real price of diesel, real price of LPG, real price of kerosene, real price of RFO, income, urbanization (as a proxy for demographic shift) and economic structure. The parameters $(\alpha_i, \beta_i, \theta_i, \phi_i, \varphi_i, \lambda_i, \delta_i)$ measures the demand elasticities whiles the error terms are captured by $(\varepsilon_t, \eta_t, \zeta_t, \upsilon_t, \nu_t, \vartheta_t, \xi_t)$.

A priori, we expect own price elasticities to be negative in line with demand theory which predicts reduced consumption in the face of rising commodity prices. Cross-price elasticities are however expected to be positive since most energy products are substitutes. Income elasticities are expected to be positive, implying that rising income increases demand for consumption goods including energy services. Urbanization is also expected to have a positive elasticity for most fuel types such as gasoline, LPG, electricity and RFO but negative for kerosene and biomass. This is because urban drift is expected to induce consumption substitutability from traditional and less efficient household fuels such as biomass and kerosene towards modern fuels such as LPG and electricity. Accessibility of these fuels in the urban centers is a key factor. Economic structure proxied by the share of industrial value added to service sector value added as used in equation (1.8) is used to capture the effects of the structural changes in the economy on electricity consumption. Given the fact that the industrial sector is a major consumer of electricity, we expect a priori that a rise in the ratio will exert positive impact on electricity consumption. The descriptive statistics of all variables are presented in Table 1.6 (Appendix A).

This study uses annual time series data obtained from the International Energy Agency, Energy Commission-Ghana, National Petroleum Authority, World Development Indicators (WDI), UNCTADSTAT and International Financial Statistics of the IMF. Due to data constraints, demand models for gasoline, kerosene and biomass energy were estimated using data from 1979-2012; diesel, LPG and RFO over the period 1979-2010; and electricity over the period 1979-2011. Also, consistent data on biomass and electricity prices were unavailable over the sample periods hence their omission from their respective estimated models. Nominal prices were also deflated to obtain real prices using the consumer price index.

4.2. Econometric Methodology

The econometric strategy for this study is essentially composed of three steps: First, we examine unit root properties of the series and proceed to test for the presence of cointegration relationship in the models outlined in equations 1.2-1.8. In the second step, we proceed to estimate the long run energy demand elasticities using the ARDL cointegration technique. As a final step, we examine the associated short run demand elasticities using the partial adjustment model (PAM).

ARDL approach

The ARDL bounds test cointegration approach developed by Pesaran and Shin (1999) and further extended by Pesaran *et al*., (2001) is among the well-known cointegration procedures. The bounds test approach, involves estimating the following unrestricted error correction model estimated via ordinary least squares method.

$$\Delta lnE_t = \alpha_0 + \sum_{i=1}^{p} \lambda_{1i} \Delta lnE_{t-i} + \sum_{i=0}^{q} \lambda_{2i} \Delta lnX_{t-i} + \varphi_1 lnE_{t-i} + \varphi_2 lnX_{t-i} + \varepsilon_t \qquad (1.9)$$

where the parameters, α_0 is the drift component; t represents time (years), ε is the white noise error term; Δ denotes the difference operator; λ_{mi} for m=1, 2 …4, represent the short run dynamics in the model whilst the long run relationships are given by φ_i . E_t and X_t denote respectively a vector of energy types and their associated demand shifters.

Determining the long run relationship between E_t and X_t via the bounds test approach requires estimating equation (1.9) and restricting the parameters of the lag level (long run) variables to zero. Thus, we test the null hypothesis of no-cointegration ($H_0 : \varphi_1 = \varphi_2 = 0$) against the alternative hypothesis of cointegration

$\left(H_1 : \varphi_1 \neq \varphi_2 \neq 0\right)$ using the F-test. The computed F-statistic is then compared to the Pesaran *et al*., (2001) two asymptotic critical value bounds to determine the existence of cointegration or otherwise. The conclusion of cointegration is derived if the computed F-statistic exceed the upper bound and vice versa. In the event where F-statistics lies between lower and upper critical bounds, the decision remains inconclusive and will require further test to ascertain the true relationship between the variables.

Partial Adjustment Model (PAM)

To estimate the short run response to changes in exogenous factors in the short run, we use the PAM which allows for inertia in the reaction of energy users to these exogenous shocks.

To begin with, let us assume that E_t is the actual observed level of energy consumed while LPG_t^* is the unobserved desired (equilibrium) level of LPG consumption. At equilibrium, the energy demand model can be represented as:

$$lnE_t^* = \varphi_0 + \beta_i lnX_t + \mu_t \tag{1.10}$$

However, the actual level of energy consumption/demand takes into account the inability of economic agents to adjust instantaneously to the desired equilibrium levels following an exogenous shock. For example, following an unexpected energy price shock, it may take some time before consumers can alter their consumption patterns in response to the price change. In other words, the response of economic agents to exogenous shocks is gradual rather than instantaneous. Therefore the PAM assumes that the change in the observed value of the dependent variable (E_t)is directly proportional to the adjustment between the desired value and the actual value at time $t-1$. Thus, the adjustment process is modelled to take the following form:

$$lnE_t - lnE_{t-1} = \tau(lnE_t^* - lnE_{t-1}) \tag{1.11}$$

where τ reflects the speed of adjustment to equilibrium. Now substituting equation (1.10) into (1.11) and rearranging we obtain

$$lnE_t = \tau\varphi_0 + \tau\beta_i lnX_t + \left(1-\tau\right) lnE_{t-1} + \tau\mu_t \tag{1.12}$$

where by $\tau\beta_i$ measures the short run elasticities. Under the assumption of serially uncorrelated residuals $\tau\mu_t$, estimating adjustment model (1.12) via ordinary least square approach produces consistent estimates. As a result, we estimate the PAM using robust standard errors to correct for any potential serial correlation.

5. Empirical Results

We present the empirical results in this section. Prior to estimating the long and short run elasticities of the different energy demand determinants, we first examine the unit root properties of the series and test for cointegration in the next step. In the final step, we estimate the energy demand models with a discussion of the results.

Unit root and Cointegration results

Establishing the long run relationship between energy consumption and its drivers requires investigating the unit root properties of the variables. Table 1.2 presents the results of the unit root test using the Augmented Dickey Fuller (ADF) and/or the Dickey Fuller-Generalized least square (DF-GLS) test(s). Results indicate that the series used in this study are either integrated of order one [*I(1)*] or zero [*I(0)*].

Table 1.2: Unit Root Test: ADF and DF-GLS

Variables	Levels	First difference	Order of integration
LnDE	-2.575326	-5.417629***	I(1)
LnEC	-2.564648	-4.289797***	I(1)
LnES	-0.609529	-4.640873***	I(1)
LnK	-4.310815***	-4.733759***	I(0)
LnLPG	-3.361511***	-6.090037***	I(0)
LnPDE	-4.944385***	-7.904521**	I(0)
LnPGS	-3.405461**	-4.781018***	I(0)
LnPK	-4.732180***	-6.075087***	I(0)
LnPLPG	-9.851233***	-7.239645***	I(0)
LnPRFO	-5.811157***	-3.917668**	I(0)
LnRFO	-3.156023***	-9.970373***	I(0)
LnU	1.104019	-4.116035**	I(1)
LnY	-2.265812	-5.480808***	I(1)
LnBE[a]	-1.531815	-3.228868**	I(1)
LnGS[a]	-2.054251	-3.278759**	I(1)

NB: a = model based on DF-GLS unit root test. All other variables are based on ADF unit root test. Models were estimated with trend and intercept. *** indicates 1% significance level ; ** indicates 5% significance level ; * indicates 10% significance level.

Given the results of the unit root test, indicating a mixed order of integration of the variables, we proceed to test for the long run (cointegration) relationship between the various disaggregated energy demand and its long run forcing variables using the ARDL bounds test approach. Results of the bounds test (see Table 1.3), confirm the presence of long run relationship in the energy demand equations outlined in equations (1.2)-(1.8), at the 5% significance level. This conclusion of cointegration in the models estimated is based on the fact that the estimated F-statistic from the bounds test model exceed their respective upper critical bounds.

Table 1.3: ARDL Bounds Cointegration Test

Model	F-Stat	Critical values			
		95% bound		90% bound	
		I(0)	*I(1)*	*I(0)*	*I(1)*
$F_{gs(gs\mid pgs,pde,plpg,y,u)}$	4.25**	3.09	4.57	2.55	3.84
$F_{de(de\mid pgs,pde,plpg,y,u)}$	7.95**	3.38	4.76	2.76	3.95
$F_{lpg(gs\mid pgs,pde,plpg,y,u)}$	5.10**	3.30	4.69	2.73	3.92
$F_{ke(ke\mid pk,plpg,y,u)}$	8.20**	3.38	5.32	3.20	4.42
$F_{be(be\mid pk,plpg,y,u)}$	29.25**	3.77	5.13	3.09	4.23
$F_{rfo(ke\mid prfo,y,u)}$	8.66**	3.38	4.78	2.77	3.97
$F_{ec(ec\mid es,y,u)}$	14.12**	4.65	5.89	3.85	4.96

** Rejection of null hypothesis of no cointegration at the 5% significance level. The critical value bounds are computed by stochastic simulations using 20000 replications. All variables are in logs.

Long Run Energy Demand Elasticities

Following the establishment of cointegration relationship between the various demand dissagregates and their determinants, we proceed to estimate the associated long run elasticities for the various disaggregated energy types, results of which are shown in Table 1.4.

Gasoline demand

Results of the gasoline demand model reveal that all the variables are significant with their expected signs except for the price of diesel. According to the results, own price elasticity for gasoline is estimated to be 0.547 and significantly negative as well. This implies that for every 1% increase in the price of gasoline, demand for the product will fall by 0.55% in the long run: hence an "ordinary good". This result compares well with findings in the empirical literature on gasoline demand (see: Polemis, 2006; Alves and Bueno 2003; Belhaj 2002; Ramanathan, 1999; Eltony, 1996; Eltony and Al-Mutairi 1995; Samini 1995, Bentzen , 1994). For instance, Akinboade *et al.*, (2008) and Iwayemi *et al.*, (2010) finds own price elasticity of gasoline to be -0.19 and -0.055 in South Africa and Nigeria, respectively. Due to the degree of substitutability among energy fuels (inter-fuel substitution), we also estimate the cross price elasticity for diesel and LPG. The choice of the prices of diesel and LPG in the model is informed by the fact that these fuels are the main energy types in the transport sector. Over the past two decades, it has been observed that vehicle owners (especially commercial operators) have made provision for use of LPG in their gasoline or diesel driven vehicles, thereby enabling them to switch between these fuels in response to exogenous shocks in price and fuel availability. This trend is confirmed by our results which show LPG instead of diesel as the main fuel substitute for gasoline with a positive and significant cross-price elasticity of 0.12. A positive cross-price elasticity implies that demand for gasoline increases with increases in price of LPG and vice versa. Cross-price elasticity for diesel is however, statistically insignificant thereby suggesting an insignificant degree of inter-fuel substitution between gasoline and diesel. It must be emphasized that the estimates suggest gasoline demand are price inelastic. In other words, changes in price gasoline and/or its substitutes results in a less than proportionate change in gasoline consumption.

Table 1.4: Long Run Elasticities

Regressors	Dependent Variable						
	Gasoline	Diesel	LPG	Kerosene	Biomass	RFO	Electricity
Price of Gasoline	-0.547 (-2.682)**	-0.782 (-4.496)***	0.241 (1.999)*				
Price of Diesel	-0.048 (0.893)	0.324 (1.446)	0.127 (3.409)**				
Price of LPG	0.120 (2.333)**	0.404 (3.802)***	-0.264 (-2.531)**	0.117 (1.932)*	-0.023 (1.044)		
Price of Kerosene				-0.483 (-5.796)***	-0.072 (-0.829)		
Price of RFO						-0.778 (-4.582)**	
Income	1.316 (2.156)**	3.562 (8.297)**	2.769 (1.392)	-3.633 (-6.543)***	-0.590 (-1.889)*	-1.738 (-1.480)**	2.710 (2.951)***
Urbanization	0.705 (1.982)*		21.971 (2.291)*	0.246 (0.771)	0.616 (4.170)***	1.782 (3.917)**	21.737 (8.032)***
Economic Structure							0.590 (1.936)*
Intercept	-11.827 (-4.405)***	-14.641 (-5.728)**	340.21 (-2.189)*	27.612 (8.753)***	5.995 (2.249)**	-15.326 (-3.720)**	335.215 (-8.156)***
Trend			-0.886 (-1.994)*				-0.980 (-8.358)***
Data	1979-2012	1979-2010	1979-2010	1979-2012	1979-2012	1979-2010	1979-2011

NB: All variables are in logs. *** indicates 1% significance level; ** indicates 5% significance level ; * indicates 10% significance level. RFO (refined fuel oil); LPG (Liquefied petroleum gas).

Further, results from the gasoline model reveals that the effect of income on gasoline demand is positive, elastic and significant at 5%. It shows that a 1% increase in income level result in a 1.3% increase in demand for gasoline. Similar results were obtained by Ramanathan (1999), Akinboade *et al.*, (2008), and Huntington (2010) with income elasticities of 2.682, 0.36 and 0.135 respectively. It has been widely acknowledged that the rising urban sprawl in developing and emerging economies is a significant driver of energy demand (Mensah, 2014; Adom *et al.*, 2012). Results from the gasoline demand model confirm this assertion, as the elasticity of urbanization is positive and significant, albeit being inelastic. The result suggests that a 1% increase in urban growth exerts a 0.7% increase in gasoline demand in Ghana. Thus the rising urban population in Ghana averaging 4.2% per annum between 1990 and 2012 (WDI, 2013) is expected to exert a significant surge in the gasoline demand as the urban centers accounts for a greater share of vehicular traffic in the country.

Diesel demand

The diesel demand equation shows interesting results: as it shows insignificant own-price elasticity. This suggests that diesel consumers in the long run are non-responsive to price changes. This result is in sharp contrast to theoretical and empirical expectations. For instance, Barla *et al*., (2014) show that the price elasticity of diesel consumption in Canada ranges between -0.43 and -0.42, and statistically significant at 1%. Cross price elasticities however shows contrasting results. Estimates suggest cross price elasticities of diesel demand with respect to price of gasoline and LPG to be -0.782 and 0.404 respectively and significant at 1%. Whereas the cross price elasticity with respect to LPG is positive and consistent with consumer theory indicating the presence of inter-fuel substitution, the elasticity with respect to gasoline predicts otherwise--suggesting the two fuels as complements rather than substitutes. Perhaps evidence of asymmetric complements. The income elasticity of diesel demand was however positive, elastic and significant, suggesting that a 1% increase in income results in 3.562% increase in diesel consumption. Thus the results indicate that the rising trend in diesel consumption is largely attributed to increasing income levels.

LPG demand

In terms of LPG demand, our results show robust elasticities with respect to price of LPG and substitute fuels like gasoline and diesel. As expected, own price elasticity (-0.264) is negative and significant (at 10% significance level) whereas the cross price elasticities with respect to gasoline and diesel are positive and significant as well, estimated to be 0.241 and 0.127, respectively. The implication is that consumers of LPG respond to price increases by switching to alternative fuels such as gasoline and diesel. However, it must be emphasized that this holds in the case of consumers who use LPG as autogas. Estimates from the Energy Commission (2011) indicate that the use of LPG as autogas constitutes 37% of total consumption of LPG in Ghana (Edjekumhene, 2011). Moreso, even in terms of household consumption, there is high degree of inter-fuel substitution between LPG and other biomass based energy types including charcoal, fuelwood, kerosene, etc. which is often due to price shocks and most importantly erratic shortages in the supply of LPG in the Ghanaian market.

Another key factor influencing demand for the product from our results is urbanization. Estimates suggest a very high elasticity of 21.97, which is statistically significant at 10%. This indicates that the emerging demographic transition from the hitherto rural dominated settlements and associated rural economy (i.e. agricultural, crafts, etc) towards urban and peri-urban settlement with an expanding services based sectors of the economy exerts significant influences on LPG demand in the country.

Surprisingly, income effect is found to be insignificant in the LPG model, thereby suggesting that income levels is not a key factor for LPG demand in Ghana. This result however, is in contrast with findings of Mensah (2014) who finds income, price and urbanization as significant factors driving LPG demand in Ghana over the period 1992-2012.

Kerosene

Kerosene use is often associated with lighting and cooking purposes especially in rural settlements with little or no access to modern energy sources such as electricity. Among urban settlements however, kerosene is sometimes used as a reserve fuel often relied upon when access to electricity and LPG is curtailed. Our results confirm the above assertion as income and price effects are negative and significant: estimated to be -3.633 and -0.483 respectively. The (negative) income effect is elastic which suggest that any (slight) increase in income levels results in a significant reduction in kerosene consumption, and vice versa. Price of LPG is also found to be positive (0.117) and significant, thus indicating the presence of some degree of inter-fuel substitution between kerosene and LPG at the household level.

Solid biomass

Biomass used herein refers to energy types such as fuelwood, charcoal, crop residue, etc. mostly derived from forest and savannah vegetation. It constitutes a significant source of energy in Ghana as approximately 89% of households in the country in 2006 depended on biomass as the main cooking energy source (Mensah and Adu, 2013). Our results suggest income and urbanization as the main significant drivers of biomass consumption in Ghana with associated elasticities of -0.59 and 0.616, significant at 10% and 1%, respectively. In line with our a priori expectation, these results suggest that a rise in income is associated with reduced consumption of biomass energy types. In other words, when income levels rise, consumers become sophisticated and develop preference for modern energy sources such as LPG and electricity, hence switching to the latter. On the other hand, the results indicate urban population growth is associated with rising demand for biomass contrary to theoretical expectations. The possible reason behind this relation is due to the fact that the high level of rural urban migration witnessed in the country over the past three (3) decades has resulted in an increase in the number of urban slums, high unemployment and increase in urban poor. Thus many of low income dwellers in the urban centers depend on sources such as charcoal and fuelwood for cooking. Again, the incessant shortages in the supply of LPG and electricity nationwide, has impacted negatively on the transition from biomass energy sources to these fuels despite the increasing rate in urbanization. Cross price elasticities of kerosene and LPG were found to be insignificant, hence not an important factor in biomass consumption in Ghana.

Residual Fuel Oil (RFO)

RFO is mainly used as industrial fuel often for power generation, vessel bunkering and other industrial applications. Our results suggest price, income and urbanization as key determinants. The price effect is shown to be negative, inelastic and significant at 5%, indicating that the price of the commodity is inversely related to its demand. Urbanization on the other hand is observed to exert a positive impact on RFO consumption, with a positive elasticity of 1.782. The income effect was however negative, and estimated to be around -1.738. This implies that rising income levels is associated with reduced consumption of RFO. The reason behind this negative income effect can be attributed to the high amount of pollutant emissions associated with the burning of RFO. Thus in line with the environmental Kuznets hypothesis, a higher level of income will inherently induce a switch away from high polluting energy sources towards cleaner alternatives.

Electricity

Electricity is an important component of the energy mix of every economy, as its use spans from household, services, to the industrial sectors. Results from our model reveal that income, urbanization and structure of the economy are significant factors behind electricity consumption in Ghana, with all drivers having positive elasticities. Overall, urbanization is shown to have the highest impact, with income and economic structure in that order with elasticities of 21.7, 2.7 and 0.59, respectively. The result indicates that the rapid increase in urban agglomeration and associated population is a key factor behind the surge in electricity consumption. This is enforced by the fact that about 55% of the 72% of total population with access to electricity live in urban centers (Barfour, 2013; World Bank, 2014). The per capita consumption in the urban centers is very high relative to rural areas. Again, given our measure of economic structure as the ratio of the value added of industrial sector to value added of the services sector, our results imply that an increase in the industrial output drives up electricity demand. In other words, the industrial requirement of electricity to generate output is a key driving force behind electricity demand in Ghana. Our results confirm the findings of Adom *et al*., (2011) and Adom and Bekoe (2013), Zuresh and Peter (2007), Lin (2007). For instance, Adom *et al*.,

(2011) showed that income and urbanization have positive income effects on electricity demand in Ghana, Zuresh and Peter (2007) also found structural change in the Kazakhstani economy to have a positive income effect on electricity demand, with an elasticity of 0.28.

Short Run Energy Demand Elasticities

In this sub-section, we focus primarily on the demand response to exogenous shocks in the determinants in the short run. This will help us in identifying the immediate response of energy users towards changes in price, income, etc., as well as the rate of convergence of the respective models to long run equilibrium following shocks in the energy sector. These short run elasticities are estimated using the PAM.

Overall, the results of the various disaggregated energy demand models showed that in the short run, demand is mostly responsive to changes in price and income. Specifically, it shows that a 1% increase in income will induce an increase in demand for gasoline and diesel by 0.6% and 1.08% respectively, while reducing consumption of kerosene and biomass by 1.2% and 0.05% respectively in the short run. In terms of price, demand is significantly responsive to short run changes in own price only in the case of gasoline kerosene and RFO. The results show that a 1% increase in price of gasoline, kerosene and RFO will lower consumption by 0.098%, 0.179% and 0.369% respectively. In terms of inter-fuel substitution in the short run, results show that gasoline demand is highly responsive to LPG prices, as a 1% fall in it will induce gasoline demand to increase by 0.044%. Interestingly, LPG demand is not responsive to its own price in the short run, but instead significantly responsive to gasoline prices; showing that a percentage increase in gasoline prices in the short run will induce substitution to autogas thereby increasing LPG consumption by 0.292%. This can be attributed to the fact that LPG in Ghana is highly subsidized hence changes in the price may be minimal. The main aim of LPG subsidy in Ghana over the past two decades is to engender household interest in switching from biomass energy to the more efficient and cleaner fuels-LPG. However, this has resulted in a positive spillover effect to vehicle users who have become "un-intended beneficiaries" as many commercial vehicle owners (especially taxis) have converted from gasoline/diesel use to LPG which is relatively cheaper, as a result of the subsidy. The response of households to increases in LPG prices in the short run is to switch to biomass energy in the short run as evidenced by the positive cross-price elasticity with respect to price of LPG in the biomass energy equation. It shows that a 1% increase in the LPG prices will induce biomass consumption to rise by 0.003% in the short run. The short run LPG demand non-responsiveness to LPG price in Ghana, is not new in the empirical literature as a similar evidence was obtained by Mensah (2014).

Table 1.5: Short Run Elasticities from Partial Adjustment Model

Regressors	Dependent Variable						
	Gasoline	Diesel	LPG	Kerosene	Biomass	RFO	Electricity
Price of Gasoline	-0.098 (-1.97)*	-0.166 (-1.73)*	0.292 [1.80]*				
Price of Diesel	-0.011 (-0.35)	0.019 [0.42]	0.102 [1.37]				
Price of LPG	0.044 (2.44)**	0.012 [0.45]	0.063 [1.15]	0.076 (0.994)	0.003 [2.13]**		
Price of Kerosene				-0.179 (-3.119)***	0.001 [0.88]		
Price of RFO						-0.369 [-2.15]**	
Income	0.616 (3.31)***	1.077 [2.71]**	0.616 [0.68]	-1.232 [-2.159]**	-0.047 [-2.56]**	0.139 [0.10]	0.043 [0.08]
Urbanization	0.519 (3.52)***	0.756 [2.42]**	0.504 [1.49]	0.109 [0.305]	0.048 [1.05]	0.468 [0.70]	0.325 [0.62]
Economic Structure							0.373 [1.09]
Degree of inertia							
Lagged dependent variable	0.295 (1.64)	0.291 [1.38]	0.665 [5.41]***	0.190 [0.889]	0.911 [11.53]***	-0.098 [-0.53]	0.670 [3.03]***
Intercept	-7.66 [-4.55]***	-13.94 [-3.07]***	-11.88 [-1.75]*	9.917 [2.77]***	0.624 [1.95]*	-4.402 [-1.34]	-3.310454 [-0.56]

NB: all variables in logs. *** indicates 1% significance level; ** indicates 5% significance level ; * indicates 10% significance level. RFO (refined fuel oil); LPG (Liquefied petroleum gas).

Further, the results show varying degree of adjustment to long run equilibrium as evidenced by the coefficients of the lagged dependent variables[4] in table 1.5. For instance, the coefficient of the lagged dependent variable in the biomass equation is very high (0.911), implying a high degree of persistence and a lower speed of adjustment-approximately 9%. In other words, there is inertia in the adjustment from short run deviations to long run equilibrium as only 9% of the divergence between the actual consumption and equilibrium levels are corrected each year. On the other hand, the level in inertia in LPG and electricity demand models is also low, with speed of adjustment around 33%.

[4] Note: emphasis is placed on only adjustment coefficient that are statistically significant

6. Conclusion and Implications for Policy

This paper presents a comprehensive analysis of energy demand in Ghana by estimating demand functions for the various energy disaggregates in Ghana, other than focusing on a single energy type as extant in the empirical literature. Specifically, we investigate the long and short run forcing variables that drives demand for energy in Ghana and their accompanying long and short run elasticities using the ARDL and PAM approaches. In all seven (7) energy types are used in this study, viz : gasoline, diesel, LPG, kerosene, biomass, RFO and electricity using time-series data.

Our results show a mix of factors influencing the demand for the various energy types in Ghana. These factors include energy prices, income, urbanization and economic structure. Specifically, we show that income, urbanization and prices of gasoline and LPG are significant factors influencing gasoline consumption in Ghana in the long run. For diesel: income, urbanization, prices of gasoline and LPG are significant long run drivers. On the other hand, income was not found to be an important determinant for LPG demand in the long run, instead, factors such as urbanization and prices of LPG, gasoline and diesel are key. In terms of kerosene demand, the key factors to consider include price of kerosene and income; whereas income and urbanization are the main factors influencing demand for biomass energy in the long run. Further, our results indicate that price of RFO, income and urbanization are significant long run determinants of RFO demand in Ghana. Finally, income, urbanization and economic structure are the main long run determinants of electricity consumption Ghana. The results unequivocally indicate rising income and urbanization behind Ghana's lower middle class status are also significant drivers of energy demand. Therefore it is important for policy makers to ensure the provision of stable, reliable and efficient supply of energy services to meet the surging demand.

An interesting observation from the results of the various disaggregates show high degree of inter-fuel substitution in energy demand in Ghana. This is evidenced by the significance of the cross-price elasticities in the models estimated. The evidence from this paper confirms the assertion that there is a high degree of substitutability from gasoline, diesel and kerosene towards LPG consumption in Ghana. This is due to the increasing conversion of vehicles especially taxis, from conventional fuels such as gasoline and diesel to autogas (LPG) largely as a result of the subsidies on LPG in Ghana. The policy implications stemming from this result is that, there is evidence of high amount of "*un-intended beneficiaries*" in the National LPG campaign program which sought to among others incentivize households in Ghana to switch from biomass to LPG as main cooking fuel, using subsidies as instruments. In other words, the increasing rate of autogas use in Ghana is largely motivated by efficiency and economic benefits relative to the conventional fuels like gasoline and diesel (Biscoff *et al*., 2012) other than environmental incentives to reduce the vehicular emissions. This calls for a careful reconsideration of the current policy subsidizing LPG in the country, as 37% of the subsidized product is consumed by economic agents (vehicle operators) other than the intended beneficiaries (households).

As a way forward, given the fact that household consumption of LPG is still low at approximately 9% (Mensah and Adu, 2013), incentives such as subsidy, removing supply constraints that often culminated in the erratic shortages in the product is essential to incentivize household demand. However, measures must be implemented to ensure that vehicle owners are excluded from enjoying the subsidy. An alternative means to avoid the *unintended beneficiary dilemma* will be to redirect the subsidy from the product to LPG related end use equipment, such cylinders, tubes, etc. The success of such measures requires a policy on autogas use in the country. Such a policy must seek to officially recognize and institutionalize autogas as a key source of energy for motor vehicles. This will ensure that 1). Appropriate institutions are set up to regulate the conversion from conventional fuel use to autogas by vehicles; 2). Maintain appropriate standards in conversion kits and offer relevant training so as to avoid unnecessary accidents/risk attributed to substandard conversions, as most of the recorded LPG related fires in the country have been attributed to the use of inappropriate autogas conversion equipment and fabricated spare parts.

Also, knowledge of the presence of inter-fuel substitution owing to price changes has implications for energy pricing in the country. In order words, since energy consumers are not only responsive to price of energy type but also alternative fuels, energy pricing can be used as an instrument to promote energy switching from inefficient and environmentally polluting sources to cleaner fuels. Again, our results suggest that price elasticities are inelastic, implying that the response of consumers to price changes is minimal. However, given the presence of a high degree of substitutability and the overall welfare implications of higher energy prices, fuel price increases must be in moderation with careful consideration to all possible spillover effects.

Overall, energy access in Ghana is still below desired levels. Also, emphasis of policymakers should not only be with regard to expanding access to modern energy sources but also ensuring sustainable and reliable supply of energy services thereof. As noted by Serwaa Mensah *et al*., (2014), the establishment of an independent power trading companies to break the monopoly power of the existing state owned firms especially in the electricity subsector, by facilitating market entry of independent power producers, however small they may be. This will enhance competition and ensure high efficiency standards than the status quo. Also, "business models such as SME based mini-grids and off-grids with respect to electricity and cylinder recirculation with centralized filling-depots" (Serwaa Mensah *et al*. 2014), can be adopted to complement the current utility-based grid supply and fuel station system, so as to enhance efficient supply of energy services in the country to further propel the engines of growth and development.

Furthermore, completion of the gas processing plant to harness the vast gas potentials of the country's offshore oil fields should be of utmost concern to policymakers since the supply of locally processed gas will boost electricity generation to fill the current shortfall and hopefully avert the perennial energy crises in the country. Likewise, the establishment of gas processing plant to process LPG in Ghana and the revival of the country's only oil refinery (Tema oil refinery) will enhance efficiency in the supply of LPG among other refined petroleum products, as the status quo where almost all refined petroleum products are imported thereby exposing the energy sector to external shocks such as currency depreciation and crude oil price volatility.

As a long term measure towards sustainable supply of energy services, reduce transportation cost of energy especially LPG, and liquid based energy types, government must make investments into building pipeline infrastructure to cart energy services from production centers to end users. Whereas, pipeline construction is known to require high initial capital investments, maintenance and minimum scale of movements (Matthews, 2014), it has proven to be the most cost effective means of fuel transport in the long term. Alternative means such as rail transport can also be explored. On the demand side, in the wake of current demand shortfalls, intensification of energy conservation programs are necessary. Example of such programs include the refrigerating efficiency and market transformation project which is aimed at replacing old and inefficient refrigerators with energy efficient ones; import ban on second-hand refrigerators; lighting retrofit project- free distribution of over 6 million fluorescent filament lamps by the Energy Commission, etc. These programs among others seek to ensure efficiency in energy use and minimize losses especially in the wake of the current energy crises.

In the next chapter, we focus on economic welfare analysis of households in the wake of energy crisis particularly electricity to ascertain whether it is worth attracting the private sector into the sector.

APPENDIX A

Table 1.6: Descriptive Statistics

Variable*	Observations	Mean	Std. Dev.	Minimum	Maximum
year	43	N/A	N/A	1971	2013
bf	43	122726.1	34001.46	67400	173008.8
lpg	43	51.49535	71.48649	3	268.5
gs	43	405.7744	219.052	172	1080.6
k	43	92.86977	30.12833	27.8	141
de	43	562.1302	414.752	193	1722.6
rfo	43	56.62326	25.57921	9	107
pg	35	3696.495	5598.189	1.65	20499.67
pk	35	3041.203	4198.146	0.77	13260
pd	35	3331.946	5532.893	1.21	20754.13
prf	35	1834.15	2868.954	0.009226	10238.28
plpg	35	3002.895	4657.258	0.18	20017.27
u	42	6499887	3282108	2576656	1.33e+07
y	42	447.6875	89.80501	320.7723	724.3497
es	42	0.8137587	0.4326984	0.4230507	1.661383
ec	41	4.91e+09	1.59e+09	1.15e+09	8.53e+09

**Description, abbreviation and a priori signs of variables are as used in section 4.*

CHAPTER TWO

Demand for Electricity in Ghana: Validity Tests for Contingent Valuation Responses.

1. Introduction

Power outages or blackouts in developing countries are still a big problem with economic and social consequences. Particularly in Africa, the demand for electricity over the last three decades has been rising significantly resulting in over 620 million people lacking access to electricity (International Energy Agency [IEA], 2015). World Bank (2013) reports that twenty-five African countries are still facing electricity crises. Evidence of some of electricity crisis in most recent times including but is not limited to Ghana (Mensah et al., 2016), Nigeria (Aliyu et al., 2013), Kenya (Mukulo, 2014), Uganda (Buchholz and Da Silva, 2010; Gore, 2009), and South Africa (Inglesi, 2010; Inglesi-Lotz, 2011). In pursuance of the target of the Sustainable Energy for All (SE4All) initiative by the United Nations, it is projected that current efforts in tackling electricity problems are set to fall short vis a vis meeting the goal of achieving universal access by 2030. It follows that by this date, about 635 million people in Sub-Saharan Africa (SSA) will remain without electricity (IEA, 2015).

Lack of electricity implies that household's income levels can significantly deteriorate and aggravate the general welfare conditions of countries (see Barnes et al., 2011). Scientific evidence shows that the perceived cost of blackouts is about 3-10 percent of household income with severe consequences for developing countries (e.g. Westley, 1984; Gellerson, 1980; Munasinghe, 1979). In more recent evidence, Praktiknjo (2014) reports that even for a developed country like Germany, the perceived cost per household of a 1-hour supply interruption is equivalent to €14.88 [WTP] or €33.68 [WTA].

The acute shortage of electricity in Ghana can be attributed to both demand and supply causal factors. Institute of Statistical, Social and Economic Research (ISSER, 2005[5]) reports that the annual rise in demand for electricity in Ghana is 10-15 percent. Fifty percent of the electricity demand is by households. This is because electricity is now very central to social events (parties, marriages, funerals, music, movies, sports, education etc.), economic activities (hairdressing, tailoring, sachet-water trade, corn milling, barbering etc.), spiritual activities (individual devotions and

[5] To the best of the author's knowledge this is still considered as the most recent report.

meditations, church etc.) and personal uses (lighting, ventilation: i.e. to control temperature with fan or air conditioner, replenish oxygen, or remove moisture, odours, smoke, heat, dust, airborne bacteria and carbon dioxide).

Since the early 1960's, Akosombo hydroelectric plant has been the major source of Ghana's energy supply. After the Akosombo hydro power project, one major electrification project in Ghana has been the National Electrification Scheme in 1989. Although this was short-lived it saw the expansion in transmission and distribution of electricity supply in Ghana. There is no doubt that the supply of electricity in Ghana has been quite a challenge. The Ghana Grid Company Limited's (GRIDCo) Wholesale Power Reliability Assessment Report (2010) also acknowledges that the current plight in electricity shortages has both demand and supply side sources. The former includes rise in economic growth, urbanization, and industrial activity while the latter includes chronic underinvestment in generation and transmission infrastructure. Since 2012, severe erratic electricity supply in Ghana has affected both households and firms. According to the World Bank Enterprise database (2013)[6], the average number of electrical outages to firms per month in Ghana is 8.4 compared to 8.3 in SSA. In addition, the losses attributed to electrical outages, as a percentage of total annual sales of firms in Ghana is 15.8 compared to 8.6 in SSA. The percentage number of firms owning or sharing a generator is 52.1 compared to 49.8 in SSA with its associated huge cost implication to firms. Indeed, contrasting the National Energy Statistics (2015) for the year 2014 and 2013, we compute from Table 2.1 and report that the total electricity generated per capita fell by 5.1kWh/capita while total electricity consumed per capita increased by 11kWh/capita. Both demand and supply sides suggest a deficit which gives a cause for concern hence the need to investigate demand side remedies in this study.

Ironically, Ghana is naturally endowed with adequate resources that can be harnessed to solve this problem. For example, Ghana has the largest (8,502 sq. kilo.) man-made lake by surface area in the world with a total capacity of 148 km^3. Thus, making electricity from hydrological stations relatively cheaper per kWh. However, because hydrological electricity generation is highly dependent on water availability, the impact of climate change on water resources has severely affected this source of electricity generation. This has shifted the focus of the country to other sources such as thermal and solar instead of hydroelectricity. Ghana has relied on thermal power plants in recent times as a solution to intermittent electricity problems. However, thermal power generation has not been too impressive as its contribution to the total

[6] A survey of business owners and top managers in 720 firms were interviewed from December 2012 through July 2014.

generation mix is not rising steadily as expected, hence Ghana's current electricity crisis. For instance, in 2006 to 2007, power generation from thermal sources rose by 15.6% and dropped significantly afterwards by 34.5% from 2007-2008, and dropped again albeit marginally by 1.4% from 2013- 2014.[7] A possible explanation for this trend is the importance that the Government of Ghana (GoG) attaches to imported natural gas and light crude oil. The Government of Ghana together with other neighbouring West African governments under the Economic Community of West African States (ECOWAS) in 1982, proposed a collaborative approach (amongst Ghana, Benin, Togo and Nigeria) for solving their common energy problems. A viability assessment study was confirmed by the World Bank in 1992, which gave birth to the West African Gas Pipeline (WAGP) and was completed in 2006. However, Mensah et al. (2016) have observed that the overdependence on Nigeria for the supply of natural gas is still a major problem confronting the sector. This is because any failure to comply with agreements due to factors such as unpaid debts, change in political leadership and policies etc. has huge implications to the entire energy sector. Ad-hoc measures such as load-shedding have been adopted by the GoG, yet its associated cost to businesses is enormous. Edjekumhene and Cobson-Cobbold (2011), argues that frequent outages leading to load-shedding are estimated to average ten hours per month, costing the Association of Ghana industries several millions of dollars.

Other possible sources of energy production which have low fuel cost but are associated with high construction and maintenance costs may include nuclear and coal fuel plants. However, the GoG is currently focusing its attention on more sustainable and accessible sources of energy such as solar and windmill. They present lower level of investment and installation costs than other electricity sources, their environmental impact is minimal and they may represent a short tem solution for immediate welfare benefits.

This chapter principally undertakes a cost & benefit analysis of electricity in a developing country (Ghana). This is achieved by first estimating and testing the reliability of our WTP estimates by discussing the WTP and WTA divergence/convergence test. Empirically, this test is achieved using both parametric and non-parametric approaches. We further discuss other reliability issues such as hypothetical bias and scope sensitivity that relate to our estimates.

This chapter contributes to an assessment of the welfare impact of electricity outages and provides an estimate of the household willingness to pay (WTP) for a 24hour service of electricity supply in Ghana. The objectives of this paper are twofold. From

[7] Author computed the changes with data from Energy Commission of Ghana (2015).

an applied point of view the results provide useful information to policy-makers who want to define the optimal level of incentives necessary to promote renewable resources or to set the appropriate level of tariffs for the electricity sector (PSEC/GRIDCo, 2010)[8]. From a methodological point of view the paper tests the reliability of our WTP estimates with a set of tests. In conclusion the paper aims at answering the following questions: 1. Are households willing to pay for an improvement in their utility vis a vis electricity supply? 2. What is the maximum WTP for 24hours electricity service? 3. Is the amount estimated reliable? 4. Is the net benefit of this project positive to attract the private sector?

The rest of the paper is organized as follows. Section 2 provides a brief overview of Ghana's Electricity Sector. Section 3 discusses the empirical literature review on electricity demand. Section 4 explains the survey method used in data collection and other methodological issues. Section 5 discusses the results from our WTP and WTA models. Section 6 presents the conclusions, and policy recommendations.

2. Brief Overview of Ghana's Electricity Sector

Figure 2.1 shows the structure of the energy sector in Ghana. The president of the Republic of Ghana appoints a minister to be responsible for the Ministry of Energy and Petroleum (MoEP). The ministry is charged with the primary responsibility of designing appropriate policies to create an enabling environment for efficient operation and growth of the sector.

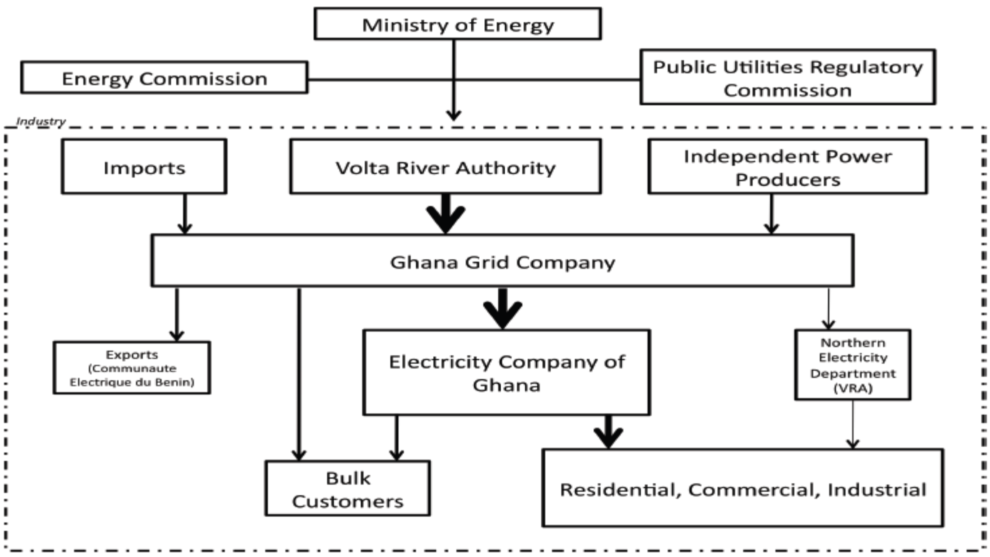

Fig. 2.1: Structure of Ghana's Energy Sector (Adapted from IAEA, 2013; Original Source: Power Sector Reform and Regulation in Africa)

[8] This is a joint report produced by Power Systems Energy Consult (PSEC) in collaboration with GRIDCo in 2010.

Volta River Authority (VRA) is known to be a major power generation company, solely owned by the Government of Ghana. In the most recent structure, VRA makes the first arm of electricity generation, transmission and distribution chain in Ghana. Its generation combines hydro, thermal and solar plants to generate electricity for supply to Electricity Company of Ghana (ECG) and export markets through GRIDCo's transmission system. The ECG is responsible for distribution hence deals directly with customers than any other in the chain.

The Electricity Department in 1947 became the Electricity Division in 1962, and the Electricity Corporation of Ghana in 1967. This was the only body solely responsible for distributing and supplying electricity power in Ghana. In 1987, the Northern Electricity Department (NED) was also established to be responsible for the distribution and management of electricity in four main regions (namely: Northern, Upper West, Upper East and Brong-Ahafo) out of a total number of ten. The NED is a subsidiary of the VRA. In 1997, the Electricity Corporation (a state-owned entity) was incorporated and became the ECG with responsibility over the other six regions (namely: Greater Accra, Ashanti, Central, Eastern, Volta and Western) of the country.

In West Africa, Nigeria is the largest electricity market in generation capacity and consumption, followed by Ghana and the Côte d'Ivoire (ISSER, 2005). This suggests how relevant the electricity market for Ghana is to the national economy and the sub-region. There are currently nine main operating generation facilities in Ghana. These can be categorised mainly under hydroelectric and thermal sources, with a total installed generation capacity of about 2,846.5MW. The VRA operates the Akosombo hydroelectric plant which is the largest (75%) generation facility in Ghana.

Table 2.1: Electricity Generation Sources and Population Trend in Ghana.

Energy Source	2012	2013	2014
Hydroelectric Power Plant	67.12%	63.97%	64.70%
Thermal Power Plant	32.88%	36.01%	35.27%
VRA Renewable (Solar) Plant	-	0.02%	0.03%
Total	*100%*	*100%*	*100%*
Total Electricity Generated/capita (kWh/capita)	*464.2*	*485.7*	*480.1*
Total Electricity Consumed/capita (kWh/capita)	*357.5*	*399.4*	*410.1*
Population, Total	25,544,565	26,164,432	26,786,598

*Author's construct with data from Energy Commission (2015) & WDI (2015).

Table 2.1 shows that, the proportion of electricity generation mix by the main energy-sources since 2012 has not been rising impressively to match the growing population. This is more pronounced in the southern part of the country where the population growth rate is approximately 3.1%[9] and demand for electricity is very high. Although, there is evidence of a slight growth in solar energy, its impacts are still negligible. This minimal effect is due to the recent approval of the Renewable Energy Law (Act 832) which has made possible for around fifteen companies to generate electricity from solar energy. Further, in 2015, the GoG supplied 51,000 solar lanterns at subsidised rate to off-grid communities, and under the National Solar Rooftop Programme (NSRP) of the Renewable Energy Development Programme (REDP), 20,000 buildings are expected to have rooftop solar systems by the end of 2016 to speed-up electricity supply in Ghana (GoG, 2015). The forecast is that solar energy production might grow considerably and support the country to satisfy the pressing demand for electricity.

Considering the 2014 energy balance[10] reported by Energy Commission (2015) it is clear that there is a deficit of 395,420 MWh (34 ktoe) in electricity which implies disruption in the energy services to households and firms. One strategy in dealing with such deficits is trying to harness and promote the indigenous production of solar energy. In the past the GoG launched promotional and educational campaigns for locals and remote communities. In 1990 the National Liquefied Petroleum Gas (LPG) programme guided the first promotional campaign and by 2004, the level of energy consumption increased by over 50,000 tonnes (about 357,142,857 barrel of oil [boe] equivalent) per annum, equivalent to about tenfold over the baseline consumption levels. In 2005, the GoG launched the Unified Petroleum Fund (UPPF) which essentially covered the cost of transporting LPG to rural areas so as to increase supply to meet the increased demand. In 2006, the West African Gas Pipeline (WAGP)[11] project, of which Ghana is a member, was completed to expand supply of natural gas[12] for electricity generation. Although some efforts have been made towards RES; its impacts are still minimal. The pressures from firms and households on government are constantly increasing making the government allocate approximately 11% of her budget to meet increasing demand in the energy sector in 2016 (GoG, 2015). However, it is worth mentioning that a significant fraction of this funding is expected to come from donors and as in all such cases, such funds are not absolutely guaranteed (funds are largely characterised by conditionalities which results in highly variable amounts and timing). Fritsch & Poudineh (2015) report that the GoG has committed to subsidizing aspects of electricity supply in Ghana for

[9] Ghana Statistical Service (2012), 2010 Population and Housing Census
[10] Energy Balance here refers to the difference between the Total Energy Supply and Final Energy Consumption.
[11] Four Countries namely Ghana, Bénin, Nigeria Togo signed an agreement for Nigeria to transport Natural Gas to the other three for power plants companies and heat-using industries.
[12] This is considered as being relatively less expensive and climate/environmentally-friendly (cleanest fossil fuel)

about US$1/Month for lifeline consumers. However, this has not been forthcoming due to limited government resources and overdependence on donors for budget support. To this, at the end of 2003, the total subsidy owned by the government to distribution utilities ranged from US$400,000-1,400,000 (ISSER, 2005).

Given this background, it is obvious that the ECG finds it a herculean task in trying to meet the demands of consumers. The Electricity Company of Ghana (ECG, 2013) has alluded to the fact that they have incurred the wrath of their customers in the form of demonstrations due to poor services. This has become so worrisome and prevalent to the extent that a local description of it can easily be googled and found in wikipedea as *dumsor*[13]. A major reason for the persistent, and unpredictable incidence of electric power outages according to ECG (2013) and ISSER (2005) is attributed mainly to low revenue-yielding customers who enjoy subsidies from government's subsidised tariff policy and therefore pay amounts that are less than the average production cost, making recapitalisation impossible. This has been a problem since its inception because of the perception that electricity supply is government's responsibility coupled with government's inability to make regular and timely remittances to the relevant utility companies.

In most developing countries such as Ghana, all the economic infrastructures are perceived as social services and this affects the pricing structure and suppliers' capacity to maintain and sufficiently provide (see Adenikinju, 2005). In addition, some common challenges which have contributed to the poor supply of electricity can be summarised under four main headings and these are generation, transmission, distribution, and administration/management problems. In a broader sense, key ones are outlined as follows: natural causes (low rainfall), shortage of imported fuels for thermal plant, obsolete infrastructure, industrial customers subsidizing residential customers, customers patronising illegal connections, irregular and/or non-payment of bills, poor maintenance culture, technical hitches etc. These problems have made the sector relatively ineffective and inefficient.

In recent times, several efforts at managing consumer's expectations and improving the sector have been observed. The ECG has been publishing a load shedding guide to help customers plan their electricity usage. However, the ECG has not been consistent in sticking to electricity rationing schedules which has attracted lots of

[13] **Dumsor** pronounced "doom-sore" or "**dum sɔ"** ("off and on") is a popular Ghanaian term used to describe persistent, irregular and unpredictable electric power outages.(See https://en.Wikipedia.org/wiki/ Dumsor).

complaints from customers. In addition, one of the commitments of ECG is to deal with distributional losses to boost supply. Against this background, an active taskforce which is made up of the Police, Fire Service and ECG officials has been commissioned to randomly visit customers to identify illegal connections and, those who have tempered with meters among others.

In August 2015, ECG through her taskforce recovered GHS1,612,560.37 (USD$514,406.76) [14] from distributional losses connections. Also, the issue of privatization has been seriously considered following the success story of the two privately owned generation firms. These firms include Sunon Asogoli power plant and CENIT Energy's plant which generate 200MW and 126MW respectively. They are considered the most reliable plants in the country today. This buttresses the call by the World Bank for a significant role by the private sector in the distribution of electricity in Ghana. Guided by the World Bank's proposal, a decision has been reached by the GoG regarding a concession agreement. By this agreement, total responsibility for operating and maintaining ECG and NEDCo assets will be entrusted into the care of the concessionaire for a period of 20-30 years, while the state continues to own the assets. This is generally believed to reduce political interference and adopt innovative solutions to the recurring crisis as well as promoting efficient revenue enhancement investments. By way of contrast, an opposing school of thought argues that the private sector is not needed for the sector to perform well, and that the government should be up and doing for the sector to get back on its feet. In both cases, more information about consumers' preference for electricity services is very necessary.

[14] GHS1 = USD 0. 319 as at 15/10/2014

3. Methodology and Empirical Literature

A myriad of methods exist in the valuation literature which are used to estimate the economic value of regular electricity supply (WTP) or infer welfare losses from irregular electricity supply (WTA). This study uses the well-known and established Contingent Valuation Method [CVM] (see Mitchel and Carson, 1989; Arrow et al., 1993) to capture WTP/WTA for electricity in Ghana. This method is considered to be consistent with consumer demand theory and captures both use and non-use values of a good. We argue that a market for a 24-hour electricity supply all-year-round does not exist presently in Ghana, and we rely on the CVM responses to derive the welfare measures. The CVM is a survey method which relies on respondents' preferences for a hypothetical market (in this case a 24-hour supply of electricity). This method's foundations are in microeconomic welfare theory where individuals or households maximize their utility under income constraint, or minimize their expenditure under utility constraint (Spash, 2008; Hanley and Spash, 1993). The empirical results of a well-designed CV study can produce reliable estimates to be used in liability claims or design policies (NOAA 1993). A set of methodological tests have been traditionally used to validate the reliability of CVM estimates and one of the most important ones is the WTP/WTA disparity or convergence. This test is guided by the theoretical convergence (Willig, 1976) and systemic empirical divergence theory (Tversky & Kahneman, 1991; Loomes et al., 2009). The former claims that WTP and WTA should be similar for the same good. However, the latter claims that WTP and WTA should be different for the same good.

In line with our aims as earlier mentioned, we test the reliability of WTP estimates as obtained from of CVM survey. We empirically provide test evidence to support the WTP and WTA debate. This test is achieved using both parametric and non-parametric approaches.

Over a decade and half now, one can argue that there is lack of WTP/WTA credible and economically sound empirical studies on electricity in developing countries. Generally, there is marked paucity of journal published empirical studies on WTP/WTA for electricity in developing countries. One observed study which was conducted in Nepal by Billinton & Pandey (1999) found that WTP values were significantly less than WTA values as normally found in empirical literature. This difference is commonly attributed to "loss aversion: losses (outcomes below the reference state) loom larger than corresponding gains (outcomes above the reference state)." (Kahneman and Tversky, 1979, p.1047), 'endowment effect: increased value of a good to an individual when the good becomes part of the individual's endowment' (Thaler, 1980; Kahneman et al., 1990, p.1326), and "income and substitution effect: [Given income], the ease with which other privately marketed commodities can be substituted for the given public good or fixed commodity, while maintaining the individual at a constant level of utility" (Hanemann, 1991, p.635). Other reasons may also include "commitment costs and asymmetric beliefs: when agents' transactional positions systematically influence their perceived level of difficulty of resale on secondary markets [i.e. value of a good is uncertain because of reversal difficulty and delay difficulty]" (Kling et al., 2013, p.920); "differences in attentional biases: focusing on forgone outcomes, sellers pay close attention to forfeiting the item (or experience) whereas buyers focus on the expenditure." (Carmon and Ariely, 2000, p.361) among others.

Only few studies report WTA estimates for energy production/services in developing countries. A study by du Preez et al. (2012) focused on WTA for a wind-farm in South Africa. They found aggregate WTA to be equal to R40, 891.29(US$ 2,638.487) per month. Another study was conducted by Hosking (2012) where she found that lower income group and higher income group were WTA reductions in compensation (otherwise WTP) for locations of the wind turbines farms at greater distance away from residences. Similarly, Hosking et al. (2015) studied WTA for a reduction in subsidy (otherwise WTP) for the location of wind turbine farms among low income residents. They found that the sampled and underprivileged respondents are WTA R21.38 and R14.25 per month in subsidy reduction respectively, if the wind farm is moved from 0.5km (base level) away to 2km away from residential areas. These perhaps are the only seemingly close WTA empirical studies for electricity in a developing country. Also, for only electricity-related WTP studies, several publications in developing countries have been identified and these include India (Gunatilake et al., 2012), Ghana (Taal and Kyeremeh, 2015; Twerefou, 2014), Nigeria (Adenikinju, 2005), Chile (Aravena et al., 2012), South Africa (Oliver et al., 2011), Kenya (Abdullah & Markandya (2012); Abdullah & Jeanty, 2011; Abdullah & Mariel, 2010), China (Zhang and Wu, 2012).

To the best of the author's knowledge, this is the only developing country study on WTP for a 24-hour service in a developing country that further evaluates the reliability of estimates using WTA, hypothetical bias and scope sensitivity analysis. Considering the relevance in testing the reliability in WTP or WTA studies, we review some developing countries studies which deal with CVM reliability tests. Guided by credible and economic sound empirical studies, the National Oceanic and Atmospheric Administration (NOAA) has set several guidelines to ensure credible WTP responses. As part of the guidelines, scope sensitivity is a crucial test which is normally carried out in split subsamples. However, Carson (1997) observes that "if one accepts the scope insensitivity hypothesis, then one would expect that willingness to pay in general would not vary with respondent characteristics' (p.24)". In line with this, Smith and Osborne (1996) found WTP to be responsive to scope in their meta-analysis study.

One leading author who has been very prolific in CV studies is Richard T. Carson. In one of his contributions as found in Carson (1997), he sought to evaluate the scope insensitivity hypothesis from a much broader picture than generally seen in publications. He explains that, respondents are said to be scope insensitive, if they are willing to pay less if more is offered or better still "respondents are not willing to pay more for more of a particular good" (p.1). He justifies the use of the term "scope" instead of "embedding" from the recommendation part of the NOAA Blue Ribbon Panel (see Arrow *et al.*, 1993). The main thrust of Carson's (1997) work was to show whether appropriate survey design, pretesting, and administration could help prevent this counter intuitive behaviour by some respondents. He argues that it is not likely to be true that surveys in CV studies are prone to scope insensitivity. The studies that have shown scope insensitivity perhaps have respondents not expressing economic values but say ideological values. Carson (1997) debunks the views expressed by Diamond and Hausman (1994) regarding the fact that except studies by Exxon and Kahneman, there exist only a few tests of scope insensitivity which use independent samples, and show about thirty literature evidences. Carson concludes that:

"any hypothesis of generic respondent insensitivity to the scope of the good being valued should be rejected…. These studies tend to suffer from (a) small sample sizes, (b) poor survey design (c) shifts in the probability that the good would be provided between subsamples and/or (d) the use of a mode of survey administration… which do not encourage respondents to pay close attention to the questions being asked" (p.31).

Furthermore, within the scope of our knowledge, all the studies cited by Carson (1997) and Smith and Osborne (1996) as having evidence of scope sensitivity effect were focused on developed countries. We now discuss such validity test studies that focused on developing countries.

Vásquez et al. (2009) CVM study estimate households WTP for safe drinking water in Mexico. They considered scope sensitivity in WTP as a vital test for validation of results. They found evidence of scope sensitivity for combined improvements in water quality and reliability water services (nested good). This was demonstrated by the fact that the nested good exceeded WTP for improvement in water quality alone. In addition, a measure of construct validity was also considered where water supply safety and reliability were considered as normal goods because of their positive relationship with household income. They further found evidence of convergent validity better still described as external validity due to the sign and significance of key variables (such as water storage facility ["storage"] and perception of quality of tap water ["quality score"]) which were consistent with earlier studies.

Soto Montes de Oca and Bateman (2006) examined what they described as novel approaches to scope sensitivity testing in households' WTP for water services in Mexico. They indicate that their WTP estimate is intended to provide the information necessary to promote equitable and economic efficient tariff schemes, identifying the priorities of heterogeneous groups of households with regard to their varied income constraints. This was achieved using the CV approach with a total sample size of 1,424 household responses. The water services were presented under two scenarios with different sample sizes. Seven hundred and eight (708) of these responses were presented with the improvement scenario while 716 were presented with the maintenance scenario. They first estimated a probit model and achieved theoretical validity when they obtained the right sign relationships between responses to the bid amounts and several variables that are consistent with economic theory and empirical justifications (e.g. income). In relation to the novel scope sensitivity test, they found that higher income groups because of current endowments of water quality, are willing to pay more to maintain the service or avoid deterioration in the service rather than for an improvement. On the other hand, lower income groups who are currently not enjoying the current quality service expressed lower WTP for maintenance yet higher WTP for improvement in the poor service.

Whittington et al. (1991) used the bidding game format to elicit respondents' WTP for water in Nigeria. They found that respondents were generally willing to pay substantially for water. In fact, respondents were already paying substantial amounts for water. However, they were not willing to pay more above the price of water charged by vendors because they felt the quality and reliability could be the same. Thus, respondents did not value their endowment differently from the perceived or expected water supply. This gave evidence of consistency in respondents' preferences for water hence justifying the theoretical and empirical validity as in standard CVM surveys. They found households WTP for water across different income levels to lie between 5%-18% of household's income. Although this was described as high, the authors justified the external validity of their results with other studies such as Lin (1983), Fass (1988), and Whittington et al (1989).

To the best of the author's knowledge, the literature has not provided any evidence of WTP and WTA study on electricity in any developing country particularly Africa. We provide one of the first WTP estimates for electricity, while undertaking relevant reliability tests for valid estimates to inform policy decisions. We also present in a summary of the literature discussed and some other related studies (see Table 2.11 in Appendix A) that consider WTP or WTA but not both. This study contributes to the literature by filling in the gap in this direction.

4. Survey Design

In order to determine the WTP (WTA) for a reliable electricity service (24hours) a contingent valuation survey was administered in the Greater Accra Region (GAR), Ghana. This region was chosen out of the other ten regions because it has the highest electrification level of 96% (Edjekumhene and Cobson-Cobbold, 2011). This region has the current highest proportion of urban household of 31.2%. Moreover, GAR has Accra as its capital city and it has been Ghana's capital since 1877. It has the highest population density and is the second most populous region in Ghana. It is also seen as one of the most populated and fast growing Metropolis in Africa. A sample from this region reflects better representation because of its associated higher demand for the good in question.

In the GAR, we randomly selected six communities within the ten districts of the region. Households within these communities were also randomly selected for the face-to-face interviews. The survey took place in February 16-March 16, 2015, and a total of 514 respondents were interviewed. Ten enumerators were well trained and further evaluated through a pilot survey. The fieldwork was conducted under the supervision of three survey experienced supervisors who monitored the process of data collection and data entry.

The structure of the questionnaire (see pg.58) can be categorised under three (3) parts namely respondent's bio-data, general utility-related information, and willingness-to-pay/accept for electricity questions. In part 1: bio-data information presents information about household socio-economic characteristics Part 2: utility-related questions presented included access to electricity, current bills and preferences. Part 3: CVM (WTP/WTA) questions were asked using the dichotomous choice and open ended format. The key WTP question asked was: "Assume your household is provided with a 24-hour electricity supply, how much would your household be willing to pay per month ?" In addition, the key WTA question asked was: "Assume your household is to be provided with a 24-hour electricity supply, however it's not reliable. How much will you accept as compensation from the government per month for the current power shortages [Note: 24-hour off, 12-hours on]? ".

The initial bid was provided by the researcher based on the range of bills paid by households per month. These values were obtained from the pilot survey and common knowledge by the researcher. The starting point amounts were randomised during the face to face interviews to control for starting point bias or anchoring effect. The initial question was followed by other dichotomous choice questions and concluded with “state the maximum amount you are willing to pay (willing to accept) for 24hours electricity service?” Four options are observed so our WTP (WTA) follows the four definitions outlined as follows:

- First definition: Yes-Yes Response $WTP_i^* \geq b^u$

For the first definition, if the respondent said yes to the starting bid, we adjusted the bid upwards by 10 Ghana cedis. If the respondent said yes again, then the respondent is given the opportunity in an open-ended format to state the maximum amount he/she is willing to pay. The WTP is therefore expected to be greater or equal to the upper bid offered (b^u).

- Second definition: Yes-No option $b^o \leq WTP_i^* < b^u$

In the second definition, if the respondent said yes to the starting bid, then we adjusted the bid upwards by 10 Ghana cedis. If the respondent said no to the second bid (upper bid (b^u)), then the respondent is given the opportunity in an open-ended format to state the maximum amount he/she is willing to pay. The WTP will therefore be expected to be greater or equal to the starting bid (b^o) but lower that the upper bid (b^u).

- Third definition: No-Yes option $b^l \leq WTP_i^* < b^o$

Regarding the third definition, if the respondent said no, then we varied it by 5 Ghana cedis. If the respondent said yes for lower bid (b^l), then we asked the respondent to state the maximum amount he/she will pay for the service. The WTP will therefore be greater or equal to the lower bid (b^l) but lower than the upper bid (b^u).

- Fourth definition: No-No option $WTP_i^* < b^l$

In our last definition, if the respondent said no, then we varied it by 5 Ghana cedis. If the respondent said no for the second time, then we asked the respondent to state the maximum amount he/she will pay for the service. The WTP will therefore be lower than the lower bid (b^l).

In all definitions, only the final WTP (WTA) values which is the maximum amount respondents are willing to pay (or accept as compensation) will be used in the analysis. The interviewers explained to respondents that the survey aimed at evaluating the 24hours electricity service for management reasons which were not motivated by any political party or public institution. A brief script, which was purposefully and carefully worded, was read to all participants before they filled in the questionnaire. The aim of this script was to make the interviewee behave as making a real world commitment subject to their limited income constraints.

Econometric Approach: WTP and WTA.

With the maximum amount respondents are willing to pay ($\mathrm{WTP_i}$) for the continuous 24-hour service, we use that as our dependent variable and formulate a linear WTP model. In the same vein, we treated the maximum amount respondents are willing to accept as compensation ($\mathrm{WTA_i}$) for not enjoying the 24-hour service as our dependent variable and formulated a linear WTA model.

Bateman and Turner (1992) provides that in defining elicitation methods, if open ended questions are asked and a continuous bid variable is obtained, OLS will be appropriate for estimation. Therefore, the Ordinary Least Squares (OLS) is used to estimate both WTP and WTA models from final open-ended questions. This primarily is to evaluate the extent to which respondents' socioeconomic characteristics and other contextual characteristics or controls influence their WTP and WTA. Such multivariate models can also be found in Casey et al. (2006), Whittington et al. (2002), Briscoe et al. (1990) etc. Similarly, we assume a linear model expressed as:

$$\mathrm{W_i} = \alpha + \mathbf{X}_i\boldsymbol{\beta} + \mathrm{u_i} \qquad (2.1)$$

Where $\mathbf{W}_i$ refers WTP or WTA, we denote $\mathbf{X}_i$ as a vector of the household's characteristics and other controls, $\boldsymbol{\beta}$ is a vector of all coefficients to be estimated, α is the constant term, and $\mathrm{u_i}$ is stochastic term with a standard normal distribution. This estimated model is expressly presented as:

$$\mathrm{lnW} = \alpha + \beta_1\mathrm{lnBid} + \beta_2\mathrm{lnBill} + \beta_3\mathrm{lnY} + \beta_4\mathrm{G} + \beta_5\mathrm{HH} + \beta_6\mathrm{MS} + \beta_7\mathrm{FD} + \beta_8\mathrm{C_{dum}} + \mathrm{u} \qquad (2.2)$$

In models 2.2, *lnWTP (lnW)* is the log of the final bid expressed by the respondent, *lnWTA (lnW)* is the log of the compensation respondent is willing to accept to forgo a 24-hour service, *lnBid* is the log of the starting point bids, *lnBill* is the log of the current electricity bill paid by respondent in the previous month preceding the interviews, *lnY* is the log of monthly take home income of respondent, *G* is the gender of the respondent, *HH* is the household size of respondent, *MS* is the marital status of respondent, *FD* is the household's financial decision maker, *C_dum* is the community specific dummies.

5. Study Results

We now present how the data used for the study was segmented and used for our estimation. First, we dropped two outliers from the WTP responses and three from the WTA responses. This was to ensure that our data is consistent with rational behaviour of consumers, as it does not sound intuitive for a household's income to be less than their WTP. In addition, to consider the sensitivity of our results to the selection of the valid responses, we sub-sampled the data considering only the responses where the WTP/income ratio was less or equal to 100%, 60%, 40% and 20% respectively.

When a missing value was observed in WTP or WTA responses the full record was dropped in order to have the same sample size for both responses. The number of observations used and shown in Table 2.3 are 504, 451, 375 and 206 for the full model, and the sub-samples of 60%, 40% and 20% respectively. We focus the descriptive statistics on the full sample (see Table 2.9 in Appendix A). The dominant gender is male constituting about 65% which depicts the characteristics of male dominated household heads in Ghana. The average household size is approximately four which is almost the same as the national figure in 2010 (GSS, 2012). About 48% of respondents are married, which is also close to about 43% at the national level (ibid). The average monthly income of respondents is about GHS429 which is quite close to the national estimate of GHS544 for the Greater Accra region (GSS, 2008).

Out of the 504 respondents' WTP responses, 41% are WTP at most GHS50, 48% are willing to pay between GHS50- GHS100, while 11% are WTP at least GHS100. For the WTA responses with same observations as the WTP, 30% are WTA at most GHS50, 50% are WTA between GHS50- GHS100 and 20% WTA at least GHS100.

The average electricity bill paid in the last month before the survey is about GHS36.10. In the case of WTP, the mean WTP constitutes about 87% higher than respondents' current electricity bill. This shows a substantially positive attitude by respondents regarding their readiness for improvement in the service. Also, In the case of WTA, the mean WTA was more than twice higher than the current electricity bill (approx.148%), suggesting that respondents really do not fancy trading off a 24-hour supply of electricity. The only way by which they will trade-off is to charge a higher price as compensation for the loss in welfare. Thus, respondents in the hope of improving the quality of service and their welfare were generally willing to pay or accept more than how much they are currently paying for the current erratic electricity service. This is found to be consistent with consumer's utility theory which provides internal validity credence to CVM studies.

5.1 Endogeneity Issues

Demand equations such as equations 2.1&2.2 are prone to endogeneity problems when estimating the parameters. We used the electricity bill as a proxy for electricity consumption in both WTP & WTA for current electricity service. Thus, this measure of consumption may be endogenous because people with higher WTP may be expected to spend more. This can affect the efficient identification of the true causal effect of electricity bill on WTP & WTA. To proceed in examining the true effects, we first undertook various tests of endogeneity to authenticate our intuitive suspicion. We instrumented bill with different instruments such as household size, age and age squared.

The commonly used tests include Durbin (1954); Wu (1973, 1974); and Hausman (1978). It is generally known that Instrumental Variable (IV) estimation is always consistent. However, the consistency in an OLS estimation depends on if all the regressors are exogenous. The null hypothesis for this test of endogeneity is that the variables are exogenous and that the difference in coefficients is not systematic.

In table 2.2, we present the various test results with their corresponding test-decisions. We find evidence to accept the null hypothesis that there is no significant difference between our IV and OLS. This results of electricity bill being exogenous in our model is consistent with existing studies such as Arzaghi and Squalli (2015), and Rietveld and van Woudenberg (2005). These authors argue that there are no serious identification concerns when prices of the type of energy are pre-set by government rather than market forces as in our case. In short, both IV and OLS estimates are the same as the test is based on the difference between IV and OLS (i.e. no endogeneity in regressors). In this instance, we will prefer the OLS to the IV because OLS is more efficient.

Table 2.2: Test for Endogeneity

Tests		P-Value	Test-decision
Durbin (score)	Chi-square value= 1.78	0.1823	OLS Preferred
Wu-Hausman	F-statistic value = 1.74	0.1879	OLS Preferred
Hausman	Chi-square value= 1.44	0.9636	OLS Preferred

Table 2.3: WTP & WTA Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full-sample (100%)		Sub-sample (≤60%)		Sub-sample (≤40%)		Sub-sample (≤20%)	
VARIABLES	WTP	WTA	WTP	WTA	WTP	WTA	WTP	WTA
Bid (Log)	0.563***	0.269***	0.546***	0.279***	0.490***	0.252***	0.448***	0.136**
	(0.051)	(0.049)	(0.054)	(0.046)	(0.059)	(0.048)	(0.077)	(0.060)
Electricity Bill (Log)	-0.047	-0.003	-0.029	-0.031	-0.011	-0.026	0.077*	0.023
	(0.030)	(0.029)	(0.037)	(0.032)	(0.042)	(0.034)	(0.047)	(0.042)
Gender (Male)	0.121***	0.055	0.134***	0.080*	0.128***	0.048	0.151**	0.060
	(0.039)	(0.042)	(0.042)	(0.042)	(0.047)	(0.044)	(0.060)	(0.059)
Household Size	0.011*	0.012	0.008	0.008	0.014*	0.018**	0.015*	0.020*
	(0.006)	(0.008)	(0.007)	(0.008)	(0.007)	(0.008)	(0.009)	(0.011)
Marital Status (Dummy)	0.082**	0.039	0.079**	0.052	0.080**	0.015	0.072	0.000
	(0.034)	(0.040)	(0.036)	(0.041)	(0.041)	(0.042)	(0.053)	(0.056)
Monthly Income (Log)	0.174***	0.143***	0.224***	0.231***	0.295***	0.326***	0.409***	0.520***
	(0.028)	(0.031)	(0.033)	(0.035)	(0.042)	(0.040)	(0.066)	(0.063)
Household Decision (Dummy)	0.189***	0.231***	0.184***	0.276**	0.185**	0.315**	0.207**	0.475**
	(0.062)	(0.086)	(0.063)	(0.118)	(0.076)	(0.135)	(0.095)	(0.194)
Constant	0.798***	2.307***	0.476	1.675***	0.134	1.053***	-0.878*	-0.209
	(0.272)	(0.287)	(0.297)	(0.294)	(0.351)	(0.327)	(0.456)	(0.460)
Community Dummies	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
Observations	504	504	451	451	375	375	206	206
Expected Mean $(\exp(\mu + \frac{\sigma^2}{2}))$	63.96	82.46	61.96	76.82	57.73	70.77	49.16	55.44
R-squared	0.557	0.324	0.564	0.346	0.574	0.408	0.674	0.543
F-test	42.96***	19.22***	42.03***	20.06***	38.98***	23.67***	59.46***	29.40***

Dependent Variable for WTA models: WTA Amount (Final); Dependent Variable for WTP models: WTP Amount (Final)
Robust standard errors in parentheses.
Note: all models estimated controlled for community specific effects with community dummies (Yes)
*** p<0.01, ** p<0.05, * p<0.1; [ ] Denotes Confidence Intervals

We present the results of our econometric estimation in Table 2.3. These models (Model 1-8) are estimated based on a full sample (100%) and sub-samples: 60%, 40% 20% of WTP or WTA to income ratio. We controlled for community specific effects with community dummies in all our estimated models. Also, due to the problem of heteroskadasticity associated with cross-sectional data, all our models are estimated with robust standard errors. In addition, all estimated models are highly significant according to the standard F-tests in our regression results.

We find that the starting point bid used in the application of the double-bound dichotomous choice format is positive and significant in all estimated models. Although we randomly allocated the bid we still found evidence of starting point bias in our results. Suggesting that this bias could have been higher hence the importance in controlling for it in our models. This bias has been reported by Boyle et al. (1997), Green (1998) and more recently Boyle (2003) to be associated with dichotomous choice format. Hence our results are not completely free from such bias.

Similar to the case of Casey et al. (2006) who expected a positive relationship between bills and WTP, we introduced electricity bill in our models to capture consumer's behaviour towards utility services in general. In our case, we expect that if the proportion of consumer's income spent on services is low, households would pay more for improved services. The coefficients of electricity bill on both WTP and WTA in all the models (except model 7) are not statistically significant implying that electricity bill is not an important determinant of WTP & WTA. However, where a smaller fraction is spent on services, we find some significance in WTP. This suggests that, the proportion of income spent by consumers in a developing country like Ghana matters in determining their WTP for general services. Stated differently, selecting valid responses of respondents who are willing to spend a reasonable proportion of their income on say electricity is found to be significant in determining WTP.

Regarding gender, we find that being a male household head relative to being a female has a positive and significant coefficient in all the WTP models. Thus, males have higher WTP relative to females. However, except for model 4 (with a weak significance) we find that WTA does not vary with gender. This is justified by the fact that men in general are mainly in-charge of a household's budget to pay but definitely not to accept.

Also, the coefficient of household size in the 20% and 40% sub-samples are positive and significant for both WTP&WTA. This suggests that household size is a determining factor in both WTP & WTA for electricity in Ghana. In the full sample, we find household size to be influencing WTP but not WTA.

With regards to marital status, we find this to be positive but not a determining factor of WTA in all our estimated models. Still, in the 20% sub-sample for WTP, marital status is also found to be positive but insignificant. In contrast, we find significance in all the other WTP models, thus, respondents who are married are more willing to pay relative to unmarried respondents.

The most interesting result which further provides evidence for scope sensitivity test is the income of the respondent. This variable is positive and strongly significant at 1% (p-value $<=0.001$) in all estimated models. That is, we have evidence that a percentage increase in income increases both WTP & WTA from as low as about 0.14% to as high as about 0.52%. Stated differently, higher income respondents have higher WTP & WTA. This implies that income elasticity of demand for electricity ranges from 0.14-0.52, and that electricity is regarded as a normal good or better still a necessity. This positive and significant result is consistent with prior studies' findings in developing countries (e.g. Abdullah & Mariel, 2010; Gunatilake et al., 2012; Twerefou, 2014; Taal & Kyeremeh, 2015). We acknowledge that, this income variable should be treated as a lower bound estimate as it is much smaller than the national estimate for the region under consideration.

Generally, we expect single decision makers to have a higher tendency for taking risk and joint decision makers to be associated with a lower tendency for taking risk. This is because single decision makers are certain on who takes the risk however, joint decision makers need to confer in order to make joint decisions. To evaluate this relationship, we included a dummy to represent families with single dominant decision makers and joint household decision makers. This primarily was to find out the extent to which single financial decision makers are able to influence WTP & WTA relative to joint financial decision makers. In other words, we expect the behaviour of high risk probability respondents with respect to WTP & WTA to be different from low risk respondents. We find the coefficient to be positive and significant in all models. This means that households where respondents need not consult other household members or are not constrained by other household member's views and take risk by themselves have higher WTP & WTA compared to households characterised by joint decision making.

5.2 Mean WTP & WTA

This section focuses on the mean WTP and WTA as obtained by the sample means before the regression and the predicted estimates after the regression. The sample means represent the observed WTP/WTA for the electricity services whereas the predicted values are moderated by the effect of relevant socio-economic components. The empirical estimates of the means as well as their ratio are all reported in Table 2.4

Table 2.4: Mean WTP&WTA Statistics

Sample	**Obs.**	**Mean WTP**	**Expected Mean WTP**	**Mean WTA**	**Expected Mean WTA**	**Mean Income**	**Mean WTA/ WTP Ratio**
Full Sample used	504	67.48 (36.40) [64.30-70.67]	63.96 (1.13) [61.52-66.49]	89.54 (47.40) [85.40-93.69]	82.46 (1.06) [80.33-84.64]	429.04 (321.35)	1.33
Censored at 60%	451	65.09 (36.04) [61.76- 68.43]	61.96 (1.13) [59.62-64.39]	83.13 (43.03) [79.14-87.11]	76.82 (1.06) [74.88-78.81]	461.61 (326.84)	1.28
Censored at 40%	375	62.42 (35.26) [58.84-66.00]	57.73 (1.12) [55.60-59.95]	79.04 (40.66) [74.91-83.17]	70.77 (1.07) [68.84-72.74]	511.60 (334.07)	1.27
Censored at 20%	206	59.91 (37.90) [54.71-65.12]	49.16 (1.15) [47.15-51.26]	74.20 (42.63) [68.34-80.06]	55.44 (1.11) [53.46-57.48]	665.02 (364.18)	1.24

†SD( ) denotes Standard Deviation, and CI [ ] denotes 95% Confidence Intervals

The results shown in Table 2.4 suggest that mean WTP for the full sample is GHS67.48 which is less than the mean WTA of GHS89.54 with a corresponding WTA/WTP ratio of 1.33. The further away the subsample is from the full sample the smaller the mean WTP and WTA values. Nevertheless, the pattern, in terms of WTA being greater than WTP is consistent for all samples. The standard deviation for the expected mean values are relatively far smaller with a more compact confidence interval.

The expected WTP for the full sample, and the 60%, 40% and 20% subsamples constitute about 15%, 13%, 11% and 7% of household income. Thus, households are prepared to pay between 7% and 15% of their income to have a 24-hour supply of electricity in the GAR of Ghana. The fraction of income on electricity is consistent with earlier CVM studies such as Whittington et al. (1991) and Taal & Kyeremeh (2015).

5.3 Within-subject Test on Continuous Variables

Moffatt (2016), indicates that within-subject test is appropriate to evaluate the effect of a treatment in a situation where each respondent/subject is observed before and after the treatment. Alternatively, if the same respondent responds to WTP questions before the WTA questions as in our case, then it provides the opportunity for a possible within-subject comparison. Moffatt (2016) argues further that within-subject test has more statistical power compared to between-subject test.

In this study, we find that all the mean WTA values exceed its corresponding mean WTP values. Also, the possible within-subject comparison between WTP & WTA values (continuous variables) make the use of within-subject test on continuous variables very appropriate. We apply both parametric (paired-comparison t-test) and non-parametric test (Wilcoxon signed-rank test) strategies.

The parametric paired-comparison t-test gives a strong evidence of statistical difference between the means of WTA & WTP (see Table 2.5). This is because we observe that the WTA is higher on average, and the average difference reported (in Table 2.5) is 22.06.

Table 2.5: Paired Comparison T-Test of WTA & WTP

<table>
<tr><th>Variable</th><th>Obs.</th><th>Mean</th><th>Std. Err.</th><th>Std. Dev.</th><th>[95% Conf. Interval]</th><td rowspan="4">t = 15.25
Ho: mean(diff) = 0
Ha: mean(diff) !=0
Pr(|T| > |t|) = 0.0000</td></tr>
<tr><td>WTA</td><td>504</td><td>89.54</td><td>2.11</td><td>47.40</td><td>85.40 - 93.69</td></tr>
<tr><td>WTP</td><td>504</td><td>67.50</td><td>1.62</td><td>36.40</td><td>64.30 -70.67</td></tr>
<tr><td>Diff</td><td>504</td><td>22.06</td><td>1.45</td><td>32.48</td><td>19.22-24.90</td></tr>
</table>

Again, the Wilcoxon signed-rank non-parametric test used here, focuses on the difference between WTA and WTP for each observation. In Table 2.6, we find that the sum ranks for positive sign (WTA>WTP) is 111,694 which is far higher than negative sign (WTP>WTA) of 8,426. Given a (two-tailed) p-value of 0.0000 we have evidence to reject the null hypothesis that the sum ranks for both WTA and WTP are equal. This test for statistical difference between WTA & WTP supports the evidence provided by the parametric test.

Table 2.6: Wilcoxon Signed-Rank Test

Sign	Observations	Sum Ranks	Expected	
Positive	355	111,694	60,060	z = 15.902 Prob > |z| = 0.0000
Negative	30	8,426	60,060	
Zero	119	7,140	7,140	
All	504	127,260	127,260	

We further consider the fact that Wilcoxon signed-rank depends on the assumption that the distribution of paired differences should be symmetric around the median. In addition, we conducted the paired-sample signed test. This test is very relevant in our case because it avoids the Wilcoxon signed-rank test assumption. Thus, it is distribution free. The test results is provided in Table 2.7.

Table 2.7: Paired-Sample Sign Test

Sign	Observed	Expected	
Positive	355	192.5	P-value for One-sided tests: 0.0000
Negative	30	192.5	P-value: 1.0000
Zero	119	119	
All	504	504	P-value for Two-sided test: 0.0000

From Table 2.7, given the huge differences in the observed positive differences than negative differences as well as the relevant p-value (one-sided test) of 0.0000, we argue that the difference is significantly different from one half given the binomial distribution. We conclude from our evidence in Table 2.7 that our results is consistent with earlier results presented in Table 2.5&2.6. Next, we try to investigate this relationship further using the difference in their distributions. Here, we apply the kernel density estimation in the next section.

***5.3.1** WTP&WTA Distribution*

We use the kernel density estimation, which is a non-parametric technique because we do not assume any underlying distribution for the variables to investigate the WTP and WTA distributions. With two distributions, we can observe from the data that although the means are different the distributions overlaps a lot. So we examine the distribution of the difference between WTA and WTP because it is paired comparison.

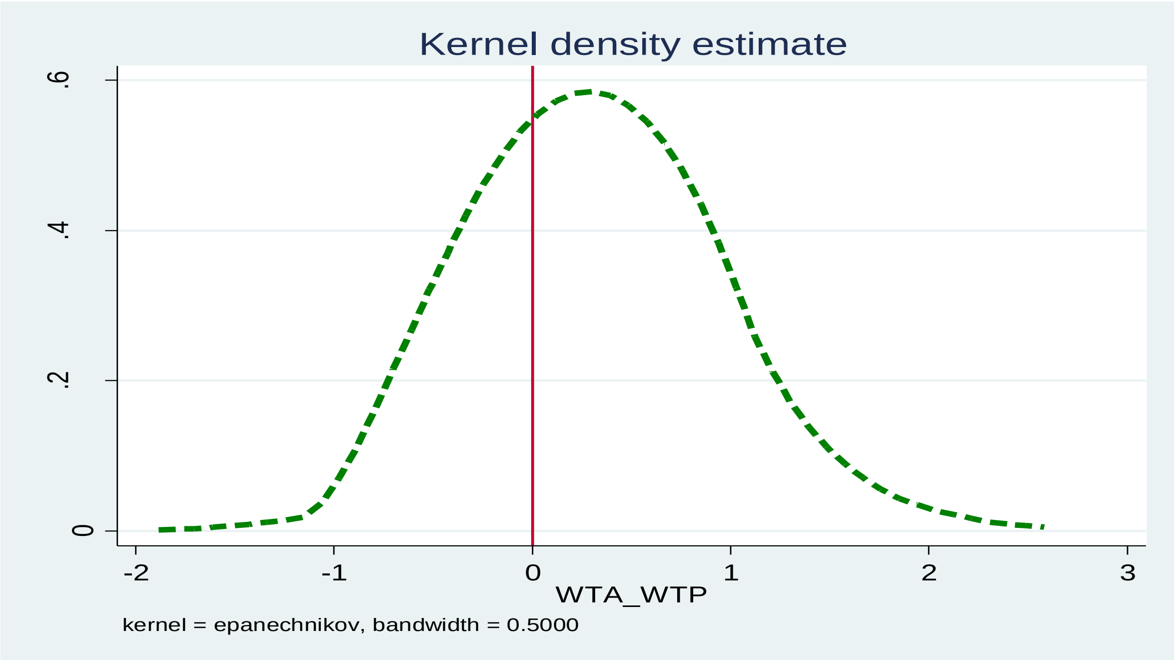

Fig. 2.2: Distribution of WTA-WTP Difference

In Fig. 2.2, we find that the mean of the distribution is different from zero and that it lies to the right of zero. This suggests that the mean of WTA is significantly different from the mean of WTP. Indeed, our tests so far establish divergence between WTA and WTP.

We admit that our results are not "order-effects" free. This problem may be relevant in our case because of framing. Indeed, we should expect that a respondent's WTP behaviour, may somehow influence their WTA behaviour and that the disparity may be attributed to the order of our elicitation design.

Applying a convolution test as proposed by Poe, et al. (2005) to evaluate the entirety of both distributions would have been an ideal test. This test is an alternative to the standard empirical approach to determine the probability that a random variable is either statistically different to another or not (Loomis and Gonzalez-Caban, 2006). However, our data is limited by the fact that the WTA and WTP values are not independent, which is a requirement in undertaking this test.

Contrary to our earlier findings of divergence, we revisit Table 2.4 and find interesting results with respect to WTA/WTP ratios. We find that all the mean WTA/WTP ratios range from 1.24 to 1.33. Several studies cited in Alberini and Khan (2006), including Knetsch and Sinden (1984), Bishop and Heberlein (1986), Brookshire et al.(1986), Kahneman et al. (1990), Shogren et al. (1994), and Horowitz & McConnell (2000), found that the WTA/WTP ratio ranged from approximately three to seven. There are however, studies that have reported WTP/WTP ratio of less than two (i.e. 1.4-1.8) these include but are not limited to Coursey et al. (1987), Harlow (1988), Kachelmeier and Shehata (1992), Boyce et al. (1992), and Eisenberger and Weber (1995). Our results are in the lower end of these differences and seem more in line with the classical utility-maximizing models as posited by Willig (1976).

The literature has provided several reasons why this WTA/WTP ratio will be smaller. First, is framing: If the WTP question followed by the WTA question are both asked to the same respondent during the same time of the interview then one would expect the WTA/WTP ratio to be smaller. Second, the good being valued: if the good being valued is considered more as a private good than a public good then WTP and WTA will converge.

From the ratios, we also argue that there is equality between the two distributions. Stated differently, there is no statistically significant difference between the WTP and WTA distributions.

5.4 Discussion

CVM has been criticized in articles published by Diamond and Hausman (1993); Milgrom (1993); McFadden and Leonard (1993); Diamond and Hausman (1994). Their core argument according to Haneman (1994) is that CVM results are inconsistent with economic theory. Haneman debunks this assertion and argues that a careful examination of their claim shows that, it is either their stance are not supported by the findings in CVM literature or they are based on unusual notions about what economic does or does not prescribe.

More recently, Hausman (2012) has revived the debate which he described the CVM as “From Dubious to Hopelessness”. He builds on Diamond and Hausman (1994) earlier critical position under three main areas namely: hypothetical bias and upward-biased results; differences between willingness to pay and willingness to accept; scope and embedding. However, other authors such as Haab et al. (2013); Kling et al. (2012); Carson (2012), have offered counter arguments to the assertions made by the critics. In support of the CVM following the three main points of their criticism, we have provided evidence to justify the credibility of our CVM application. Indeed, we provide internal validation of this study following:

- Hypothetical Bias: Rowe et al. (1980, p.6) defines hypothetical bias as “the potential error induced by not confronting any individual with the real situation”. The good in question is not a hypothetically market described good. What is being valued is not new to respondents. They have until recent crisis enjoyed 24hour supply of electricity throughout the year (except for technical faults) in

Ghana. We therefore classify this good being valued not as something new to respondents hence lacking the possibility of being prone to hypothetical bias.

- WTP & WTA: What is being measured in a CVM study is either WTA or WTP for especially changes in non-marketed goods. We have applied both WTA and WTP in this study and tested for possible convergence and divergence between them. The within-subject tests on continuous variables suggest that there is a significant difference between the ranks of the medians. This satisfies the empirical divergence found in some studies. However, the mean WTA/WTP ratios (Table 2.4) suggests that the two distributions are approximately the same. This satisfies the theoretical convergence in the two approaches. We are therefore not conclusive without the convolution test.
- Scope Sensitivity: Morey *et al.* (1991) acknowledged that, "economic theory suggests that in general WTP [or WTA] will depend on income, [thus] justifying the inclusion of income in the utility difference model" (Park and Loomis, p.154). This study estimated WTA and WTP subject to consumer's income. This is consistent with consumer demand theory. We find that WTP and WTA varies across various income groups. Hence, we can argue that this study satisfies the scope sensitivity test.

Although CVM is regarded as the most controversial of all environmental valuation methods (Hanley and Barbier, 2009), it is still a pioneer stated preference method in estimating both use and non-use values. From our evidence, we support the claim of Loomis (1989) and argue that CVM is credible and provides accurate estimate of the respondent's full nonmarket value of a good, which is demonstrated to be valid and reliable over time

5.5 Energy supply vs Aggregate WTP estimates

To determine the cost and benefit of electricity supply in Ghana, we first compute the aggregate annual WTP and WTA for a 24-hour electricity supply. According to the 2010 Housing and Population Census by the Ghana Statistical Service (2012), the total population of the GAR with ten districts is 4,010,054 and the total number of households is 1,036,426. The conditional or expected means from the regression results are all presented in Tables 2.3 and 2.4 (detailed). Given that the sample was randomly selected, and the full sample expected mean for WTP and WTA as GHS63.96 and GHS 82.46, we can now compute the aggregate WTP & WTA per month as GHS66,289,806.96 and GHS85,463,687.96 respectively. The annual aggregate WTP & WTA can also be calculated as GHS795,477,683.5 ($206.01million) and GHS1,025,564,256 ($265.59million).

Data available for cost of energy production come from National Energy Statistics final report of the Ghana Energy Commission (2015). From Table 2.10 (see Appendix A) summarised in Table 2.8, we compute the annual total cost of electricity to the households in the GAR as GHS 1,363million ($352.98million). This shows the cost burden on all households for electricity supply in GAR. Using the year 2014's cost estimate (lower bound) as the most recent available data, we find the cost of electricity per household to be GHS1,315.10 per annum or GHS109 per month.[15] This constitute about 25% of household's income which is 10 percentage points higher than proportion of expected WTP mean to income (15% for the full sample). Subtracting the total cost from the benefit (WTP) yields a net cost of GHS567.52million ($146.97million). This suggests that a complete removal of subsidies on electricity tariff in Ghana will be very disastrous to household's electricity consumption. This probably underlines the reason why the government is reluctant to fully privatise the sector in spite of the substantial interest shown by both local and foreign firms.

Now, notwithstanding how huge this burden is on households, it has the probability of worsening further if the country continues to depend on thermal plants and still import light crude and natural gas to power the plants. In Ghana, electricity generation from thermal plants is based on pricing which is subject to the volatility in the exchange rate, political will by trading partners, cost of transportation etc. Since electricity pricing is highly subsidised in Ghana, this has the likelihood of putting more pressure on government's limited budget which receives donor support annually. A government that is unable to meet the needs of the people is prone to demonstrations, riot and political unrest. It is not a surprise that the year 2015 witnessed more strikes and demonstrations than any other year since the country became democratic.

Table 2.8: Cost & Benefit Analysis of Electricity in Ghana

Year	Annual Household Total Cost (Million GHS)	Monthly Household Total Cost(Million GHS)	Annual Cost/Benefit Analysis† (Million GHS)
2010	463.64	38.64	331.84
2011	525.56	43.80	269.92
2012	566.72	47.23	228.76
2013	744.02	62.00	51.46
2014	1,363.00	113.58	-567.52

Note: Refer to Table 2.10 (appendix) for detailed cost table. †We assume a constant benefit across the years.

[15] Cost per household=cost/household =GHS 1,363million/1,036,426.

In Table 2.8, we observe the cost and benefit trend since 2010. We observe a downward spiral in the trend from 2010 to 2014. It is obvious that the fall was quite gentle from 2010 to 2012. We however observe a sharp decrease from 2012 to 2013, and a marked fall thereafter.

Although the sector has not performed impressively over the last decade, the prospects associated with the sector, evidenced by the positive attitude shown in households' WTP for improved service, could be the reason why as of March, 2016, about forty-two companies[16] have shown interest in private sector participation in ECG. Other reasons that make Ghana a good destination for local and foreign direct investment in the electricity (energy) sector; are the abundant renewable energy potential, economic climate, stable political atmosphere, low crime rate, and socially friendly and hospitable environment among others.

6. Conclusion and Policy Recommendation

The Sustainable Development Goal (SDG 7[1]) provides that "by 2030 [the world should] ensure a universal access to affordable, reliable, sustainable and modern energy for all". The SSA has a responsibility of ensuring that the 635 million people without electricity have electricity. Ghana has a responsibility of ensuring that the electricity crisis is permanently over and the about 35.9% of the population without access to electricity are not just using electricity but are enjoying affordable, reliable, and modern energy services.

We establish that the current electricity crisis in Ghana has serious socio-economic and political implications. For example a country with a phenomenal annual economic growth rate of 14.05% in 2011 and 7.3% in 2013, recorded a growth rate of 4.2% and estimated 3.4% in 2014 and 2015, respectively (see World Bank, 2016). In addition, 2015-2016 is observed to have recorded unprecedented demonstrations, increase public outcry and declining support for the ruling party. Not harnessing the potential of the country to ensure sustainable economic growth and enhance human welfare can have serious consequences.

A key reason for this persistent, and unpredictable incidence of electric power outages, plunging the country into electricity crisis is attributed mainly to low revenue inhibiting access to sufficient fuel for thermal plants, maintenance and expansion exercises.

[16] List of these companies can be found at http://www.myjoyonline.com/news/2016/March-23rd/scramble-for-ecg-as-42-companies-show-interest-in-concessions.php

It is against this background that we sought to estimate demand for a 24hour service. By this, we investigate whether households will be willing to pay for an improvement in the current electricity challenges. Some key validity concerns such as hypothetical bias, willingness to pay and willingness to accept, and scope sensitivity which have been highly debated in the literature were addressed. Our results show that estimated mean WTP is GHS63.96 and WTA is GHS 82.46. The annual aggregate WTP & WTA can also be calculated as GHS795,477,683.5 (795.48 million or $206.01million) and GHS1,025,564,256 (1,025.56 million or $265.59million). Our estimates constitute between 7% and 15% of respondents' take-home income. Unfortunately, the cost & benefit analysis showed a deficit of GHS567.52million ($146.97million) per annum.

We recommend that first, the private sector should not be in a haste to take over the electricity sector in Ghana if other cheaper sources of electricity supply are not going to be harnessed. Second, in the event that the private sector is to be considered in this sector, we recommend that this should be implemented with due diligence because of the social welfare implication to the poor and vulnerable whose ability to afford is hugely in doubt. Thus, any move towards removal of subsidies immediately should not be considered as the amount households are prepared to pay is quite high yet not sufficient to cover the cost of supply. Third, providing incentives for private households to go renewable (solar) and managing their sources of electricity could be the way forward by the government. This has a huge advantage of weaning the country off overdependence on generation-mix that are not reliable with its associated huge distributional losses which is also a major concern to ECG. Also, the electricity subsidy by the government should be made known to customers by presenting it on electricity bills to raise the awareness and ensure transparency in electricity pricing in Ghana. Lastly, from the welfare point of view, we recommend government's commitment to honouring her subsidy obligations as this is very crucial to the recovery and development of the sector.

APPENDIX B

Appendix B1: Data and Summary Literature Tables

Table 2.9: Descriptive Statistics for both WTP &WTA

Variable	**Description**	**A priori**	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Bid (GHS)	Discrete	+	504	54.54	28.66	10	100
Bill (GHS)	Continuous	+	504	36.10	32.62	5	250
Household Size	Continuous	+	504	4.00	3.00	1	17
Marital Status (Married=1) Married Unmarried	Dummy	+	504	0.48 [48.21%] [51.79%]	0.50	0	1
Gender (Male=1) Male Female	Dummy	+	504	0.65 [64.68%] [35.32%]	0.48	0	1
Take-Home Monthly Income (GHS)	Continuous	+	504	429.04	321.35	100	1750
Financial Decision (Single Fin. Dec. Maker=1 Several Fin. Dec. Makers=0)	Dummy	+	504	0.95 [94.64%] [05.36%]	0.23	0	1

*percentages are provided in square brackets [ ]

Table 2.10: Cost of Electricity in Ghana

Items		Index	2010	2011	2012	2013	2014
			Year				
Annual Residential Electricity Consumption by Households (Residential Class) (GWh)		A	2,738	2,761	2,803	3,228	3,223
Annual Total National Electricity Production (GWh).		$\sum B_i$	10,167	11,200	12,024	12,871	12,963
Annual Generation by Plant (GWh)	Hydrological	B_1	6,996	7,561	8,071	8,233	8387
	Thermal	B_2	3,171	3,639	3,953	4,635	4,572
	Solar (VRA)	B_3	N/A	N/A	N/A	3	4
Import		C	106	81	128	27	51
Export		D	1036	691	667	530	522
Distribution Losses		E	1,981	2,058	2,067	2,203	2,363
Transmission Losses		F	380	531	522	569.7	565.1
Tariff							
Annual Electricity End User Tariff (GHS/kWh)		G	0.211	0.245	0.232	0.307	0.464
Annual Electricity End User Tariff(GHS/GWh)		H	211,000	245,000	232,000	307,000	464,000
Residential Electricity Tariff layers							
0 - 50 (Exclusive)		I	9.5	9.5	9.5	11.1	18.6
51 - 300 (GHp/kWh)		J	14.5	16.5	17.6	21.1	37.2
301 - 600 (GHp/kWh)		K	18.5	21.3	22.8	27.3	48.4
600+ (GHp/kWh)		L	21.0	23.5	25.3	30.3	53.7
Service Charge (GHp/month)		M	100.0	153.5	165.3	197.9	350.1
Service Charge (GHS/Year)		N	12.0	18.396	19.836	23.748	42.012
Annual Average Residential Electricity Tariff (GHp/GWh =Average(I,J,K,L))		O	15.9	17.7	18.8	22.4	39.5
Annual Average Residential Electricity Tariff in GHS/GWh =Average(I,J,K,L)		P	0.159	0.177	0.188	0.224	0.395
Number of Households (2010 Census data)		Q	1,036,426	1,036,426	1,036,426	1,036,426	1,036,426
Cost of Electricity							
Annual Household Total Cost of Electricity [GHS Million]) $\sum\gamma_i = ((A * P + M * Q)/1{,}000{,}000)$		$\sum\gamma_i$	463.64	525.56	566.72	744.02	**1,363.00**

Source: Authors Computation with data from Energy Commission of Ghana (2015). †We have assumed that each household has one electricity meter.

‡The number of households used here suggest that our estimate should be treated as a lower bound (The number of households is assumed to be constant from 2010-2016 although the population growth rate is estimated at 1.82%).

Table 2.11: Summary of Literature

No.	Author(s)	Country	Good/Service Valued	Valuation Method	Econometric Technique	Results
1	Adenikinju (2005)	Nigeria	Electricity Cost to Firms	PFA:WTP	OLS	N19.66-65.83/ kilowatt-hr
2	Menegaki (2008)	Mexico	Renewable Energy	Review	N/A	Research gap exist that is yet to be filled
3	Abdullah and Mariel (2010)	Kenya	Electricity services	CE	Mixed logit	Mean WTP across scenarios ranges from KSh. 28.30-74.91
4	Oliver et al. (2011)	South Africa	Premium priced green electricity	WTP	Logit	R44.72- R201.18
5	Abdullah and Jeanty (2011)	Kenya	Renewable Energy for rural electrification	CVM:WTP	Nonparametric and a parametric model	Respondents are WTP more for GE services than PV
6	du Preez et al. (2012)	South Africa	wind farm	CVM:WTA	Logit	R40,891.29/M
7	Gunatilake et al. (2012)	India	24 hour electricity supply	CVM:WTP	OLS/Probit	Rs.219/233/M
8	Aravena et al. (2012)	Chile	RES	CVM:WTP	Logit	RES over hydro from large dams $350m /yr. RES over Fossil Fuel is $413m/ yr
9	Abdullah and Markandya (2012)	Kenya	Grid electricity (GE) and solar photovoltaic (PV)services	CVM:WTP	N/A	PV=$10, GE=($13) PV option appear to be a more fruitful direction for gov't programs to pursue.
10	Hosking et al. (2012)	South Africa	Location of Wind Turbine Farms	CE:WTA for reduction in subsidy (WTP)	M-Logit	High Income WTA = R1088.28-R4302.44 Lower Income WTA = R21.38-R84.51
11	Zhang and Wu (2012)	China	green electricity	CVM:WTP	M-Logit	Average WTP is RMB 7.91($1.15)-10.30($1. 51) yuan/month
12	Twerefou (2014)	Ghana	Improved electricity	CVM:WTP	Ordered Probit	¢0.2734 / kilowatt-hr
13.	Taal and Kyeremeh (2015)	Ghana	Reliable Electricity	CVM:WTP	Tobit	Average additional WTP amount is GHS6.80
14	Ma et al. (2015)	Mixed	Renewable Energy	WTP	Meta-Analysis	Higher WTP for electricity from solar than wind, hydro or biomass

Appendix B2. Questionnaire

Interviewer: ………………………………

Supervisor…………………………………..

Region: ……………………………………….

Metropolitan Area……………………..

Locality……………………………...........

Interview date :………../………../ 2014

Start Time: Hrs.……../Min………

End Time: Hrs...……../Min……….

Survey Price Draw

Yes[ ]	No:
No[ ]	Thanks

TOPIC: Demand for Electricity in Ghana: Validity Tests for CV Responses

District………………………………

House Number……………………….

Respondent's ID…………………….

Language used in the survey:

1. **English** [ ]
2. **Twi** [ ]
3. **Ga** [ ]
4. **Ewe** [ ]
5. **Other** [ ]

A BRIEF BACKGROUND OF STUDENT

My name is [Give Name and show I.D]. I'm part of a team headed by Anthony Amoah, a PhD student from the School of Economics, University of East Anglia, UK. He is conducting a survey of people's opinions about the electricity situation in Ghana.

I humbly wish to request your kind participation in this research, which aims at estimating the economic value of electricity in Ghana. The research does not probe into your private affairs but we are interested in your personal perception and experience of electricity supply in Ghana. Your answers will only be used for empirical analysis in the framework of this research**.** Your information will not be shared or used for any other purpose. It will be treated as ***strictly confidential.*** Nevertheless, you still reserve the right to refuse or indicate don't know to questions where necessary. Completing this survey automatically enters you into a free rechargeable mobile credit draw (if you wish) where you could win one of the ten GH¢10 mobile credits.

Thank you very much for your kind cooperation.

NB. Please tick [✓], underline or write where appropriate.

Part I: BIO-DATA

A. Respondent's household status: [ ]
   1. Head 4. Parent of Head
   2. Wife of Head 5. Child of Head
   3. Husband of Head 6. Other: If other, specify……….

B. Year of birth (If provided skip QC): [ ]

C. Age range (Age in completed years):
1.18-29 3. 40-49
2. 30-39 4. 50+

D. What is your gender?
0. Male
1. Female

E. How long have you lived in Accra?
1. Whole life
2. More than 10 years
3. 5 10 years
4. 2-5 years
5. Less than 2 years

F. What is your marital status?
1. Single
2. Married
3. Widowed
4. Divorced

G. What is the highest level of education you have completed?
1. No schooling
2. Primary
3. JHSS
4. SHS
5. Polytechnic
6. Professional degree
7. First degree
8. Advanced degree

H. What is your current occupation?
1. Student
2. Unemployed or casual workers
3. Employed
4. Self-employed
5. Inactive (e.g. housewife)
6. Retired
7. Other

I. Do you consider your earnings on a monthly or weekly basis?
0 Monthly
1 Weekly

J. How much do you earn on average per month in Ghana cedis?

1. <160 **2.**160-599 **3.**600-999 **4.**1000-1399 **5.**1400-1799 **6.**1800-2199 **7.**2200-2599 **8.**2600-2999 **9.**3000-3399 **10.**3400-3799 **11.**3800-4199 1**2.**4200-4599 **13.** 4600-5999 **14.** ≥6000 **15.** I don’t know **16.**I won’t tell you

K. Who usually makes the final financial decisions in your household?
1. Me/Respondent only
2. Spouse only
3. Parent(s) only
4. Other senior relative
5. Joint decisions incl. me
6. Joint decisions not incl. me
7. Other

Part II: [Used] Contingent Valuation Questions on Electricity

A: Some Electricity Consumption Questions

L. Do you have electricity supply 24 hours in a day throughout the year? Yes [ ] No [ ] ; ***24hr_ec***

M. How much do you currently pay as electricity bill per month? GH¢………..; ***ec_bill***

***B: Willingness-to-pay* for Electricity**

N. Assuming your household is provided with a 24 hour electricity supply. Would your household be willing to pay GH¢………… per month?

YES [ ] No [ ]; ***ec_starting point response***

- If No, (NB: decrease it by GH¢5) what about GH¢ ………per Month? ***ec_first charge***

  Yes [ ] No [ ] ***ec_first charge response***

- If No, please specify amount which your household would be willing to pay GH¢…… ***ec_final***

- If yes (NB: Increase it by GH¢10), continue….
  GH¢…………………….. per month. ***ec_first charge***

  YES [ ] NO [ ] ; ***ec_first charge response***

If **yes**, it means your household would be willing to pay more. Please state your maximum amount per month in GH¢……….. ; ***ec_final***

If **no**, it means your household would be willing to pay less. Please state your maximum amount per month in GH¢…………. ***ec_final***

O. Assume your household is to be provided with a 24-hour electricity supply, however, it is not reliable. How much will you accept as compensation from the government per month for the current power shortages [Note: 24-hour off, 12-hours on]? .... ***ec_compensation***

CHAPTER THREE

Estimating Demand for Reliable Piped-Water Services in Urban Ghana: An Application of Competing Valuation Approaches.

1. Introduction

Over the past three decades substantial progress has been made towards global domestic water security. Despite the global success in meeting the 7th Millennium Development Goal[17], several developing countries still suffer from poor water supply problems and the associated consequences. It is estimated that about 780 million people mainly from developing countries are still without access to clean drinking water (Salaam-Blyther, 2012). Ironically, some of these countries have abundant water resources. Ghana, for example, is naturally endowed with a sizeable amount of renewable fresh water for domestic and other uses. UNICEF and the World Health Organization (UNICEF/WHO, 2012) report that, an estimated 91% of urban Population in Ghana have access to improved water supply while 33% have piped-water on their premises. This is, however, highly erratic and undependable. Taylor et al. (2002) confirm the erratic nature of water supply, and indicate that less than 10 percent of the population enjoy a reliable in-house potable water connection. Most (87%) of these people are either officials in the public service or high income individuals in the private sector (Owusu and Lundehn, 2006). Water rationing and low quality storage systems, however, leave large portions of the population without adequate potable water (see Stoler et al. 2012).

This situation has since the early 1990s been attributed to high operational costs and low revenue returns (Water Aid, 2005). World Bank (1991), and Brookshire and Whittington (1993) have proposed full cost recovery programmes in the water sector as a way of bridging the cost-revenue gap, in an attempt to solve the supply-deficit gap. They suggest government and donor exclusion but full consumer inclusion in the payment of water supply in Ghana.

However, due to information asymmetry among agents, these suggestions have been disattended. According to Ghana's National Water Policy (2007), one major challenge in the water sector is realistic pricing, the main uncertainty relates to how

[17] To halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation. Currently, more than 2.1 billion people have gained access to improved drinking water sources since 1990, exceeding the MDG target (88%) by 1%. This makes 6.1 billion (89%) having access to improved drinking water sources (see UN Dept. of Public Information, September 2013).

much consumers would be actually willing to pay for improved water services. This study seeks to fill this informational gap.

This study aims to inform policy making and provide useful guidance for reliable piped-water supply. This is achieved by estimating households' willingness to pay and undertaking a cost & benefit analysis for reliable piped-water supply. The choice by researchers on preferred method is sometimes subjective, therefore application of several methods to same choices provide some degree of neutrality (see Carson et al., 1996) and validate estimates.

This study applies and compares three different valuation techniques, namely the Hedonic Price Method (HPM), the Travel Cost Method (TC) and the Contingent Valuation Method (CVM), to estimate the willingness to pay (WTP) for a reliable piped-water supply. Thus, the main contribution of this paper is its application of three independent valuation methods to provide robust estimates of the WTP to inform policy. The estimates seek to bridge the information asymmetry gap in this market by providing evidence for investment in the water sector. In line with providing information to inform policy, we find WTP to constitute 3-8% of households' income. In addition, our cost & benefit analysis show a positive net benefit for investing in reliable piped-water supply in Ghana. Our results are consistent with existing studies on WTP for piped-water as seen in the literature such as Van Den Berg and Nauges (2012), and Choumert (2014b).

The rest of this study is structured as follows: Section 2 reviews previous studies relevant to the study. An overview of the methodological framework used in the study is presented in section 3. The data collection processes are presented in section 4. Section 5 shows the econometric modelling of the various valuation methods used. The estimation and discussions of results are presented in section 6. Section 7 presents the conclusion and policy relevance of the paper.

2. Review of Previous Studies

Here, we discuss empirical studies on residential water demand in both developed and developing countries. We also discuss single and multiple valuation methods used in general valuation studies.

Empirical studies on residential water demand dates back to notable works by the likes of Metcalf (1926), Seidel and Baumann (1957), Fourt (1958), Renshaw (1958) and Gottlieb (1963). Since then, more studies have taken place in developed countries than in developing countries. Evidence from the literature shows that there have been more studies in the USA on this than any other country. Further evidence in a study by Worthington and Hoffman (2008) shows that since the 1980s there have been more published studies in this area in the USA than in any other country. Metcalf (1926) studied the relationship between water rates and growth in population based on per capita consumption. Here, a cross-sectional study of 30 cities was used and the findings show that city size affects per capita water consumption positively. The study obtained a price elasticity of -0.65. Gottlieb (1963) also estimated residential water demand for Kansas in the USA where he found income elasticity of 0.28 to 0.58 and price elasticity of -0.66 to -1.24. A similar country study was done by Howe and Linaweaver (1967) using a cross-sectional analysis, they estimated demand using ordinary least squares and concluded that the demand for residential water is price inelastic (-0.23) for off peak periods. Some of the earlier studies in the literature which include Metcalf (1926) and Gottlieb (1963) are reported by Barkatullah (1999) for using average prices rather than marginal prices as it led to exaggeration of their prices. Also, different elasticities observed in the literature have been acknowledged by Dalhuisen et al. (2003) in their meta-analysis with 64 studies to be attributed to functional forms, aggregation levels, data features and other estimation issues.

Other notable contributions in this area of research have sought to investigate the cost-benefit analysis of having improved water services or projects. Gramlich (1977) in his study on the demand for clean water, the case of the Charles River in the USA used the CVM and concluded that the project will not have a positive net benefit as the benefit is of the same order as the cost. Similar findings is seen in Carson et al. (1993) in their study on the value of clean water with focus on the public's WTP for boatable, fishing and swimmable quality water. Pattanayak (2006) used 1800 households in a WTP study in Sri Lank and found that demand for piped services was low and private sector involvement would fail. These evidence suggest that net benefit for WTP studies is not always positive.

Contrary to the studies by Gramlich (1977), Carson et al. (1993) and Pattanayak (2006) where the net benefit was found not to be positive; Briscoe et al. (1990), Whittington et al. (2002), and Soto Montes de Oca et al. (2003) found net benefits to be positive. In the case of Briscoe et al. (1990) who worked on ensuring equitable and sustainable rural water supplies in Brazil, they found that major increases in tariffs for yard taps can attract the private sector and reduce subsidies. Also, with the first evidence from South Asia, Whittington et al. (2002) looked at only piped water services in Nepal unlike Nauges and Van den Berg (2009) who investigated both piped and non-piped. Using the CVM and Probit model they found that households WTP for improved services are much higher than their current water cost.

The first developing country water demand study was undertaken by White et al. (1972). In their study on drawers of water; with focus on domestic water use, they used interviews which were obtained from 1966-1968 and observations at 34 study sites in Kenya, Uganda and Tanzania. They found that piping spring is not feasible for urban high density but ideal for houses in dispersed highland humid areas. Subsequent to this is the study on income and price elasticities of demand for water by Katzman (1977). This cross-sectional study was based on a random sample of 1400 households in Malaysia. He found an income elasticity of 0.2 to 0.4 and a price elasticity of -0.2 to -0.1. It is observed that studies in developing countries have mainly used cross sectional data because of the challenges of obtaining secondary data in these countries. A more recent study by Nauges and Van den Berg (2009) using cross-sectional household data in Sri-Lanka estimated price elasticity with Probit and Tobit models and found price elasticity of -0.15 for only piped-water and -0.37 for piped and other sources.

In the area of water demand and valuation methods in developing countries, studies have mostly used the CVM followed by the HPM and the TCM. It is observed that mostly, single method studies use CVM or HPM with few considering the TCM. Single CVM studies include Whittington et al. (1990a), Briscoe et al. (1990), Whittington et al. (2002), and Soto Montes de Oca et al. (2003). Whittington et al. (1990a) used CVM and Ordered Probit econometric approach in estimating demand for water services in developing countries, with Haiti as a case study. They found CVM to be a feasible method in estimating individuals’ WTP for improved water services. Single HPM studies include Anselin et al. (2008), Nauges and Van Den Berg (2009) and Vásquez (2013a, 2013b). Single TCM studies include Smith & Desvousges (1985), and Hedonic Travel Cost also includes Brown & Mendelsohn (1984) and Bockstael et al. (1987). Current trend of research prefer the other single methods to TCM in water demand studies.

Application of several methods in a single study dates back to the work of Knetsch and Davis (1966) where they compared the CVM and TCM for forest recreation evaluation. 185 users were interviewed in Maine-USA. They found that CVM estimates are greater than TCM estimates. They observed however some degree of closeness (12%) in the two estimates. Similarly, Choe et al. (1996) estimated the economic benefits of surface water quality improvements in developing countries using CVM and TCM methods. They found that these methods provide close estimates and are quite low, both in absolute terms and as a percentage of income. In addition, Brookshire et al. (1985) investigated a test of the expected utility model with evidence from earthquake risks in Los Angeles and San Francisco using the CVM and HPM. They found that CVM and HPM are quite similar. In both cases, similar findings are also found in Cummings et al.(1986), Carson et al. (1996), MacNair and Desvousges (2007). With TCM and HPM, Bateman (1993) acknowledges the closeness of these methods however he observes that both methods do not capture non-use values yet with strong assumptions they produce valid and similar welfare estimates. It is also observed by Carson et al. (1996) and Devicienti et al. (2004) that CVM estimates are averagely smaller but not grossly smaller than revealed preference (RP) estimates. However, Carson et al. (1996) were quick to acknowledge that it is not in all cases that stated preference (SP) estimates are smaller than revealed preference estimates. This suggests inconclusiveness in empirical studies on the method that provides relatively greater estimates. Albeit, most studies agree on the similarity in SP and RP estimates.

Regarding water valuation studies in Ghana, there has not been a single study that combined more than one of the valuation methods. There are a few single-method "weak" studies that focused on water demand such as Quartey (2011) and Botchway, (2013). These studies are flawed to a certain extent as their sample sizes are not representative of the total population of the study area. Botchway (2013) acknowledges that his sample is not representative due to time and financial constraints hence their results are handled with caution. In contrast, other notable studies found in the literature which include Boadu (1992), Whittington et al. (1993) and Berry et al. (2012) had different focus other than domestic water demand. In broader sense, Boadu (1992) looked at the case of rural households, Whittington et al. (1993) investigated sanitation services and Berry et al. (2012) examined WTP for household water filters. It is important to state that the cost of such valuation studies especially using large samples is quite high hence not much has been done in Ghana. Whittington and Pagiola (2012) while reviewing CVM studies in developing countries have observed that quality and usefulness of CVM studies could be improved at only a modest increase in costs.

These empirical studies are important because they show the possible valuation methods useful for this study and their expected results. Also, it highlights significant gaps in the studies, especially in the case of Ghana and other developing countries as already mentioned, which need to be bridged.

3. Overview and Methodological Framework of Valuation Methods

This section presents an overview of all the three valuation methods and their methodological frameworks used in the study.

3.1 The Hedonic Price Method (HPM)

The HPM is an indirect valuation method for non-market goods which follows the RP theory. This method has been applied to several valuation areas or markets which include but is not limited to estimating the economic value of characteristics of say property (e.g. Palmquist, 2003; Blomquist and Worley, 1981; Rosen, 1974); wine (e.g. Nerlove,1995); food (e.g. Wilson and Preszler, 1993); automobile (Court, 1939); computer (e.g. Triplett, 1989); housing (e.g. Bartik and Smith, 1987); prostitution (e.g. Moffatt and Peters, 2004), Marriage (e.g. Rao, 1993); quality changes(e.g. Muellbauer, 1974); pollution, noise/quite (e.g. McMillan et al., 1980); road traffic (e.g. Bateman et al., 2001); Water (e.g. Choumert, 2014a,b; Vásquez, 2013a; Van Den Berg and Nauges, 2012). For environmental and natural resource valuation studies (such as access to water, access to publicly supplied amenities, noise, air quality, etc.), the housing market approach is widely used. In this study, the HPM is based on the presumption that real rental values are a function of the characteristics of the area and the house. For example, rental values are formulated as a function of structural characteristics (e.g. dwelling age, number of rooms, size of living space, number of stories; access to water, toilet, electricity in residence etc.), neighbourhood characteristics (e.g. mean-neighbourhood income, crime rate, distance to school, work, market, transportation, other public services), and environmental characteristics (e.g. aesthetic view, noise/air pollution or quietness, etc.) (see Choumert et al., 2014b; Van den Berg and Nauges, 2012; Birr-Pedersen, 2008; Rosen 1974).

The basic intuition of this approach in this study is that a house can be fully characterised by its attributes (structural, neighbourhood and environmental), and that price differentials reflect the values associated with the different attributes of the house in question. Thus, the valuation of piped-water is based on the presumption that the rental value of a house is a function of the house's attributes which include piped-water. This relationship has its foundations in the consumer demand theory. Following Birr-Pedersen (2008), Zabel (2004), Malpezzi (2002), Day (2001) and Sheppard (1999), we assume a rational household with a fixed income, M, and the price function $P(\mathbf{z})$ that obtains utility by consuming vector **z** of different attributes, plus consumption of a composite good x which is normalised to take a unit price of one. These vectors explain variations in household preferences. This expression can be presented by the utility function:

$$u_i = u(\mathbf{z}, x, \boldsymbol{\alpha}) \tag{3.1}$$

Thus, the household's level of utility is conditioned on the vector $(\boldsymbol{\alpha})$. Where $\boldsymbol{\alpha}$ is a vector parameter captured in the model to explain both observable and unobservable household characteristics. We further assume that a household faces a static setting in preferences which is conditioned on his budget constraint. The household maximises utility subject to his budget constraint specified as equation 3.2.

$$\max_{z,x}: u(\mathbf{z}, x; \boldsymbol{\alpha}) \quad \text{s.t} \quad P(\mathbf{z}) + x \leq M \tag{3.2}$$

$$L = u(z, x, \alpha) + \lambda\big(M - x - P(\mathbf{z})\big) \tag{3.3}$$

We obtain equation 3.4 which shows the implicit price function or implicit marginal price for the property attribute z_i from the partial derivatives of equation 3.3.

$$P(\mathbf{z}_i) = \frac{\partial P}{\partial z_i} \tag{3.4}$$

This method was formalised by Rosen (1974). He assumes perfect competition and perfect observability of attributes. However, this assumption is not applicable in this study considering the fact that the property market is heterogeneous. We consider a property market that is described by n attributes,

$$P(\mathbf{z}_i) = P\big(z_1, z_{2,} \ldots \ldots z_n\big) \tag{3.5}$$

…and denote $\mathbf{z}_i$ as measuring amount of i^{th} attribute in the property, **z**. The houses in this market are assumed to be unique intrinsically and extrinsically. Following the processes of the HPM as presented by Choumert et al. (2014b), we determine the implicit marginal price of the different attributes from the aggregate price of the property, $P(\mathbf{z})$. The partial derivative of the aggregate price function relative to an attribute ($\mathbf{z}_i$), yields the implicit marginal price, p_i, herein referred to as the marginal willingness to pay for the attribute i.

In short, two stages can be applied in determining the marginal willingness to pay for an attribute. First, determine implicit prices of attributes associated with the good, and then the summation of the implicit prices, multiplied by the measure of the attribute will equal the market price of the good (see Devicienti et al., 2004). In our case, we generate the implicit marginal price by regressing the monthly rental values on the various attributes which include access to reliable piped-water supply in residence. Then in the second stage, we multiply this implicit value by the average house value to yield the marginal willingness-to-pay for reliable piped-water supply in residences.

3.2 The Travel Cost Method (TCM)

As in the case of the HPM, TCM is also an observed indirect non-market valuation method which follows the RP theory. This method is recognised in literature as the oldest method of all economic valuation methods. It mainly uses consumption behaviour in related markets to determine economic values (Fleming and Cook, 2008). In 1947, this idea was first conceived and proposed by Harold Hotelling[18] in response to the director of the US National Park Service's request on how economic methods could be used to determine recreational benefits (Smith and Kaoru, 1990). Hotelling's idea was based on a possible inverse relationship between travel distances (price or direct and/or indirect cost of travel) and rates of visit (quantity or number of travel). This was achieved my measuring the differential travel rates and the associated travel distances that visitors had to cover in reaching the park (Ahmad, 2009).

This concept and methodology was first implemented individually by Trice and Wood (1958), Clawson (1959) and Clawson and Knetsch (1966). These authors together with Garrod and Willis (1999) have by way of application demonstrated the consistency of this method to economic theory. That is, all else constant, as the price of accessing a recreational site (cost of travel) rises, the rate of site visits falls (quantity). This method has been used extensively in outdoor recreational demand studies such as national parks, fishing, hunting etc. Albeit, some studies which include Bockstael et al. (1987) have applied it to value water improvement.

In spite of its shortcomings, Smith (1993, p.3), still recognises it as "…one of the 'success stories' of nonmarket valuation and occupies a major place in the applied research programmes of resource and environmental economists". This has been explained by Zanderson (2005) as being the case because estimates are generally consistent with consumer demand theory. She further argued that TCM offers a utility consistent and robust methodology which explains factors that significantly explain variance in valuation outcomes.

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[18] Hotelling's (1949) letter - which was dated 1947 - originally described the method as follows: Let concentric zones be defined around each park so that the cost of travel to the park from all points in one of these zones is approximately constant. The persons entering the park in a year, or a suitable chosen sample of them, are to be listed according to the zone from which they came. The fact that they come means that the service of the park is at least worth the cost, and this cost can probably be estimated with fair accuracy. . A comparison of the cost of coming from a zone with the number of people who do come from it, together with a count of the population of the zone, enables us to plot one point for each zone on a demand curve for the service of the park. By a judicious process of fitting, it should be possible to get a good enough approximation to this demand curve to provide, through integration, a measure of consumers' surplus.. .(See Smith and Kaoru, 1990, p.267)

Given individual household's income, M_i, the i^{th} individual household chooses V_{ij} round-trips to haul for water assuming a single location or site (j) at a travel cost C_{ij}. The individual household's utility function can be expressed as

$$U_i = u(V_{ij}, z_i) \quad (3.6)$$

Where z is described as the Hicksian composite good. Here we assume that the location household's travel to haul for water is separable from all other locations. The individual household maximises utility subject to his budget constraint specified as equation (3.7):

$$\max_{V,z}: u(V_{ij}, z_i) \ \text{s.t.} \quad C_i V_{ij} + z \leq M_i \quad (3.7)$$

In the words of Garrod and Willis (1999, p.55), TCM is usually estimated as a trip generating function. This is simply presented as:

$$V = f\ (C, \boldsymbol{S}) \quad (3.8)$$

Here; V is the visit rate, C is the cost of travel to the site and **S** is a vector of travel cost to substitute sites. This function is presented by Garrod and Willis (1999); and Bateman (1993) in two main forms namely the Zonal Travel Cost Method (ZTCM) and the Individual Travel Cost Method (ITCM). The main difference between the two methods is that the dependent variable of ITCM is defined as V_{ij}, the number of visits made per period by individual i to site j (See Brown and Nawas, 1973; Gum and Martin, 1975 and Bateman, 1993) while ZTCM is defined as V_{hj}/N_h which represents visits per capita for zone h to site j (See Garrod and Willis, 1999 and Bateman, 1993). By way of comparison, according to Garrod and Willis (1999), the ITCM is observed to have a distinct advantage over the ZTCM in that while the latter depends on zonal aggregate data which does not take into account inherent variation in the data, the former does. Moreover, the ITCM is regarded to be statistically more efficient. We focus on the ITCM which allows the specification of a number of individual (household)-specific explanatory variables. This can be modelled as:

$$V_{ij} = f\ (C_{ij}, T_{ij}\ \boldsymbol{X_j}, \boldsymbol{S}_{j,} \boldsymbol{Q_i}) \quad (3.9)$$

Again, V_{ij} is the number of round-trips made by individual household i to site$j$; C_{ij} is the travel cost incurred by individual household i when visiting site j; T_{ij} is the time cost incurred by individual household i when visiting site j; $\boldsymbol{X_j}$ is a vector of the perceived qualities of the site j; $\boldsymbol{S}_j$ is a vector of characteristics of available substitute sites, $\boldsymbol{Q_n}$ is a vector of socioeconomic characteristics of individual household i.

3.3 The Contingent Valuation Method (CVM)

Following the work of Hotelling (1947) and Ciriacy-Wantrup (1947), Robert Davis (1963) also initiated and formalised the basic foundation of bidding methods or bidding games as a way of describing the iterative question regarding respondent's maximum amount they would pay for a specified commodity. This was an attempt by researchers to put values on non-market goods unlike market goods. One useful technique proposed is the stated preference method. The contributions in the 70s which include Randall et al. (1974), Hammack and Brown (1974) and Brookshire et al. (1976) saw the earnest development of stated preference method. This method includes contingent valuation method, and choice experiments[19].

These methods follow the idea that individual's behaviours are observed as they provide responses to hypothetical questions. The theoretical basis for such an approach to valuing environmental assets relies on microeconomic welfare theory where individuals or households maximize their utility under income constraint, or minimize their expenditure under utility constraint (Spash, 2008; Hanley and Spash, 1993). This is what the neoclassical theorists refer to as neoclassical rationality which is understood to imply 'maximization and individualist'. Vatn (2004) explains 'maximization' to be based on the assumptions of completeness, transitivity and continuity[20]. In addition, 'individualist' is taken to mean that the consumer is autonomous and that his acts are independent of social contexts. Thus, consumers are assumed to make rational decisions or choices if preferences are rational. For example, holding all else constant, a consumer would be expected to behave rationally if he is provided with an improved version of an unimproved drinking-water.

The CVM is described by Garrod and Willis (1999) as an essential tool in resource valuation because revealed preference, or behaviour in markets, cannot be used to determine the economic value of all commodities. A chapter by Stewart and Kahn in Alberini and Kahn (2006) presents the CVM as a survey-based approach for estimating the value of non-market commodities based on how a subject responds to a question about his/her WTP or WTA compensation to obtain or forgo a change in quantity or quality of the commodity. The main theory underlying CVM is based on the assumption that individuals are equally strategic in their behaviour. In as much

[19] Sometimes referred to as conjoint analysis or choice modelling (see Hanley and Barbier, 2009; Stewart and Kahn in Alberini and Kahn, 2006)

[20] According to the formal definitions (See Gravelle and Rees, 2004) preferences are complete if for all x and y in X : $x \geq y$ or $y \geq x$. They are transitive if for all x, y, and z in X where $x \geq y$ and $y \geq z$, then also $x \geq z$ holds. Finally, preferences are continuous if x is preferred over y and z is sufficiently close to y, then x is also preferred over z.

as the CVM is acknowledged to have become the most widely used technique for monetary valuation of especially environmental assets (Spash, 2008; Hanley and Barbier, 2009); it is also regarded as the most controversial of all environmental valuation methods (Hanley and Barbier, 2009).

However, the advantages of the CVM cannot be overemphasized. Mitchel and Carson (1989) provides some strengths of this method and this include flexibility of the hypothetical methods. This implies that the method is flexible to the extent that the researcher in his design can provide a variety of states of the good being valued and its associated conditions. They further cited Sen (1977, 339-340) to have observed that, "once we give up the assumption that observing choices is the only source of data on welfare, a whole new world opens up, liberating us from the informational shackles of the traditional approach". A second advantage is it helps to obtain ex-ante judgements. This allows WTP amounts for existence values to be obtained which is not possible with just observed behaviours. Thus, both use and non-use values are estimable by this method. Lastly, the problem of wrong assumptions leading to potential bias vis a vis the form of individual utility functions is avoided. This is because the CVM is able to directly measure specific points of the individual's compensated demand curve. As part of their conclusion, they indicated that CVM is a method "simultaneously capable of obtaining option price estimates in the presence of uncertainty, valuing goods not previously available or marketed, estimating all existence class-benefits, and obtaining in a direct manner the relevant Hicksian demand curves" (p.90).

We present the theoretical framework of the CVM for chapter three of the thesis following Irvin et al. (2007). We assume that consumers maximize their consumption preferences subject to their income and prices (budget constraint). This is presented as:

$$\max_{\mathrm{x},q} U(\mathrm{x},q) \qquad s.t. \;\; y = q + px \tag{3.10}$$

Where y represents the income of respondent, q is a composite of all other goods and services, p and x are the marginal price and quantity of piped-water respectively. From the maximisation problem specified in equation 3.10, we obtain the indirect utility function as:

$$v(p,y) = \max_{x,q}\{U(x,q)|px + q = y\} \tag{3.11}$$

We specify the respondents WTP as a proportion of his income spent on reliable piped-water. We show the reliable piped-water as an increment in respondent's expenditure, $x^1 > x$. This is shown in equation 3.12.

$$v(p,x,y) = v(p,x^1,y - WTP) \tag{3.12}$$

The respondent's utility is assumed to change from u^0 to u^1 which we show as

$$u^0 = v(p, x, y) < u^1 = v(p, x^1, y)$$

The inverted utility maximisation is expenditure minimisation, so we specify the expenditure function as:

$$e(p, u) = \min_{x,q}\{px + q \,|\, u^1(q, x^1) > u^0(q, x^0)\}$$

WTP is shown as the difference between the expenditure functions specified as

$$WTP = e\big(p, x, v(p, x, y)\big) - e(p, x^1, v(p, x^1, y)) \quad (3.12)$$

We also obtain the compensating surplus function where WTP is a function of some factors,

$$CS(x, x^1) = WTP = e(p, x^1, v(p, x^1, y)) - y \quad (3.13)$$

Equation 3.13 (compensating surplus function) represents a measure of WTP for the reliable piped-water as a function of quantity of water and income of households. Thus, it shows how much each household is willing to sacrifice and yet remain on the same utility level (u^0) before the change. For empirical purposes we rewrite the structural economic function given by equation 3.13 into an econometric function. Here we assume that the WTP function in equation 3.13 takes the following parametric linear form:

$$WTP_i = \gamma + \varphi p_i + \propto q_i^1 + \partial y_i + \varepsilon_i \quad (3.14)$$

We rewrite equation 3.14 assuming that the maximum amount household i is willing to pay for reliable piped-water is posited as WTP_i. The error term is represented as ε_i which follows a normal distribution function with mean zero and standard deviation (σ). In addition to the regressors in equation 3.14, factors such as fence type, number of households, other family members (family size), age, age squared, knowledge of local and international environmental issues have the potential to explain household's WTP for reliable piped-water. Furthermore, these factors are more likely to correlate with income and quantity hence omitting them from the model is likely to lead to omitted variable bias. To ensure consistent and efficiency of the parameters in the WTP function we account for these additional factors in our empirical specification. We specify our explicit a linear functional relationship as:

$$WTP_i = \gamma + \varphi p_i + \propto q_i^1 + \partial y_i + \mathbf{X}_i\boldsymbol{\beta} + \varepsilon_i \quad (3.15)$$

Where $\mathbf{X}$ is a vector of household characteristics, $\boldsymbol{\beta}$ is a vector of parameters to be estimated. All other variables remain as already defined.

From the theoretical point of view we expect the CVM which captures both use and non-use values to be greater than the HPM and TCM methods which captures on use values. In short, we expect the SP method to be greater than the RP methods.

4. Data

This section presents a description of the study area and population, data collection process, sampling frame, sampling technique and sample size computation.

4.1 Study Area and Population

The Republic of Ghana is a sovereign state endowed with a broad range of natural resources, which include but are not limited to crude oil, water resources, gold, diamond, and timber. The population of Ghana is over 25million. Politically, it has consolidated democratic rule and it is described by experts as having made giant strides in democratic rule especially after their 2012 elections. Economically, until most recently, it was regarded as one of the best performing economies in Africa. Ghana's Gross Domestic Product (GDP) growth reached a record high of 14.05% in 2011. From 2008 up until 2013 it recoded an average annual GDP growth of about 8.6% which is more than twice that of the average of the whole sub-Saharan Africa which recoded about 4.1%. Ghana attained a lower middle income status in 2007 with a GDP per capita of (current US$) 1,099 and still is (World Bank, 2014).

The study focuses on the Greater Accra Region (GAR) of Ghana on grounds that it is one of the hardest hit regions regarding acute water shortages and has since 1970s dominated in the percentage increase in the share of households[21]. This region has the current highest proportion of urban household of 31.2%. Moreover, GAR has Accra as its capital city and has been Ghana's capital since 1877. It has the highest population density and is the second most populous region in Ghana. It is also seen as one of the most populated and fastest growing Metropolis in Africa (AMA, 2006)[22]. GAR is made up of Metropolitan/Municipal and/or District Assemblies. Until recently that new districts [23] have been created, it consisted of ten administrative regions. According to the 2010 Housing and Population Census (GSS, 2012), the total population of the GAR with ten districts is 4,010,054. The population in households is 3,888,512 with male and female distributions as 1,938,225 and 2,071,829 respectively. The total number of households is 1,036,426 with an urban household population of 766,955 and a rural household population of 269,471. Since this study focuses on the urban household, the reference population is represented by the 766,955 urban households.

[21] 1970-1984 stood at 66.9%, 1984-2000 also stood at 74.6%, and 2000-2010 recorded 65.4%. (Source GSS, 2012 P.71)

[22] Accra Metropolitan Assembly (AMA, 2006) accessed @http://ama.ghanadistricts.gov.gh on

[23] The new districts as of the time of the study was constrained by complete population and household data. Therefore the data as of the last population census was used for this study.

4.2 Data Collection Process

This study used a sample size of 1,650 household heads who were interviewed in the survey using a questionnaire. The study designed a structured questionnaire (see appendix B) which included the personal data of the respondent, besides general water, sanitation and environmental questions; hedonic valuation questions, travel cost questions; and contingent valuation questions. The questionnaires were administered by 20 fieldworkers and 4 coordinators under the overall supervision of the researcher. They were first trained, and were made to undertake a pre-pilot survey before the actual pilot survey so as to build their experience with the questionnaire. The data was collected between March and May, 2014. This period represents a balanced season for the South so we do not expect the seasons to influence our data.

The in-person survey method which has been described as the method of choice in surveys by Mitchel and Carson (1988) was used to control for sampling problems and low response rate associated with telephone and mail surveys. They further acknowledged that in the case of moderately lengthy valuation surveys as in this case, it is highly recommended to use the in-person technique so as to maintain respondents' interest to control for fatigue and boredom effects.

4.3 Sampling Frame

Mitchel and Carson (1988) suggest that after a properly defined population, one important factor that can affect the generalisation of results is how the sampling frame is structured. They argue that when there is a divergence between population of the study and the sampling frame, sampling frame bias occurrence is possible. They recommended that the area should be geographically-defined with occupied dwelling units. In this study, the sampling frame was mainly housing units within each district. The district should be one of the ten districts in the GAR of Ghana ensuring sufficient geographical coverage and spatial variation. The unit of analysis were household level respondents mainly household heads who are 18years and above, and of sound mind. They should have worked within the last five years and are currently employed or unemployed within the last seven days of the month of the interview. They should be living in the district and not be visitors. All potential respondents reserved the right to either accept to participate or decline participation.

One problem observed in valuation studies is the intra-household allocation issues. According to Whittington and Pagiola (2012) this has been acknowledged by several other studies such as Adamowicz et al., 2005; Whittington et al., 2008; and Prabhu, 2010. To control for intra-household allocation issues, the simplest recommended approach is to consider the entire household as the sampling unit but interview whoever the household considers as the household head or decision maker

(Whittington and Pagiola, 2012). This they argue could either be the husband or the wife. However, in the cooperative bargaining case, this approach would be inadequate. In this study, the interviewers were made to find out who the head of the household was. The head was described as prescribed by the GSS (2012). That is one who is economically and socially responsible for the entire household. In the event of cooperative bargaining, the interviewers asked who bears majority of the household water cost and decision. Such a person was interviewed in this case.

4.4. Sampling Technique and Sample size computation

A valid application of valuation methods require an appropriate sampling survey technique and sample size computation. This sub-section discusses how both of them were determined in this study. Experts have recommended the use of probability sampling for valuation studies against the background that each economic agent (household) will have equal probability of being selected. Inappropriate sampling technique could lead to a substantial threat to WTP estimates (Mitchel and Carson, 1988). It is important to observe that drawing a probability sample at household level could be quite challenging in cases where there exist improper listing of houses and planned housing units as in most developing countries. Indeed, some researchers are therefore forced to use a smaller sample (see Whittington, 1998) which perhaps may not be representative enough. It is recommended that in such cases interviewers cover every house or every other house (FAO, 2000). This is quite problematic in developing countries like the GAR of Ghana where houses are not properly planned coupled with inappropriate listing. Although, the government is putting measures in place to ensure proper listing but this was not until the study. However, with the unplanned settlements in urban GAR, a multistage quota sampling technique was applied (see Whittington, 1998). This was achieved by clustering the region into ten districts, then into their respective communities. Then we listed these communities in each district following the Town and Country Planning list of communities and randomly selected the houses from these communities within the districts of the region. According to our quota, we interviewed all households in the sample houses within the randomly selected communities in the districts. In sum, we applied the multi-stage quota probability sampling technique in drawing our sample of 1,650 from the population.

Here, respondents are observed to have equal probability of being selected in the sample. Further, fieldworkers' task was to interview urban households in residences distributed around GAR at any time between 8am to 6pm (time hired) within the localities of all ten districts. This study adopts a simplified formula to calculate sample size as developed by Yamane (1967[see Appendix B Table 3.11]). This yielded a sample size of 400 households. However, the study used a sample size of

1,650 households from 10 districts. This is important because valuation studies of this nature require large sample sizes to control for large variance in respondents' responses (Mitchel and Carson, 1989). This helps to obtain from respondents responses that yields the desired level of precision (Boyle, 2003).

5. Econometric Modelling of Valuation Methods

Following the theoretical framework (sub-section 3.1) and the econometric proposition by Rosen (1974), the proposed model for HPM is stated as:

$$P(\mathrm{Z}) = \mathrm{P}(\mathrm{S}, \mathrm{N}, \mathrm{Q}) \tag{3.16}$$

$$\mathrm{Z} = \mathrm{f}(\mathrm{S}, \mathrm{N}, \mathrm{Q}) \tag{3.17}$$

Where dependent variable is the rental rate, $P(\mathrm{Z})$, **S** represents a vector of structural (or residential) characteristics, **N** denotes a vector of neighbourhood attributes /accessibility variables, and Q is neighbourhood socio-economic characteristics. **S** include access to reliable piped-water supply in residence(ARP), access to toilet facility in residence(T), access to installed water reservoir in residence(R), number of garages(G), and number of storeroom(SR). The priori expectation of the effects of these variables on rental rates are all positive. Thus, higher valued structural characteristics should influence rent values positively. **N** include distance to highway(DH), distance to financial institution(DFI), and distance to school(DS). More public neighbourhood characteristics should influence rent values positively. However, neighbourhood characteristics associated with negative externalities are expected to be negative on rent values.

The economics literature has provided little theoretical guidance on the specific functional forms of hedonic pricing and housing characteristics (see Lisi, 2013; Malpezzi, 2003; Taylor, 2003). Halvorsen and Pollakowski (1981) proposed a flexible functional form commonly used in empirical studies known as the Box-cox function. This however has been made unpopular by the likes of Cassel and Mendelsohn, 1985; Cropper et al., 1988, Sheppard, 1999; Choumert et al., 2014b. Their justification is based on the sensitivity of the data to small variations and difficulty in interpreting parameter estimates. Following Choumert et al. (2014b) who argue that simpler functional forms produce more stable parameter estimates, this study uses ordinary least squares with a log-lin and log-log functional forms. We re-write equation (3.17) in a more explicit form and specify our preferred log-lin econometric model as equation 3.18. We tweak it to include a proxy for wealth as shown in equation 3.19 and present results in model (1&3[see Table 3.1]).

$$lnV = \beta_0 + \beta_1 ARP + \beta_2 T + \beta_3 R + \beta_4 G + \beta_5 SR + \beta_6 DH + \beta_7 DFI + \beta_8 DS + \beta_9 \mathrm{Dum} + u \tag{3.18}$$

$$lnV = \beta_0 + \beta_1 ARP + \beta_2 T + \beta_3 R + \beta_4 G + \beta_5 SR + \beta_6 DH + \beta_7 DFI + \beta_8 DS + \beta_9 \mathrm{lnQ} + u \tag{3.19}$$

5.1 The Travel Cost Method (TCM)

The most common model employed for travel cost estimation is the single-sight model (Parsons, 2003). This is a demand model that seeks to estimate number of trips by a household to say a source of water supply over a period of time. Since demand is expressed as quantity demanded over price, the quantity demanded is represented by the number of trips a household make to the source of water supply. The price is also represented by cost per trip in reaching the source of water supply. Generally one would expect an inverse relationship between these two variables as in the case of its analogous demand form. From equation 3.9, we now follow Parsons' (2003) specification and present the estimated non-linear model as:

$$V_i = (\ln CM_i, \ln CO_i, ARP_i, R_i, OFM_i, \ln Y_i, S_i) \qquad (3.21)$$

Where $lnCM_i$ is the log of the amount it cost per round-trip for an individual household to visit the main source of water supply. We expect this to be negative. $lnCO_i$ is also the log of the cost per round-trip for an individual household to access other sources of water supply which accounts for substitution effect. This is expected to be positively related to V_i. APR_i denotes household access to reliable piped-water in residence, R_i represents household alternative source of water supply in residence such as boreholes and wells. This is represented as reservoir in residence, OFM_i is the other family members in household, lnY_i represents log of monthly income of the household, and S_i is household savings behaviour.

As in the case of the HPM discussed earlier, economic theory is not emphatic on the exact theoretical and appropriate functional form of travel cost models. However, it is important to note that in the case of the non-negative integer feature of round-trip or count data, truncation of data at zero visits, and some over-dispersion problems OLS is inappropriate and should be replaced by procedures such as maximum (ML) estimation (Shrestha et al., 2002; Bateman 1993).

It is against this background that studies (such as Creel and Loomis, 1990; Hellerstein, 1991; Feather et al., 1995; Hausman et al., 1995, Englin and Shonkwiler, 1995; Grogger and Carson, 1991; Cameron and Trivedi, 1998; Winkelmann, 2000; Shrestha et al., 2002; Ahmad, 2009 etc.) have used count data ML estimation techniques models such as Poisson and Negative Binomial. We therefore estimate the Negative Binomial model because of evidence of over-dispersion and use OLS and Poisson model for robustness checks.

5.2 The Contingent Valuation Method (CVM)

We simplify equation 3.15 to yield equation 3.22 following Whittington et al. (1990), and assume that the maximum amount an individual household (i) is willing to pay for a proposed service is given as WTP_i. Given the traditional consumer theory which suggests a relationship between price and quantity demanded or supplied, we presume a linear functional relationship between WTP_i and household's characteristics and attributes of the water sources. This is specified as:

$$WTP_i = \alpha + \mathbf{X}_i\boldsymbol{\beta} + u_i \qquad (3.22)$$

Where $\mathbf{X}_i$ is a vector of household's characteristics and attributes of the water sources, α and $\boldsymbol{\beta}$ are parameters of the model, u_i is the error term with a standard normal distribution. To determine WTP, the NOAA Panel Guidelines requires an "Accurate Description of the Program or Policy" or [Project] and for "adequate information" to be provided to respondents about the program being offered (Arrow et al. 1993, p.10). In this case, NOAA requires an accurate description of the (hypothetical) market.

Market Description of Commodity

- As part of the guidelines prescribed by NOAA in CV studies, (hypothetical) market description is one essential key that cannot be underestimated. In a simplified context, our market is an imaginary situation respondents are asked to demonstrate what they think they will do assuming they are behaving rationally. In this study, we describe the piped-water services that could be made available to households and their corresponding market values. An estimation of the demand for piped water is contingent upon the existence of our described market. Thus, households' WTP responses are based on how the market was described. The (hypothetical) market was to urge households to reveal their maximum WTP for an uninterrupted (reliable) pipe water. This study describes the target commodity to the household in a market-like situation in two phases (see appendix B) as: First, "*I would want to find out from you, if you value the provision of an improved water supply system in Ghana particularly in the Greater Accra Region. By improvement we mean you are connected to the Ghana Water Company Limited (GWCL) main lines, water flows directly in your residence at all times, and the quality of the water is up to an acceptable international standard…"* In the Second phase, *a picture (see Fig 3.1 & Fig 3.2) representing the scenario described in the first phase is shown and narrated to the respondent*.

This is also a preferred approach to describe a hypothetical market. Its implementation is to use visual aids such as pictures, maps, diagrams, figures, and tables (see Whittington and Pagiola, 2012; Labao et al., 2008; Boyle, 2003, 1989; Ahearn, et al., 2003). This helps the respondent especially in areas where the illiteracy level is quite high to appreciate the CV scenario being described. The clearer the market description the better position the buyer could express his preference. Whittington and Pagiola (2012) have argued that the use of visual aids during presentation of hypothetical CV market scenarios is an indicator of a high-quality CV study.

In this regard, the two phases were put together and the question asked was: *"Generally, we know that every good thing comes at a cost and you may be required to pay a permanent amount that will be factored into your water bills provided by GWCL. Suppose you are supplied with an uninterrupted (reliable) piped-water as orally and pictorially described, how much would your household be willing to pay to fetch a 34cm bucket of water?"*

5.3 Bidding Mechanisms

There are several bidding mechanisms or elicitation mechanisms used in survey studies for determining WTP. These include bidding game format, payment card, open ended question, close ended question, single-bounded referendum, double-bounded referendum, and triple-bounded referendum.

The double bound design approach (Carson et al., 1986; Carson and Mitchell, 1987; Welsh and Bishop, 1993) with open ended is used in this study. According to Whitehead, J. (2000), "Estimation of the double-bounded willingness to pay data with the interval data econometric model improves the statistical efficiency of WTP estimates relative to single bound models (Hanemann et al., 1991). However, this approach is prone to starting point and anchoring effect biases.

To control for this, Bateman et al. (2002) have suggested the use of randomized card sorting procedure (RCS). This was modified and we used randomized questionnaire sorting (RQS) procedure which applies the same principle as the card. The only difference is that one uses questionnaires while the other uses cards yet all are randomized to achieve the same purpose. In sum, this study used the dichotomous choice double-bound format plus open ended with RQS.

5.4 Obtaining Respondent's Bid

Against the background that Ghana is a developing country, it was prudent to control for large number of non-responses which could arise if the study had adopted interactive computer medium, mail questionnaire with follow ups, and telephone interview as a result of illiteracy and incidence of poverty rates. The in-person or face-to-face approach was used by this study because it provides a stronger engagement with respondents which has the advantage of reducing questionnaire misunderstanding and making spontaneous questions and answers possible.

In obtaining bids, WTP is determined when an individual in the household herein the household head who represents the entire household indicates through a bidding mechanism the maximum amount he/she is willing to pay for a reliable piped water services. The double bound with open ended format used in this study provides two options. A yes/no response data, an interval data and the maximum amount respondents state on how much they are willing to pay.

Responses from this question were used as the dependent variable subject to the model type. The Ordinary Least Squares (OLS: log-log) uses the open ended final WTP amount stated by the respondent. For the Ordered Probit (Oprobit), the final WTP values were ordered into four different categories. In the case of the Interval Regression (Interval) there were four different expectations from respondents' responses. The yes-yes responses, yes-no responses, no-yes responses and no-no responses. Where the option yes-yes was given by the respondent, the upper limit is positive infinity and the lower limit is the second higher bid. In case of yes-no option, the upper limit is the second higher bid and the first bid the lower limit. For no-yes options, the upper limit is the first bid and the second lower bid was the lower limit. In the last no-no options, the upper limit is the second lower bid given and the lower limit is negative infinity (see Carson et al. 2003; Krishna et al. 2013). Equation 3.22 is explicitly formulated and presented for estimation as:

$$lnWTP_i = \beta_0 + \beta_1 MSD_i + \beta_2 MSGU_i + \beta_3 E_i + \beta_4 F_i + \beta_5 NHH_i + \beta_6 OFM_i + \beta_7 lnY_i + \beta_8 Age_i + \beta_9 Age_i^2 + \beta_{10} KL_i + \beta_{11} KI_i + \beta_{12} lnBid_i + u_i \quad (3.23)$$

Where MSD_i is households' reliable main current source of water for drinking, $MSGU_i$ is households' reliable main current source of water for general use, E_i is average households' expenditure on current water sources per month, F_i household residence fence type, NHH_i is number of households in residence, OFM_i is Other family members in the household, Y_i is household heads' income, Age and Age squared in years of respondent are denoted as Age_i and Age_i^2, KL_i is knowledge of domestic or local environmental issues, KI_i is knowledge of international environmental issues, Bid_i is the starting point bid/amount, and the error term (u_i).

5.5 Descriptive Statistics for HPM, TCM and CVM

The average rent paid by households the last month before the survey used for the study was GHS 138.23, with the minimum rent being GHS 10 and the maximum being GHS 1,000. The mean district monthly take-home income was GHS 636.18, almost the same as the household take-home income of GHS636.37. Both are quite close to the national estimate of GHS544 for the GAR (GSS, 2008). The average rental value constitutes 22% of the district income. We described reliable piped-water supply as those who have daily supply of piped-water (except for technical fault). About 29% of respondents have access to reliable piped-water supply, which is quite close to the 33% reported by UNICEF/WHO (2012). This provides evidence of the severity of access to piped-water in Ghana. Also, about 91% do not have access to garage facilities in their homes followed by about 7% having at least a garage and the rest having about two or three garages in their residence. A significant fraction constituting over 72% have access to toilet facilities while over 52% do not have access to reservoirs (such as wells and boreholes) in their residences. This supports the rationale for households demanding reliable supply of water in residences. The average distance from residences to the nearest highway, financial institution and school were 0.65km, 0.67km, 0.25km respectively.

Households make an average of approximately 100 round-trips to their main water sources per month. This constitutes an average of three round-trips per day. About 83% have other family members staying with them. This reflects the communal living nature of the study area. The average age of respondents was about 39 years. It cost household GHS 2.29 per round-trip to main source of water supply and GHS13.99 per round-trip to other sources of water supply. The responses to the question on who bears household hauling burden revealed that about 48% of the burden on water lies heavily on children.

The mean WTP for a 34cm bucket of water from piped-water sources in residence is approximately GHS 0.40 which is greater than the average GHS 0.35 they currently pay in GAR. The ordered responses had approximately 52% in the lowest or first category followed by the 43% for the second category, then about 4% and 1% in the third and fourth categories respectively. With the interval WTP responses, we observed that the lower WTP amounts and the upper WTP amounts recorded averages of about GHS 32 and approximately GHS 53. The starting point bid were in four discrete values: 0.20, 0.30, 0.40, and 0.50 (all in GHS). The number of average households in a house was about 5. About 97% and 75% affirmed that their main source of drinking water and water for general use is not reliable. Average expenditure by households per month on water was about GHS 52.22. This constitutes approximately 8% of households take-home income which is almost within the approximately 3%-8% estimated by this study. About 59% of houses had fence. Lastly, Respondents who had knowledge about local and international/global environmental (climate change) issues comprises of 55% and 61% respectively.

6. Estimation and Discussion of Survey Results

This section presents the results from the three valuation approaches employed in this chapter.

6.1 Hedonic Price Valuation Results

Table 3.1: Hedonic Regression Results [with and without Localization]

VARIABLES	(1) Lin-Log	(2) Lin-Lin	(3) Log-Log	(4) Log-Lin
Access to Rel. Piped Water in Residence	37.7175***	35.1151***	0.2946***	0.2803***
	(10.619)	(10.990)	(0.058)	(0.059)
Access to Toilet Fac. in Residence	52.1381***	56.2479***	0.5017***	0.5174***
	(8.156)	(8.253)	(0.051)	(0.051)
Reservoir in Residence	29.0835***	22.9241***	0.1996***	0.1744***
	(8.890)	(8.840)	(0.049)	(0.050)
Number of Garage	52.4993***	47.9972**	0.2477**	0.2315**
	(19.715)	(19.895)	(0.096)	(0.097)
Number of Storeroom	37.2483***	36.8579***	0.1878***	0.1874***
	(13.067)	(13.021)	(0.068)	(0.068)
Distance to Highway (Km)	-4.9820***	-5.1941***	-0.0272***	-0.0301***
	(1.461)	(1.487)	(0.010)	(0.010)
Distance to Financial Institution (Km)	-8.1965**	-7.9263*	-0.0276	-0.0317
	(4.136)	(4.124)	(0.031)	(0.030)
Distance to School (Km)	-20.4648***	-16.9776**	-0.1129**	-0.0992**
	(7.083)	(7.089)	(0.046)	(0.046)
Mean District Income (Log)	90.8318***	N/A	0.5253***	N/A
	(30.116)	-	(0.168)	-
Constant	-512.4415***	69.9812***	0.4304	3.8304***
	(191.040)	(9.442)	(1.069)	(0.057)
District Dummies	*No*	*Yes*	*No*	*Yes*
Observations	1,375	1,375	1,375	1,375
R-squared	0.114	0.130	0.167	0.177
Adjusted R-squared	0.108	0.120	0.162	0.167
Akaike Information Criterion (AIC)	17,923.42	17,911.98	3,585.99	3,584.166
Mean Variance Inflation Factor (VIF)	1.12	1.12	1.12	1.12

Dependent Variable: Rent per month in Ghana cedis (1GHS= 0.319 US$ as at 15/10/2014)
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To commence with the discussion, this study conducts some diagnostic tests on the models in Table 3.1. First, we acknowledge the fact that the models are susceptible to heteroscadasticity. This is against the background that housing markets are heterogeneous which can cause the variance not to be homoscedastic. Also, the cross-sectional data being used by this study is generally prone to heteroscadasticity. The Breusch-Pagan /Cook-Weisberg test [24] rejected the constant variance

[24] Chi2(10)= 67.56 and Prob > chi2 = 0.0000. We rejected Constant variance for model 4.

(homoscedastic) hypothesis in favour of the alternative. To control for this, all the models are estimated with robust standard errors. Our preferred model is model 4 because it reports the highest coefficient of variation of approximately 18%, and a relatively lower AIC test value of 3,584.166. More so, it is estimated with district dummies which allows for differences in the average level across districts in addition to adjusting the standard errors to take into account specific intra-group correlations. This helps to control for unobserved heterogeneity making it much more likely that the coefficients of the variables do change across districts (see Englin and Cameron, 1996). For robustness purposes, we observe that all the variables, irrespective of model, kept their respective signs with marginal changes in some of their significance levels as well as their coefficients. The variance inflation factor (VIF) is used to test for the severity of multicollinearity in the models. A Mean VIF of 1.12 is not even significantly greater than 1 hence we can conclude that multicollinearity is not a serious problem in these models shown in Table 3.1 (See Chatterjee and Hadi, 2006; Choumert et al., 2014b).

The results support the a priori expectation of a positive and significant relationship between structural characteristics (access to reliable piped-water supply in residence, access to toilet facilities in residence, existence of reservoir in residence, number of garage(s) in residence) and rental values. Focusing on the main variable of interest, houses with reliable piped-water supply and/or other water-related basic attributes are associated with higher rental values. That is, holding all else constant, households with access to reliable piped-water in their residence are willing to pay 28.03% more in rental rates than those without it. By implication, access to these water-related facilities or services in residence are very relevant in Ghana and probably other developing countries with similar characteristics. Other recent African context studies had similar findings, (e.g. Choumert et al., 2014a,b; Gulyani and Talukdar, 2008; and Knight et al. 2004), as well as studies focussing on other developing countries (e.g. Vásquez (2013a, b) and Van Den Berg and Nauges (2012)). Therefore, relatively lower rental values are expected to be associated with houses without basic structural characteristics.

As earlier mentioned, neighbourhoods with better socio-economic and environmental amenities attracts higher rental values. In effect, the closer a house is to quality neighbourhood characteristics that represent education, peace, safety, and wealth (i.e. brisk business activities), one would expect higher rental values. Our results is consistent with a priori expectation. It shows that neighbourhood characteristics have negative signs, with most of the variables being significant as expected. This suggests that the closer a residence is to a highway, financial institution and/or school the higher its associated rental values. Distance from financial institutions which are normally clustered in the central business district had the right negative sign yet insignificant in the preferred log-lin model.

In addition, we included a new variable, mean-district-monthly-income to represent neighbourhood socio-economic characteristics while excluding district dummies (see models 1&3 in Table 3.1). We found this to have a positive effect on rental values. This socioeconomic characteristic in the neighbourhood is used as a proxy to describe the level of wealth, knowledge, awareness and perception of the neighbourhood (see Van Den Berg and Nauges, 2012). Holding other factors constant, higher levels of education are normally associated with good jobs, higher earnings and property ownership. Generally, informed and wealthy household will prefer staying in a house with essential services that improves their quality of life, signifies prestige and honour in society to a house without essential services. It is important to acknowledge that, one main conclusion from this investigation is that differences in income between districts is one principal cause of differences in rents between districts in Ghana.

6.1.1 Marginal WTP for Piped-Water in Residence

This section focuses on the derivation of the marginal willingness-to-pay for having access to reliable piped-water in residence. This is achieved by using the results in Table 3.1 (Model 4). Thus, we re-introduce our preferred log-lin model which is presented as:

$$lnV = \beta_0 + \beta_1 ARP + \beta_2 T + \beta_3 R + \beta_4 G + \beta_5 S + \beta_6 DH + \beta_7 DFI + \beta_8 DS + u \quad (3.24)$$

Since this study is interested in the marginal effect of access to reliable piped-water in residence on rental values and not the proportional change in rental values (lnV), we transform equation 3.24 using anti-log to yield the conditional expectation and it is presented as:

$$lnV = \exp(\beta_0 + \beta_1 ARP + \beta_2 T + \beta_3 R + \beta_4 G + \beta_5 S + \beta_6 DH + \beta_7 DFI + \beta_8 DS + \sigma_u^2) \quad (3.25)$$

Here, σ_u^2 is the population variance of the error term in equation 3.25. Further, to show that $E[e^u] = e^{\sigma_u^2/2}$, we assume that the error term (u) is normally distributed, with zero mean and a constant variance. Also, access to reliable piped-water in residence which is a dummy variable takes two values ($\text{ARP} = 1$ and $\text{ARP} = 0$). Now, forming the conditional expectation with respect to $\text{ARP} = 1$ and $\text{ARP} = 0$ yields:

$$\text{E}[\text{V}|\text{ARP} = 1] = \beta_0 + \beta_1 + \beta_2\text{T} + \beta_3\text{R} + \beta_4\text{G} + \beta_5\text{S} + \beta_6\text{DH} + \beta_7\text{DFI} + \beta_8\text{DS} \quad (3.26)$$

$$E[V|ARP = 0] = \beta_0 + \beta_2 T + \beta_3 R + \beta_4 G + \beta_5 S + \beta_6 DH + \beta_7 DFI + \beta_8 DS \quad (3.27)$$

The difference between the two expectations [3.26 & 3.27] gives [3.28]:

$$E[V|ARP = 1] - E[V|ARP = 0] = \beta_1 \quad (3.28)$$

Given that the variable of interest is dummy, we compute the relative change in rental values

$$V^{ARP} = \frac{E[V|ARP = 1] - E[V|ARP = 0]}{E[V|ARP = 0]}$$

$$= \frac{\exp\left(\beta_0 + \beta_1 ARP + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7 + \beta_8 + \frac{\sigma_u^2}{2}\right) - \exp(\beta_0 + \beta_1 ARP + \frac{\sigma_u^2}{2})}{\exp(\beta_0 + \beta_1 ARP + \frac{\sigma_u^2}{2})}$$

$$= \exp(\hat{\beta}) - 1 \quad (3.29)$$

From Table 3.1 (Model 4), $\hat{\beta} = 0.2803$ depicting the difference in access to reliable piped-water in residence and absolute increase in rental values. Thus, relative change in rental values shows the additional amount in rent that households with access to reliable piped-water in residence are willing to pay.

Relative change: $V^{ARP} = \exp(0.2803) - 1 = 0.3235 \times 100 = 32.35\%$

The standard error: $\sqrt{\left(\exp(\hat{\beta})\right)^2 \times \sigma_u^2} = \exp(0.2803) \times 0.060 = 0.017$

This study finds that the average amount households will be prepared to pay per month for access to pipe-water in residence is GHS 44.73 which constitutes 7.03% of the mean-district-income (see Table 3.2). This according to Bartik (1988) and Choumert et al. (2014b) should be interpreted as an upper bound values because the utility dummy may include unobserved attributes and utilities.

Table 3.2: Predicted Increase in the Value of a House with Access to Reliable Piped-Water

Marginal implicit house value per month(GHS)	Current average HH expenditure on water per month (GHS)	Increment as a % of monthly district-income	Increment as a % of Monthly Household Income
Mean[25] 44.73 [23.69-65.76]	Mean 52.22 [50.34-54.09]	Mean[26] 7.03% [3.72%-10.34%]	Mean[27] 7.03% [3.72%-10.33%]

95% *Confidence Interval in square brackets [ ].*

[25] Relative change (water dummy)×Average House Value=44.73 per month
[26] Marginal Implicit house value/Average district- income=0.07031×100≈7.03%
[27] Marginal Implicit house value/Average Household income=0.07029%≈7.03%

6.3 Travel Cost Results

Six models are estimated and the results are presented in Table 3.3. We evaluate the relevance of district dummies by excluding them from the first three models while including it in the last three.

Table 3.3: Travel Cost Regression Results

VARIABLES	(1) OLS	(2) Poisson	(3) Neg-Bin	(4) OLS	(5) Poisson	(6) Neg-Bin
Cost to Water Source (Log)	-3.662***	-0.037***	-0.039***	-4.094***	-0.040***	-0.044***
	(0.341)	(0.004)	(0.003)	(0.345)	(0.004)	(0.003)
Cost to Other Source (Log)	4.562**	0.068***	0.051***	5.930***	0.085***	0.066***
	(2.144)	(0.020)	(0.020)	(2.193)	(0.020)	(0.020)
Access to Rel. Piped-Water	-13.038***	-0.118***	-0.152***	-9.125**	-0.085*	-0.104**
	(4.372)	(0.044)	(0.046)	(4.600)	(0.045)	(0.046)
Reservoir in Residence	-13.071***	-0.125***	-0.137***	-10.140**	-0.099**	-0.110**
	(4.449)	(0.043)	(0.045)	(4.516)	(0.044)	(0.045)
Other Fam. Mem. HH	16.518***	0.168***	0.166***	16.463***	0.172***	0.152***
	(5.084)	(0.053)	(0.058)	(5.001)	(0.053)	(0.056)
HH Income(Log)	-5.717*	-0.058*	-0.053*	-5.414*	-0.052*	-0.057*
	(3.028)	(0.031)	(0.030)	(3.051)	(0.031)	(0.030)
Savings_dum	-14.329***	-0.136***	-0.173***	-15.190***	-0.145***	-0.164***
	(5.382)	(0.048)	(0.052)	(5.219)	(0.046)	(0.050)
Constant	147.206***	4.934***	5.001***	149.766***	4.911***	5.037***
	(20.716)	(0.205)	(0.197)	(21.233)	(0.208)	(0.201)
District Dummies	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Observations	1,243	1,243	1,243	1,243	1,243	1,243
R-squared	0.19			0.24		
Adjusted R-squared	0.18			0.23		
AIC	14,366.89	73,944.49	13,732.2	14,298.51	69,739.43	13,664.43

Dependent Variable: Number of Round-Trip to Water Sources per Month
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Before the discussion, we admit the possibility of practical estimation problems associated with TCM. Bateman (1993) acknowledges among other things inappropriate functional forms and estimation technique, truncation bias, heteroskedascity and multicollinearity as potential problems in practical TCM studies. To control for these potential problems we first test for the presence of multicollinearity using the VIF test on the OLS model. The mean VIFs is reported as 1.56 (model 1) and 1.34 (model 4) which suggests that the VIFs are even not significantly greater than 2. This implies that multicollinearity is not a severe problem in this model. (See Chatterjee and Hadi, 2006; Choumert et al., 2014). It is argued in Literature that although the “economic theory of constrained optimisation with complementarity provides no particular functional form for trip generation equations” (Wattage, 2002, p.13), [yet functional forms have] “non-trivial implications on results obtained” (Perman et al., 2003, p.442). We may not have a particular functional form for trip generation equations, yet, Bateman (1993) has argued that the appropriateness of a functional form can be evaluated using the relative degrees of explanation. An R-squared of 24% and an adjusted R-squared of 23% which is also seen in Creel and Loomis (1990) as generally not bad to discredit the model's appropriateness. The models are estimated with robust standard errors to control for evidence of heteroscadasticity[28]. The OLS is estimated alongside Maximum Likelihood (ML) estimations for robustness checks. The latter is highly recommended for TCM studies to control for truncation bias (see Bateman, 1993).

The OLS is used in this study as a baseline model for robustness checks as it is not suitable for count data of this nature. The next appropriate model is the Poisson model. However, a test of over-dispersion provides evidence that the conditional variance is higher than the conditional mean. These differences suggest that over-dispersion is present and that a Negative Binomial model (Neg-Bin) would be more appropriate to use (see Table 3.4). This is further supported by the Akaike information criterion (AIC) tests (Table 3.3).

Table 3.4: Test of Over-dispersion

Variable	**N*	*Mean*	*Std. Dev.*	*Variance*	*C. I. [95%].*	*Remark*
Poisson Model Test						
**No. of Trips	1243	105.487	43.858	1,923.551	103.046-107.927	[29] Evidence of Over-dispersion
Negative Binomial Model Test						
	alpha			*S.E*	*C.I. [95%]*	*Remark*
**No. of Trips	0.532933			0.022	0.500-0.568	Reject $\alpha=0$
Likelihood-ratio test of alpha $(\alpha)=0$ chibar2(01) = 6.000 Prob.>=chibar2 = 0.000						

**Where N is the number of observations. **Number of Round-Trips to Water Sources.*

From Table 3.4, we obtained a chi-squared value of 6.000 with one degree of freedom and a p-value of 0.000. With this, we have evidence to reject the null hypothesis that alpha is zero $(\alpha=0)$ and strongly suggest that alpha is non-zero (0.53) and the Neg-Bin model is more appropriate here than the Poisson model because of its appropriateness for over-dispersed count data.

Due to the different characteristics of the districts regarding their sources of water supply, this study introduced district dummies to control for district specific effects on the number of round-trips to various water sources (see Table 3.3, Models 4-6).

The results vis a vis the coefficients, significance and standard errors after introduction of district dummies did not significantly change. They produce similar

[28] Chi2(7)= 81.52 and Prob > chi2 = 0.0000. We rejected Constant variance.

[29] Poisson assumes that the conditional mean and the conditional variance are the same. Thus, ((Var(y|X)=E(y|X)) However, the conditional variance (1,923.551) is far greater than the conditional mean (105.487), ((Var(y|X)>E(y|X)), hence an evidence of over-dispersion.

results as obtained without the district dummies. Here also, the introduction of the district dummies, given the same number of observations, the Adjusted R-squared increased from about 19% (model 1) to 24% (model 4) for the OLS model. Also, the AIC falls from 13,732.2 (model 3) to 13,664.43 (model 6). This suggests that the model assumes a better fit with the district dummies than without them.

As earlier mentioned, we estimate a Neg-Bin model (Table 3.3), with the other two models (OLS and Poisson) used as robustness checks. The variables we are most interested in are the cost related variables therefore we discuss them first followed by all other variables.

As suggested by economic theory, we expected a negative relationship between the cost of the good itself (i.e. cost per round-trip to the main source of water supply per month) and the number of round-trips households make per month to their water sources. The results confirmed our theoretical priors, suggesting that for each percentage increase in the cost of round-trips to the main source of water supply, the expected count decreases by 0.044, holding all else constant. This suggests that households who spend more money in traveling to their water sources make fewer trips per month. Alternatively, we expected a positive relationship between the cost of substitutes (i.e. cost per round-trip to other sources of water supply per month) and the number of round-trips households make per month to their water sources. This also means that for each percentage increase in the cost of round-trips to the other sources of water supply, the expected count increases by 0.066, holding all else constant. This implies that in the absence of the main source, households who make more trips per month spend more money in traveling to the alternative water sources relative to the main source. These cost related variables are highly significant in all estimated models.

We find that access to reliable piped-water in residence is negative and significant. This suggests that the probability of having access to reliable piped-water supply in residence decreases the expected count to haul for water by 0.104, holding all else constant. In addition, households with access to reservoir in their residence were not expected to have behaved differently in terms of signs as it would have been an irrational behaviour on the part of the household or consumer. We again find a negative and significant effect of reservoir in residence on number of round-trips households make per month. This means that the probability of having access to a reservoir in residence also decreases the expected count to haul for water by 0.110, holding all else constant. These suggest that households with a source of water supply in their residence are expected to make fewer trips to haul for water. Having a reliable piped-water supply and/or a reservoir in residences in the form of wells and boreholes as source of water supply do not warrant making trips to alternatives. This provides some evidence on how piped-water is very important to urban Ghana and in its absence households depend on other more expensive sources for survival.

It is evident from Table 3.3 that households with larger family size as a result of other family members in the household has a positive and highly significant effect on number of round-trips to the water sources. We find that the probability of having other family members in the household increases the expected count to haul for water by 0.152, holding all else constant. This implies that, by summing up all the trips by individual household members, we see this to be influencing the number of round-trips per month. It can be inferred that if all members are being tasked with household water responsibility, it means that children will definitely not be spared in this with its associated effects on their academic and personal development. As mentioned earlier, we find that 48% of the water burden lies on children.

This study also finds household income variable to be negative and significant, meaning that a percentage increase in household income, decreases the expected count to haul for water by 0.057, holding all else constant. Also, saving is negative and highly significant. This implies that the probability of a household saving some of their income, decreases the expected count to haul for water by 0.145, holding all else constant. Thus, relatively wealthy households (characterised by higher earnings and positive saving behaviour) who can afford not to travel yet have access to potable water supply through tanker services which most poor people cannot afford were seen to have been making less trips to water sources. This inverse relationship between household wealth levels and number of round-trips to water sources is as expected and it is significant in all estimated models.

6.4 TCM WTP Estimate (Marginal WTP)

Information on TCM survey defines the demand curve and therefore helps to determine point estimate of consumers' surplus (see Bateman, 1993; Freeman 1979). In order to estimate consumer surplus and determine the WTP for reliable piped-water supply, we now use the estimated function provided by the Neg-Bin model as shown below:

$$V_i = 5.037 - 0.044(CM_i) \qquad (3.30)$$

According to Creel and Loomis (1990) point estimate of consumers' surplus (CS) per predicted trip $(\hat{V})$ is given as:

$$\frac{\widehat{\mathrm{CS}}}{\hat{\mathrm{V}}_{\mathrm{i}}} = -\frac{1}{\hat{\beta}_{\mathrm{i}}} = \frac{1}{0.044} = \mathrm{GHS}\ 22.72\ [19.89 - 26.62]$$

It is possible that our cost to main source of water supply variable may captured not only piped-water supply but also other improved sources in some cases. Nonetheless, we do not expect this to be many though as majority (over 64%[30]) in GAR prefer and depend on piped-water sources. Therefore our estimate of consumers' marginal WTP is for improved water supply and not necessarily piped water supply. Also, it is not out of place to use improved source as a proxy for piped-water supply in this study as all piped-water supply are improved. In short, the point estimate of consumers' marginal WTP to have access to improved water supply (piped-water) is GHS 22.72 which constitutes 3.57 % of households' income (see Table 3.5).

In spite of the fact that our model captured improved water supply, this should be interpreted as a lower bound because we used only the opportunity cost of travel time to determine the cost per round-trip made by households. By this, we do expect results from the CVM and HPM to be greater than TCM. Some studies which include but are not limited to and Czajkowski et al. (2015), Hill et al. (2013) and Shrestha et al. (2002) have all used this same method in obtaining point estimates of consumers' surplus per predicted trip.

Table 3.5: WTP Estimate and Share of Household's Income

Measure	WTP Estimate (GHS)	Mean(GHS)/Month
HH Income	22.72 [19.89-26.62]	636.37 [607.90-664.84]
% Share of HH Income in CS (WTP)		3.57% [3.13%-4.18%]

*95% Confidence Interval in square brackets [ ].

[30] GSS (2012)2010 Population and Housing Census, pg.30

6.5 Contingent Valuation Results

To determine how much households are willing to pay for reliable piped-water under this CV approach, we first investigate whether households' WTP determinants are consistent with demand theory. This section present results of five models used for the CVM. These are presented in Table 3.6 and subsequently discussed.

Series of multivariate regression analysis presented in Table 3.6 were estimated using test characteristics of access to water variables and some household level characteristics as controls in the models. For simplicity in our discussion, the independent variables are further put under five different categories following Lauria et al. (1999). First, respondents' personal characteristics (age, age^2 and income), respondents and other households' characteristics in residence (number of households in residence, other family members in respondents' household, average household expenditure on water per month and household residential fence type), characteristics of administered questionnaire to respondent (starting point amount), main variable describing respondents' household water situation (main source for drinking and main source for general use) and respondents' knowledge or awareness and attitudes about environmental issues (knowledge of domestic environmental issues and knowledge of international environmental issues).

As already explained in section 5 (*Obtaining Respondent's Bid)*, the dependent variable used depends on the structure of the model. For example, Models 1&4 (Oprobit) ordered the final WTP amount into four different categories, Model 2&5 (Interval[log]) transforms the lower and upper WTP bids into natural logs and Model 3&6 (OLS[log]) uses the final bid or maximum WTP amount. Overall, the OLS model provided the best results. This is based on the fact that, in addition to its simplicity for analysis, it has the best AIC test value of 587.568. It is important to note that the adjusted R-squared of 20% for the our preferred model is above the 15% proposed by Mitchel and Carson (1989) as the minimum for reliable CV studies. The mean VIF is 6.06 for our preferred model. This is quite high because of age and age squared yet it does not invalidate our results because multicollinearity is deemed not severe. Our preferred model is also estimated with robust standard errors and controls for district specific effects using district dummies. Table 3.6 below shows the regression results for all the six models presented, however, discussion is based on our preferred model 6.

Table 3.6: Regression Results-CVM

VARIABLES	(1) Oprobit	(2) Interval (Log)	(3) OLS (Log)	(4) Oprobit	(5) Interval (Log)	(6) OLS (Log)
Main Source for Drinking Reliability Index	0.574***	0.088**	0.136**	0.564***	0.081**	0.129**
	(0.188)	(0.039)	(0.053)	(0.189)	(0.039)	(0.052)
Main Source for General Use Reliability Index	0.263**	0.047*	0.069**	0.312***	0.050**	0.068**
	(0.114)	(0.024)	(0.029)	(0.119)	(0.024)	(0.029)
Average HH Expenditure on Water/Month (Log)	0.103	0.023*	0.041**	0.090	0.021	0.034**
	(0.065)	(0.013)	(0.016)	(0.068)	(0.013)	(0.017)
Residence Fence Type	0.252***	0.042***	0.061***	0.198**	0.038**	0.052***
	(0.078)	(0.016)	(0.020)	(0.081)	(0.016)	(0.020)
Number of Households	0.034***	0.008***	0.007**	0.034***	0.007***	0.007**
	(0.011)	(0.002)	(0.003)	(0.011)	(0.002)	(0.003)
Other Family Members in HH	0.278***	0.022	0.072***	0.302***	0.024	0.076***
	(0.107)	(0.022)	(0.024)	(0.110)	(0.022)	(0.024)
Household Income(Log)	0.437***	0.087***	0.130***	0.433***	0.084***	0.128***
	(0.052)	(0.010)	(0.014)	(0.053)	(0.010)	(0.014)
Age (Years)	-0.052**	-0.012**	-0.018***	-0.050**	-0.012***	-0.018***
	(0.022)	(0.005)	(0.006)	(0.022)	(0.005)	(0.006)
Age-Squared (Years)	0.001**	0.000***	0.000***	0.001**	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Knowledge of Domestic. Environmental Issue	0.197**	0.021	0.045**	0.230***	0.022	0.041**
	(0.079)	(0.017)	(0.020)	(0.083)	(0.018)	(0.020)
Knowledge of International. Environmental Issue	0.164**	0.024	0.025	0.142*	0.027	0.030
	(0.082)	(0.018)	(0.022)	(0.085)	(0.018)	(0.022)
Starting Point Amount (Log)	0.242**	0.391***	0.231***	0.241**	0.389***	0.231***
	(0.111)	(0.020)	(0.028)	(0.113)	(0.020)	(0.028)
Constant		1.785***	2.290***		1.838***	2.330***
		(0.142)	(0.182)		(0.144)	(0.184)
District Dummies	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Observations	1,014	1,014	1,014	1,014	1,014	1,014
R-squared (Adjusted R-squared)			0.20(0.19)			0.22(0.21)
Log-Likelihood (LR-test statistic), [F-statistic]	137.96***	368.12***	[18.97***]	167.37***	390.73***	[12.69***]
Akaike Information Criterion (AIC)	1,725.88	2,093.79	454.00	1,712.463	2,087.177	441.36

Dependent Variables: OLS (log)-MWTP; Oprobit- cat_MWTP; Interval (log)-LWTP UWTP, Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

We commence the discussions with the main variables of interest (i.e. water related variables). There is an evidence that reliable source of drinking water supply has a positive and significant effect on WTP. This implies that households with access to reliable drinking water supply are WTP approximately 13% more than households without access, all else held constant. Furthermore, there is evidence that reliable source of water for general use has a positive and significant effect on WTP. This also suggests that households with access to a relaible source of water for general use are WTP approximately 7% more than households without access. It can be inferred that households who have reliable source of piped-water supply for drinking and general use in their residence have a higher probability to pay more for a service they are already enjoying. This shows that households with a reliable piped-water supply would be willing to pay more to keep enjoying what they have been enjoying. Moreover, households that are currently spending huge sums of money in their quest to access reliable potable water are still indifferent with respect to their spending behaviour to access potable water. Thus, household average expenditure on water per month is positive and significant to willingness-to-pay.This provides evidence that a percentage change in a household's average expenditure on water per month will change WTP by 3.4%, all else held constant. In short, we find evidence of an endowment effect with respect to reliable piped-water supply.

Second is respondents' personal characteristics. Krupnick et al. (2002) argue that theory cannot predict exactly the relationship between age and WTP. The age variables (age and age^2) which are highly significant, together depict a U-shaped relationship with WTP. This gives a minimum turning point of approximately 40 years, which lies in a 95% confidence interval of 35-45 years. This U-shaped relationship according to De Oca et al. (2003) demonstrates the essential nature of the good in question with changing priorities in the lifetime of respondent. Cameron and Englin (1997) in their study on "respondent experience and CV of environmental goods", strongly recommend age as a very crucial variable in WTP studies as it provides an upper bound on respondent's experience.

Third, respondents' household characteristics. Economic demand theory suggests that, all else held constant, wealthy households will pay more for enhancement in their utility. Here, take-home income of the household heads is used as a proxy for household income and wealth. It met the a priori positive and significant expection. This suggests that a percentage change in household income level is expected to yield approximately 13% change in their WTP for piped-water supply. Thus, water is a normal good and that households with larger income sizes are willing to pay to have reliable piped-water in their residences. Similar findings are found in Elnagheeb and Jordan (1997), Lauria et al. (1999) and Soto Montes de Oca et al. (2003). Moreover, from a general perspective, larger household sizes are expected to use more water relative to smaller household sizes and are therefore expected to pay more for quantities used. Number of households in a residence was observed to be positive and significant. This means that there is evidence that a unit increase in the number of households in a residence will increase WTP by 0.7%, all else held constant. This perhaps could be explained by the communal living effect which is a characterisic of most districts in Ghana. However, it is important to acknowledge that people are quite careful when the free riders are not from the same residence but unwanted guest. More so, we used households with other family members to capture household size. This is also positive and significant, providing evidence that, all else held constant, larger household sizes are WTP 7.6% more for reliable piped-water than those with relatively smaller household sizes. Thus, the probability of having other family members in the household increases respondents' WTP. Similar findings are found in Soto Montes de Oca et al. (2003). Also, household fence type is positive and highly significant. This provides evidence that fenced households are 5.2% more likely to pay for reliable piped-water relative to unfenced households. The intuition underlying this result could mainly be attributed to the free riding associated with communal living societies.

Regarding respondents' awareness and knowledge of environmental issues, we used knowledge of both domestic and international environmental issues to determine households behaviour towards having access to reliable piped-water supply in residence. Thus, will households who are aware of the implications of a poor environmental community be prepared to pay more for improvement? All the models had the right signs signifying that informed households appreciate the good in question and would be willing to pay for it. However, this was significant for only domestic but not international environmental issues.

Lastly, the starting point bid[31] results show a positive and significant effect on WTP. This suggests that there is an evidence that an increase in the starting point bid by 1% will induce about 23% increase in WTP values, all else held constant. Although this study adopted the RQS as suggested in the literature to control for starting point point bias and anchoring effect, the models still show some evidence of starting point bias. It

[31] The starting point bids were GHS 0.2, GHS 0.3, GHS 0.4, GHS 0.5. These values were noted during the fieldwork before the first pilot survey and they represent ranges of how much a 34cm bucket of piped-water is sold within the Greater Accra Region of Ghana.

should be noted that dichotomous choice questions are not completely free from anchoring problems (see Boyle et al., 1997; Green et al., 1998; Boyle, 2003). This implies that the starting point bias could have been higher without the controls.

6.5.1 CVM WTP Estimates

Table 3.7 presents the WTP estimates as well as the share of households WTP to income from the CVM.

Table 3.7: Estimated Household WTP Measures

Measures	Max. WTP for a 34cm bucket of reliable piped-water (GHp)	95% Confidence Interval (CI)	Max. WTP for reliable piped-water (GHS)	*HH Max. WTP for reliable piped-water (GHS)/Month
Mean	39.86	38.83-40.90	1.59	47.80
Median	35.00	30.00-40.00	1.40	42.00
% share of HH monthly Income			0.25%	7.51%

Note: Computation used a Mean Household (HH) Income of 636.372 and a CI of 607.90-664.84.
**0.3986×4×30(days)*

Available evidence from the literature in developing countries as shown by the likes of Whittington et al.(1990a,b); Whittington et al.(1991); Altaf et al.(1992); Briscoe et al. (1993); Whittington et al.(1993); Whittington et al.(1998); Soto Montes de Oca et al. (2003) indicates that the percentage of Household income to WTP ranges between almost 2% to 18%. This suggests that our results fall within the range estimated in literature.

We concur that the objective of suppliers is important in determining prices. For example a profit maximizing supplier will set price to be greater than average variable cost in order to achieve his objective. Generally, setting lower prices increases demand, "other things held constant". Alternatively, setting higher prices for a good with less or no alternatives will generate the highest expected revenue. From Table 3.7 it is evident that households are prepared to pay 39.86 pesewas (approx. GHp0.40) for the 34cm bucket of piped-water in their residence. From the survey, this is marginally high because it is greater than the average of what they are currently paying (GHp0.35) in the region for the same service. So by GHS1.59, the highest expected revenue per day of about GHS1,514,202.03 (US$483,030.45) is realised for the maximum reliable piped-water for a household per day. This implies that the price option for the supplier to expand coverage by providing reliable piped-water in residences and maximize revenue at the same time is approximately GHp0.40.

Also, by the CVM, we indicated that piped-water is a normal good to the people of Ghana and that households have expressed high WTP to have such a good or service in their homes to increase the quality of their lives. This constitutes 7.51% of their incomes.

6.6 Comparison of Willingness-to-Pay Estimates

The results from the competing valuation methods are presented in both Ghana cedis (GHS) and in United States dollars (US$) as shown in Table 3.8 below for easy comparison and comprehension.

Table 3.8: Comparison of Valuation Methods' Results.

Method	WTP(GHS)/M*	95% CI	WTP US$/M*	% of Income Index
CVM	47.80	[46.60-49.08]	15.25	7.51%
HPM	44.73	[23.69-65.76]	14.27	7.03%
TCM	22.72	[19.89-26.62]	7.25	3.57%

*M=Month (GHS=US$0.319 as at 15/10/2014)

Table 3.8 compares the three valuation methods and finds that the value from the CVM (GHS47.80 or US$15.25) is greater than the HPM (GHS44.73 or US$14.27) which is also greater than the TCM (GHS22.72 or US$7.25). These values fall within household income ranges of 3.57-7.51%. Similar findings where stated preference method estimates are greater than estimates from revealed preference methods have been found in studies by Knetsch and Davis (1966), Brookshire et al. (1985), Cummings et al., (1986) as summarised in the literature of this study. In addition, as mentioned earlier Whittington et al.(1990a,b); Whittington et al.(1991); Altaf et al.(1992); Briscoe et al. (1993); Whittington et al.(1993); Whittington et al.(1998); De Oca et al. (2003) have also found that the percentage of household income to WTP ranges between almost 2% to 18%.

It is imperative to observe that the comparisons must however, be interpreted carefully. This is because the estimates of willingness to pay from the valuation approaches are not measuring precisely the same thing. Whilst the HPM is an upper bound which is measuring use value of current reliable piped-water service in residence, the TCM is a lower bound measuring improved water supply which includes piped-water. The CVM is upper bound measuring use value of the proposed reliable piped-water supply. Thus, TCM is interpreted as lower-bound because it used only the opportunity cost of travel time. However, HPM is upper-bound because the utility dummy may include unobserved attributes and utilities. Although the CVM is designed here to capture only use values however, we cannot rule out the possibility that some respondents may have other values in mind whiles stating their WTP values. In sum, the CVM and HPM are upper bounds and are expected to be greater than the lower bound TCM. In addition, CVM is expected to be greater than HPM because while both include use values, HPM does not capture non-use values but CVM does.

6.7 Cost & Benefit Analysis

United Nations (2004) has indicated in their study on Freshwater Country Profile for Ghana that it costs the country US$0.80 per one m^3 (1,000 litres) to produce, transport and distribute potable water. Table 3.9 shows the cost benefit analysis using the equivalent cost of US$0.06 for 75litres as a proxy for the required amount of piped-water needed per household/day.

Table 3.9: Cost & Benefit Analysis

*Cost (HH/day)		Total Urban HH Cost/day (No. of HH 950,336)		Total HH (Urban and Rural) Cost (No. of HH 1,036,426)		Expected Revenue (Uban HH/day)		Net Benefit (Urban HH/day)	
GHS	US$	GHS	US$	GHS	US$	GHS	US$	GHS	US$
0.19	0.06	180,563.84	57,020.16	196,920.94	62,185.56	1,514,202.03	483,030.45	1,333,638.19	426,010.29

Note: We assume that the cost of efficient production, transportation and distribution of 75 litres is US$0.06 of piped-water to households in Ghana per day.

From Table 3.9, given the total number of urban households in the ten districts as 950,336. We assume the cost of efficient production, transportation and distribution of 75litres (US$0.06) of potable piped-water to households in Ghana per day is approximately GHS180,563.84 (US$57,020.16). Again, our computed expected revenue for supplies per day is approximately GHS 1,514,202.03 (US$483,030.45). Therefore the difference between the expected revenue and the expected cost per day yields GHS1,333,638.19 (US$426,010.29). This provides evidence of a positive net benefit of the project. Similar results are found in Briscoe et al. (1990), Whittington et al. (2002), and Soto Montes de Oca (2003) as discussed in the literature. We still find evidence of net benefit for both urban and rural households cost together at the same expected revenue.

The cost-benefit analysis provides evidence that, it is possible to successfully implement a full cost recovery programme in the water sector in Ghana without government subsidy. Thus, it is economically feasible to improve the supply of water in Ghana by providing reliable piped-water in residences and making the once inefficient GWCL to be managerially and technically efficient.

Also according to African Ministers Conference on Water (AMCOW, 2011), an estimated US$237million in capital investment is required annually to meet the water supply rural and urban subsector targets of the then MDGs target (now SDGs). With this, the government is expected to contribute about 50% and still leave a deficit of about US$118.5 million per year. With the estimated revenue, it implies that even with the revenue from the Greater Accra Region alone, it will take less than two years to cover the capital investment required as estimated by AMCOW. This will save the government all annual expenditures into the water sector which could be reallocated to other sectors.

In sum, this section presents how viable this project is to the private sector and the extent to which piped-water can be supplied to urban and if possible rural households while they pay the full cost of their consumption without government or donor support.

7. Conclusion and Policy Relevance

In our quest to provide empirical evidence towards implementing the full cost recovery programme in Ghana's water sector, we follow the guidelines and valuation design processes as recommended by NOAA Blue Ribbon Panel Committee (see Arrow et al., 1993). Here, three valuation methods are employed namely the HPM, TCM and CVM to satisfy internal validity checks. A household sample of 1,648 is used from the GAR of Ghana.

In the CV survey, the double-bound dichotomous choice formats which were followed by open-ended questions were used to elicit households' maximum WTP bids. Also, in the Hedonic survey, monthly rental values paid in the last month before the survey was used as a proxy for the market value of properties. For the TC survey, the number of round-trips to and from the water sources were used in this study. This study finds that household WTP for a reliable piped-water supply per month is GHS 44.73 or US$14.27 (HCM), GHS 22.72 or US$ 7.25 (TCM) and GHS 47.80 or US$ 15.25 (CVM) respectively. These amounts are equivalent to say 3%-8% of households' income. These results are observed to be consistent with existing studies in the literature. This study further provides evidence of the economic viability of private sector involvement in the water sector as proposed by the World Bank (1993). Overall, our results satisfy internal and external validity check criterion, and thus to a large extent we are confident of our estimates for policy decisions.

To the best of the author's knowledge, this is the first study to use three valuation methods on a water related survey data in Africa. It complements existing studies that have combined more than one method in developing countries.

APPENDIX C

Appendix C1.1: QUESTIONNAIRE

Interviewer: ……………………………….

Supervisor…………………………………..

Region: ……………………………………….

Metropolitan Area……………………..

Locality…………………………...........

Interview date :…………/…………/ 2014

Start Time: Hrs.……../Min………

End Time: Hrs...……../Min……….

Survey Price Draw

Yes[ ]	No:
No[ ]	Thanks

TOPIC: Estimating Demand for Reliable Piped-Water Services in Urban Ghana

District………………………………

House Number……………………….

Respondent's ID…………………….

Language used in the survey:

6. **English** [ ]
7. **Twi** [ ]
8. **Ga** [ ]
9. **Ewe** [ ]
10. **Other** [ ]

A BRIEF BACKGROUND OF STUDENT

My name is [Give Name] from Central University College [show I.D] and I'm part of a team headed by Anthony Amoah, a PhD student from the School of Economics, University of East Anglia, UK. He is conducting a survey of people's opinions about the water situation in Ghana.

I humbly wish to request your kind participation in this research, which aims at estimating the economic value of domestic water supply in Ghana. The research does not probe into your private affairs but we are interested in your personal perception and experience of water supply in Ghana. Your answers will only be used for empirical analysis in the framework of this research**.** Your information will not be shared or used for any other purpose. It will be treated as ***strictly confidential.*** Nevertheless, you still reserve the right to refuse or indicate don't know to questions where necessary. Completing this survey automatically enters you into a free rechargeable mobile credit draw (if you wish) where you could win one of the ten GHS10 mobile credits.

Thank you very much for your kind cooperation.

NB. Please tick [✓], underline or write where appropriate.

SECTION A: Personal Data of Respondent (Household Head)

A.1. Respondent's household status: 1. Head 4. Parent of Head 2. Wife of Head 5. Child of Head 3. Husband of Head 6. Other: If other, specify……….	**A.2.** Gender: **1.**Male **2.**Female
A.3. Year of birth (If provided skip A.4): **A.4.** Age range (Age in completed years): 1.18-29 3. 40-49 2. 30-39 4. 50+	**A.5.** Marital Status: **1.** Single **4.** Separated **2.** Living with partner **5.** Divorced **3.** Married **6.** Widowed
A.5 Which of the following life-cycles describe your household? 1. Single Adult 2. New Couple (≤1yr) 3. Family with Children 4. Family with Teenagers 5. Family with launching(ready for self-dependence) children 6. Family in later life (Retired i.e. ≥60 with or without children) 7. Several Adults living together (with or without children)	**A.6** a. Number of people in your household? b. Number of household's in your residence?
A.7 Highest level of educational qualification achieved/completed: **1.** None 4. Professional **2.** Primary/Middle/J.S.S 5. Second Degree **3.** Secondary/Vocational/Technical/Training College. 6. Doctorate (PhD) **4.** First Degree/Diploma 7. Others (specify)…........	**A.8** What is your employment status? **1.**Unemployed (during the last 7-days) **2.** Full time employee of private firm **7.** Apprentice **3.** Full time employee of public firm **8.** Domestic employee **4.** Self-employed without employee(s) **9.** Contributing family worker **5.** Self-employed with employee(s) **10.** Retired **6.** Casual worker **11.** Other (specify)…………….
A.9 What is your monthly take-home income in Ghana cedis (GHS): **1.** <160 **2.**160-599 **3.**600-999 **4.**1000-1399 **5.**1400-1799 **6.**1800-2199 **7.**2200-2599 **8.**2600-2999 **9.**3000-3399 **10.**3400-3799 **11.**3800-4199 1**2.**4200-4599 **13.** 4600-5999 **14.** ≥6000 **15.** I don't know **16.**I won't tell you	**A.10** How much do you save per month? (GHS) **A.11** Are there other people in your household who work? **1.** Yes **2.**No
A.12 If yes, how much on the average is their monthly take-home income in GHS: 1. <160 2.160-599 3.600-999 4.1000-1399 5.1400-1799 6.1800-219 7.2200-2599 8.2600-2999 9.3000-3399 10.3400-3799 11.3800-4199 12.4200-4599 13. 4600-5999 14. ≥6000 15. I don't know 16.I won't tell you	**SECTION B: General Water Supply and Environmental Questions** **B.1.** Which of the following water systems is installed in your residence? **1.** Piped water **2.** Non-piped water **3.** None **(NB: Skip B.2 if None)** **B.2.** Is the installed water in your residence reliable? (*Reliability means it flows or you can fetch at least once a day*)? **1.** Yes [ ] **2.** No [ ]
Select any of the **SOURCE DESCRIPTION CODES** to answer questions **B.3 and B.5** **01**………….Indoor plumbing **09**……………Borehole **02**…………..Inside stand pipe **10**……………Protected well **03**…………Water truck/tanker service **11**……………Unprotected well **04**……….. Water vendor(gallons) **12**……………..River/Stream/lake/dam **05**…………Pipe in neighbouring household **13**…………..Rain water/spring **06**……….. Private outside standpipe **14**…………..Dugout pong **07**……….. Public Stand pipe **15**.……….. Other (specify)………… **08**…………Sachet/bottled water/packaged	**B.3.** What is the main source of water supply for your household? **(Use source description codes)** DRINKING GENERAL USE

Select any of the **TIME UNIT CODES** for **B.4 and B.6** to answer questions **B.4 and B.6**

1………………..Daily
2………………..Weekly
3………………..Monthly
4………………..Quarterly
5……………..…Half Yearly
6………………..Yearly
0………………..Not Applicable

B.4. How frequently (regular) do you receive drinking water supply from your main source?

Time unit (see **time unit codes**) Number of times

B.5. What is (are) the other source(s) of water supply for your household?

(**Use source description codes)**

DRINKING GENERAL DOMESTIC USE

B.6. How regular (reliable) is your water supply for GENERAL domestic use?

Time unit (see **time unit codes**) Number of times

B.7. If NOT piped water, why do you use these other sources of water supply?

1. No access to private piped water
2. Other sources are less expensive
3. Other sources are more reliable
4. Other (specify]……………….....

B.8. Do you have any home water treatment system?

1.Yes **2.** No

NB: If No, skip question B.9

B.9. Identify the rate at which is it cleaned/repaired/replaced?

1. Frequently **2.** Sometimes **3.** Not at all **4.** don't know

B.10. In your last five years, which of the following is true? After purchase of water for other sources, you can…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use

B.11. In your last five years, which of the following is true? After purchase of water for drinking, you …..…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use

B.12. In your last five years, which of the following is true? After purchase of water for general domestic use (not including drinking), you….…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use

B.13. Have you ever felt the need to have had an improved quality of the water you use?

1. Yes
2. No

NB: If No, it means you are satisfied with the quality of your domestic water. Please skip question B.12, B.13 and B.15.

B.14. What could you have done to improve it?

1. Apply Chemicals. Identify the type of chemicals
2. Allow water to settle. How many minutes would it take to get settled?
3. Boiling. How long would it take to be ready?
4. Filtering. How long does it take to filter your water?
5. Other. Specify and indicate how…..

B.15. In the last five years, which of the following have you done before to improve water quality before use?

1. Boiling- On the average, how many minutes does it take?
2. Applying chemicals- How much do you spend on this per month?
3. Allowing debris to settle- On the average, how many minutes does it take?
4. Filtering. How much do you spend on filters per year/ how long does it take?
5. Other- Specify and identify either the time or amount spent on it…………

B.16. How much would you spend or do you spend on average to make this source potable for use per week?

B.17. How much do you spend (on average) on water per month irrespective of source?

B.18. Who is mainly responsible for ensuring that your household has enough water?

1. Husband **2.** Wife **3.** Children

B.19. Do you promote good environmental practices? (e.g.: promoting good sanitation, cleaning environment, weeding compound etc.)

1. Yes
2. No (**If No, Skip question B.18**)

B.20. If yes, rank the extent of your promotion to the indicators listed in the table below. (Yearly(Y) , Monthly(M), Weekly (W), Daily(D) Every Purchase(E))

Factors/Indicators	**All the time**	**Some-times**	**Not at all**
Green Environment/ afforestation e.g.: planting trees (M)			
Cleaning of Environment (D) e.g.: sweeping			
Efficient Water use by preventing waste(D)			
Indiscriminate waste disposal(D)			
Use of Eco-product (E) :Identify as Eco-product before purchase			
Good sanitation(W) e.g.: regular collection of refuse			
Other…………………			

B.21. If No to **B.17**, briefly give your reason(s) ……………………………
……
…………………………………………………….

B.22. Which of the following international environmental issues do you know of?

1. Global warming/Green House Effect [Yes] [No]
2. Climate Change[Yes] [No]
3. Kyoto Protocol [Yes] [No]
4. I don't know any

B.23. Mention any National/District/Local environmental law/practice you know of?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

B.24. How important is protecting the environment to your household?
1. Very Important **2.** Important **3.** Fairly Important **4.** Not important

B.25. Is your locality dusty enough to pollute your water? **1.** Yes [ ] **2.** No[ ]

B.26. In your view, is water a major problem in your district? **1.** Yes [ ] **2.** No [ ]

B.27. How is the water supply system operated and managed?

1.Self **2.**Community operated and managed
3.Community Watered Sanitation Agency **4.**NGO
5. Ghana Water Company Ltd **6.**Other (Specify) ………
7. Not Applicable **8.** Don't know

B.28. In your view, which of the following are some of the water problems in your district?

1. Cost **4.** Poor quality
2. Lack of flow **5.** Poor Management
3. Difficult to access **6.** Other [ ] If other, specify…………………………

B.29. In your view, who in your district is mainly responsible for your water problems?
1. Colonial Administration] **2.** Government **3.** GWCL **4.** Consumers
5. Don't know Give reason for your choice?
………………………………………………………………………………………

SECTION C: Hedonic Valuation Questions

C.1. Who owns your residence?
1. You **2.** An Organisation (Property Company)
3. Landlord **4.** Your employer
5. Government(Municipal, District, Local, Assembly)
6. Other (If other, specify)………………………………

C.2. Nature of residence?
1. Compound house **5.**Shanty town/slum
2. Separated house 6. Flat/Apartment
3. Duplex **7**. Other [ ] Specify………
4. Traditional (mud/hut/wooden)

C.3. Residence outer wall (fence/ boundary/perimeter) type
1. No wall **5** .Stone
2. Mud bricks/Earth **6** .Cement/Concrete
3. Wood **7** .Bamboo/Palm leaves/thatch (grass)
4. Metal sheet/slate/asbestos **8** .other. Specify…………………..

C.4. Residence Roofing type
1. Mud/Mud bricks/Earth **5.** Slate/asbestos
2. Ceramic/marble/Vinyl Tiles **6.** Cement Concrete/Terrazzo
3. Wood **7.** Bamboo/Palm leaves/thatch (grass)
4. Metal/Aluminium sheet **8.** If other. Please specify…………………

C.5. Complete the number, size and nature of the facilities in your residence provided below:

C.6. Do you have access (at least electricity within the last one month) to electricity in your residence?
1. Yes [ ] **2.** No [ ]

C.7. . What is the main source of lighting for your household?
1……………………National Electricity Grid
2……………………Kerosene
3…………………… Gas lamp
4……………Candles/Touches (flashlights)
5……………………Solar energy

Facility	Number	Average Size(Square feet)
Bathroom Toilet Garage Storeroom Kitchen		
Bedroom		
	Nature: cemented/ wool/ rubber/ tiled/paved/ grass /none	
Plot or floor space of your residence	**Size**(Sq. ft)	Nature: cemented/tiled/paved/grass/none

6……………………Generator
7……………………No light
8……………………Other

C.8. If Electricity, what type of electricity bulbs do you use?
1. Energy saving bulbs **2.** other (such as incandescent light bulbs)
3. Both

C.9. Do you have access to a toilet facility in your residence? Yes [ ] No [ ]

C.10. Do you have a poly tank (reservoir) in your residence? Yes [ ] No [ ]

C.11. **Question for non-owners only:** How much did you pay as rent last month

GHS……………………

C.12. **Question for Owners only:** If you are the owner of the house, assuming you decide to leave your residence for a new residence. How much would you charge if you were renting your old residence out per month?

GHS............

C.13. What is the distance (measured in meters) from your residence to the following:

1. School [ ]

2. Coal tar road [ ]

3. Financial Institution [ ]

4. Health centre [ ]

5. Market [ ]

6. Transport Station [ ]

7. King's Palace [ ]

8. Hotel [ ]

C.14. In making your current residential decision how important were the following factors?

Determinants	On the scale of 1 to 5 where ***1=very important*** *and* ***5 =Very unimportant***					***Don't Know***
Rental rate	1	2	3	4	5	
Water Supply	1	2	3	4	5	
Electricity Supply	1	2	3	4	5	
Family and Friends	1	2	3	4	5	
Workplace Proximity	1	2	3	4	5	
Security	1	2	3	4	5	
Public Services	1	2	3	4	5	
Prestige	1	2	3	4	5	
Noise pollution	1	2	3	4	5	
Air pollution	1	2	3	4	5	

***DK means Don't Know or DR means Don't Remember**

SECTION D: Travel Cost Questions

D.1. Do you need to spend some time looking (hauling) for water in your district?

1. All the time
2. Sometimes
3. None of the above

[ ]

D.2. If NONE, does that mean you have no problem with potable water from Ghana Water Company Limited (GWCL)?

True	
False	

D.3. How far is your household's **main** source of water supply from your dwelling?

DRINKING — NUMBER(see water codes in page 3) [ ] — DISTANCE UNIT (Meters) [ ]

GENERAL USE — NUMBER(water code) [ ] — DISTANCE UNIT(Meters) [ ]

D.4. How far is your household's **other** sources of water supply from your dwelling?

DRINKING — NUMBER(see water codes in page 3) [ ] — DISTANCE UNIT (Meters) [ ]

GENERAL USE — NUMBER(water code) [ ] — DISTANCE UNIT(Meters) [ ]

D.5. Indicate in the table below the of mode water is transported to your household

Mode of water transportation	Number of round trip per household/ week		Travel cost per round trip(Ghs)	
	Main Source	Other Sources	Main Source	Other Sources
Walking				
Private car				
Commercial car/bus/truck				
Commercial manual truck				
Tanker services				
Other				

D.6. Are you satisfied with the following:

1. Source of water? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].
2. Quality of water? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].
3. Mode of transporting water to your residence? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].
4. Number of trips made for water to get to your residence? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].

E. SANITATION QUESTIONS

E1. How does your household dispose of refuse?
1…………………Collected
2…………………Public Dump
3…………………Dumped elsewhere
4…………………Burned by household
5…………………Buried by household
6…………………Other specify

E2.Does your household pay for the disposal of refuse?

Yes ……………………………………… 1

No …………………………………….. 2 >>> >>SKIP >>E4

TIME UNIT CODES

1………………..Daily
2………………..Weekly
3………………..Monthly
4………………..Quarterly
5……………..…Half Yearly
6………………..Yearly
0………………..No Applicable

E3. How much does this household pay for refuse?

Amount in GHS and P

GHS [ ] p [ ]

Time Unit [ ] see codes

E4. What type of toilet is used by your household?
1…Flush Toilet
2….Pit latrine
3…KVIP
4…………Pan/bucket
5…………Public toilet(flush, bucket, KVIP)
6…Toilet in another house
7. .No toilet facility (bush, beach)
8……other , specify

E5. The last time your youngest child under 5 years passed stools, what was done to dispose it?
1……...Child used toilet latrines
2……...Put/rinsed into drain or ditch
3……...Thrown into garbage
4…………Buried
5………Left it in the open
6. ……..…Other , specify ________________
7 ………...Don't know
8. No child under 5 years in Household

E.6 Does your household pay for the disposal of refuse?

Yes ……………………………………… **1**

No …………………………………….. **2** >>> **>>SKIP E.7 to E.8**

E.7. How much does your household pay for the use of the toilet facility?
Amount in GHS and P

GHS [ ] p [ ]

E.8 Are you aware of any water borne disease?

1. Yes [ ] **2.** No [ ].If yes, specify………..

E.9. Which of these sicknesses was last experienced by any member of your household?

1. Malaria [ ] **2.**Cholera [ ] **3.**Diahorrea [ ]

4. Typhoid [ ] **5.** Diabetes [ ] **6.**None[ ]

Other [ ] If other, please specify……………………………………………………

E. 10 Do you think toilet or/and refuse gets into your domestic water? 1. Yes 2. No.

Briefly explain your answer in **E.10**………………………………………

E. 11 What are the likely HEALTH effects of unclean domestic water on your household?

SECTION F: Contingent Valuation Questions

F.1. Assuming the associated cost of an improved water service in Ghana is manageable. Would you like an improved service in Ghana's water service delivery?

1. Yes

2. No

(**If yes, continue with hypothetical market scenario on the next page**).

F.2. If no, give reason..
…………………………………………………………………………………………
…………………………………………………………………………………………**End**

Hypothetical Market Scenario:

- I would want to find out from you, if you value the provision of an improved water supply system in Ghana particularly in the Greater Accra Region. By improvement we mean you are connected to the Ghana Water Company Limited (GWCL) main lines, water flows directly in your residence at all times, and the quality of the water is up to an acceptable international standard. Generally, we know that every good thing comes at a cost. You may be required to pay a permanent amount that will be factored into your water bills provided by GWCL.
- Refer to pictorial description for further understanding of oral/written description

Willingness-To- Pay Questions

F.3. Would you prefer another medium of payment other than GWCL monthly bills?

Yes [ ] No [ ] If yes, how would you want to pay it? ……………

A: Willingness-to-pay (WTP)

F.4. Suppose you are supplied with an uninterrupted (reliable) piped-water as orally and pictorially described, how much would your household be willing to pay to fetch a 34cm bucket of water?" Would your household be willing to pay

- GHS………… (for the household **not** entire residence) YES [ ] (**if yes, skip to B-WTP**)
- If NO, What about GHS …………………………………………...? YES [ ]
- If No, please specify amount which you would be willing to pay less than GHS………..….

Briefly explain why...

………………………………………………………………………………………

……………………………………………………………………………..END

B: Willingness-to-pay (WTP)
If yes, continue….

- GHS……………………. YES [ ]

If yes, it means you will be willing to pay more. Please state how much you would be willing to pay which is more than the GHS………………….

GHS………..………………………….

If no, it means you will be willing to pay less. Please state how much you would be willing to pay which is less than the GHS…………………

GHS ……………………………

E.6. How did you find the survey questions?

1. Very difficult	**4.** Very Easy
2. Difficult	**5.** Don't know
3. Easy	**6.** Refuse

END OF QUESTIONNAIRE

THANK YOU FOR YOUR ASSISTANCE!

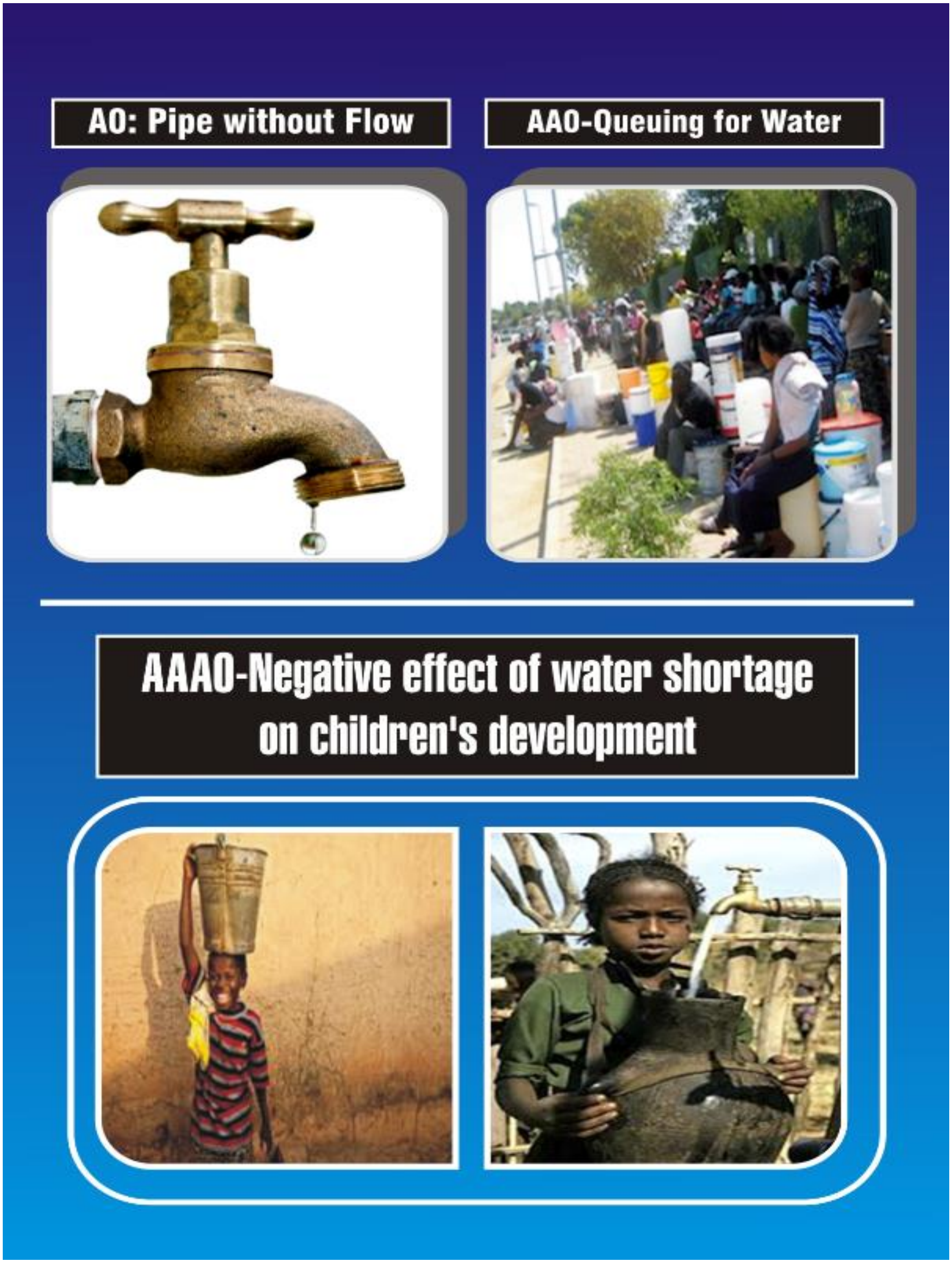

Fig. 3.1: Pictorial Description of Market 1

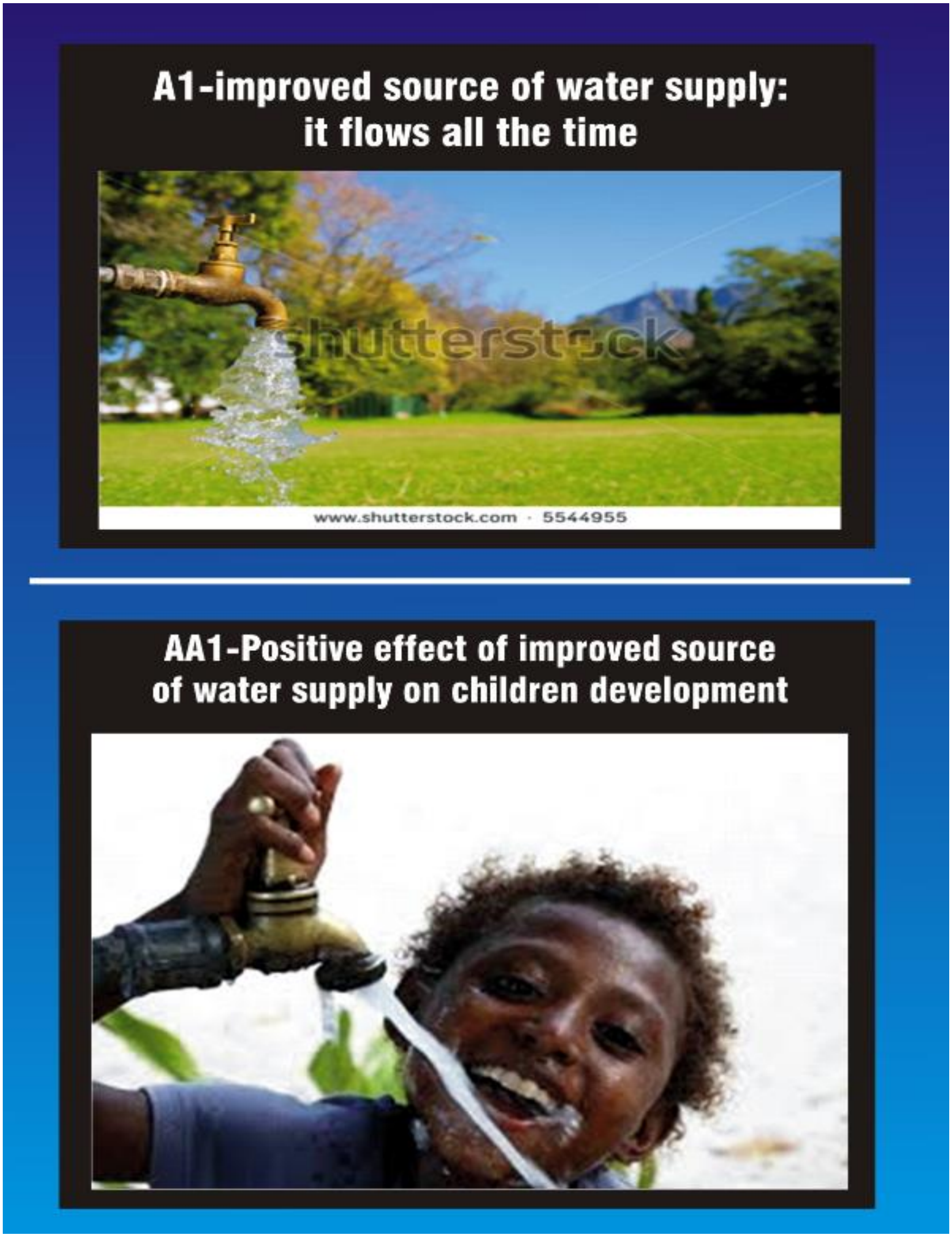

Fig. 3.2: Pictorial Description of Market 2

APPENDIX C1.2: STUDY AREA, POPULATION AND SAMPLE SIZE

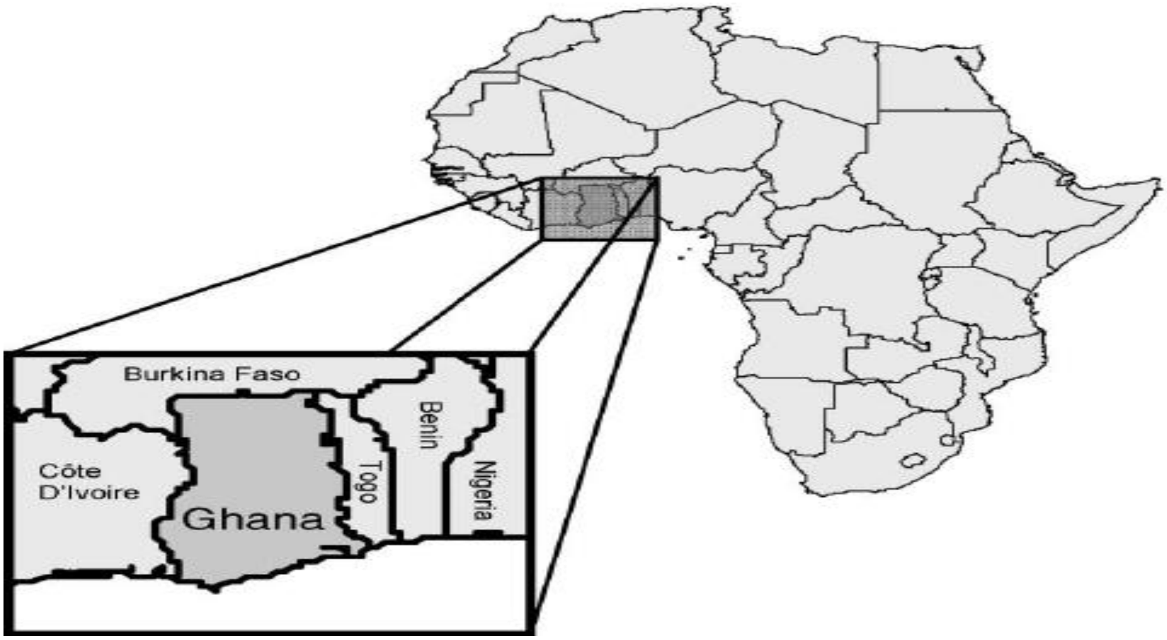

Fig. 3.3: Map of Ghana in Africa
Source: Adapted from Fuest and Haffner (Originally from Haffner)

Fig. 3.4: Map of Greater Accra Region

Table 3.10: Population by District, Gender and Type of locality in the GAR

	Population				Population in Households	Number of House-holds	House-hold size	Locality		Population 18 years and older		
District/Municipal	Percent	Total	Male	Female				Urban	Rural	Both Sexes	Male	Female
All Districts	**100.0**	**4,010,054**	**1,938,225**	**2,071,829**	**3,888,512**	**1,036,426**	**3.8**	**3,630,955**	**379,099**	**2,530,344**	**1,213,916**	**1,316,428**
Weija (Ga South)	12.1	485,643	237,558	248,085	477,467	118,846	4.0	430,780	54,863	282,620	137,243	145,377
Ga West	6.6	262,742	128,727	134,015	256,509	66,706	3.8	181,526	81,216	161,452	78,773	82,679
Ga East	6.5	259,668	127,258	132,410	252,914	66,286	3.8	227,172	32,496	167,043	82,189	84,854
Accra Metropolitan Area	46.1	1,848,614	887,673	960,941	1,779,165	501,956	3.5	1,848,614	-	1,214,414	579,029	635,385
Ablekuma South	*5.3*	*213,914*	*101,392*	*112,522*	*206,627*	*57,913*	*3.6*	*213,914*	-	*134,228*	*62,069*	*72,159*
Ablekuma Central	*6.7*	*268,424*	*128,678*	*139,746*	*264,160*	*72,230*	*3.7*	*268,424*	-	*174,103*	*82,676*	*91,427*
Ashiedu Keteke	*2.9*	*117,525*	*55,165*	*62,360*	*111,180*	*34,964*	*3.2*	*117,525*	-	*78,314*	*36,312*	*42,002*
Osu Klotey	*3.0*	*121,723*	*58,457*	*63,266*	*115,070*	*35,508*	*3.2*	*121,723*	-	*84,586*	*40,124*	*44,462*
La	*4.6*	*183,528*	*86,738*	*96,790*	*179,251*	*51,155*	*3.5*	*183,528*	-	*119,174*	*55,311*	*63,863*
Ayawaso East	*4.6*	*183,498*	*88,235*	*95,263*	*178,915*	*43,755*	*4.1*	*183,498*	-	*120,653*	*58,127*	*62,526*
Ayawaso Central	*3.5*	*142,322*	*68,390*	*73,932*	*138,167*	*39,116*	*3.5*	*142,322*	-	*95,128*	*45,814*	*49,314*
Okai Koi South	*3.0*	*121,718*	*58,592*	*63,126*	*116,722*	*34,800*	*3.4*	*121,718*	-	*81,021*	*38,727*	*42,294*
Ablekuma North	*4.9*	*197,024*	*94,280*	*102,744*	*193,508*	*53,039*	*3.6*	*197,024*	-	*127,350*	*60,422*	*66,928*
Okai Koi North	*5.7*	*228,271*	*110,681*	*117,590*	*223,568*	*64,567*	*3.5*	*228,271*	-	*146,241*	*70,748*	*75,493*
Ayawaso West Wogon	*1.8*	*70,667*	*37,065*	*33,602*	*51,997*	*14,909*	*3.5*	*70,667*	-	*53,616*	*28,699*	*24,917*
Adenta	2.0	78,215	39,366	38,849	76,601	20,478	3.7	49,995	28,220	49,666	25,419	24,247
Ledzokuku / Krowor	5.7	227,932	109,185	118,747	221,757	60,859	3.6	227,932	-	143,432	67,713	75,719
Ashaiman	4.8	190,972	93,727	97,245	185,804	49,936	3.7	190,972	-	119,150	58,995	60,155
Tema	10.0	402,637	193,334	209,303	391,537	97,597	4.0	392,044	10,593	256,110	122,349	133,761
Tema West	*3.2*	*127,807*	*61,501*	*66,306*	*124,385*	*31,154*	*4.0*	*127,807*	-	*85,241*	*41,107*	*44,134*
Tema East	*4.0*	*160,213*	*75,979*	*84,234*	*155,994*	*38,508*	*4.1*	*160,213*	-	*102,354*	*47,835*	*54,519*
Kpone Katamanso	2.9	114,617	55,854	58,763	*111,158*	*27,935*	*4.0*	*104,024*	*10,593*	*68,515*	*33,407*	*35,108*
Dangbe West	3.1	122,836	58,806	64,030	118,542	26,489	4.5	41,629	81,207	68,197	31,416	36,781
Dangbe East	3.3	130,795	62,591	68,204	128,216	27,273	4.8	40,291	90,504	68,260	30,790	37,470

Source: Ghana Statistical Service (GSS), 2012

Table 3.11: Total Population, No. of Households and Sample size per District

District	Total Population	No. of Households	Urban	Sample	Rural	Sample	Total Sample
Weija	485,643	118,846	87,946	172	30,900	69	241
Ga West	262,742	66,706	49,362	97	17,344	39	135
Ga East	259,668	66,286	49,052	96	17,234	38	134
AMA	1,848,614	1,779,165	371,447	726	130,509	291	1017
Adenta	78,215	76,601	15,154	30	5,324	12	41
Lezokuku	227,932	221,757	45,036	88	15,823	35	123
Ashaiman	190,972	185,804	36,953	72	12,983	29	101
Tema	402,637	391,537	72,222	141	25,375	56	198
Danbge West	122,836	118,542	19,602	38	6,887	15	54
Danbge East	130,795	128,216	20,182	39	7,091	16	55
Total	4,010,054	1,036,426	766,955	1500	269,471	600	2100

Sample Size Computation (Yamane 1967)

$n = \frac{N}{1+N(e^2)}$, $n = \frac{1,036,426}{1+1,036,426(0.05^2)}$ ≈400; $\frac{950,336}{1+950,336(0.05^2)}$ ≈400

N=population size (Total Number of Households) and e=margin of error 0≤e≤1

APPENDIX C1.3: DESCRIPTIVE STATISTICS FOR HPM TCM AND CVM

Table 3.12: Descriptive Statistics for HPM

Type of Variable Name	Obs.	Mean (Std. Dev.)	Variable Description: Type/Codes
Rent Per Monthly in Ghana cedis (GHS)	1648	138.23 (174.23)	Continuous 10 (Min) 1,000(Max)
Average-district monthly Take-Home Income in GHS	1648	636.18 (89.65)	Continuous 463.62 (Min) 842(Max)
Access to Reliable Piped-Water in Residence	1376	0.29 (0.45)	Dummy Yes=1, No=0
Number of Garage	1646	0.10 (0.36)	Dummy Yes=1, No=0
Access to Toilet in Residence	1648	0.722 (0.45)	Dummy Yes=1, No=0
Reservoir in Residence	1648	0.48 (0.50)	Dummy Yes=1, No=0
Distance to Nearest Highway (km)	1648	0.65 (1.64)	Continuous 0.10 (Km)- 32.14 (Km)
Distance to Nearest Financial Institution (km)	1648	0.67 (0.81)	Continuous 0.015 (Km)- 12 (Km)
Distance to Nearest School (km)	1648	0.25 (0.46)	Continuous 0.01(Km)- 9.29 (Km)

*Hypothesised on WTP

Table 3.13: Descriptive Statistics of TCM and CVM

Type of Variable Name	Obs.	Mean (Std. Dev.)	Variable Description: Type/Codes
No. of Round-Trips to Water Source(s) per month	1648	99.58 (89.975)	Continuous/Count 0(Min)- 592(Max)
Monthly Take-Home Income in Ghana cedis	1604	636.37 (581.35)	Continuous 160 (Min) 4,400(Max)
Other Family Members in Household	1648	0.83 (0.38)	Dummy 1-Yes, 0-No(Single Adult Only)
Age of Respondent (Years)	1648	39.29 (11.86)	Continuous 18yrs-72yrs
Age of Respondent Squared (Years)	1648	1685.04 (986.86)	Continuous 324yrs-5184yrs
Access to Reliable Piped-Water in Residence	1376	0.29 (0.45)	Dummy Yes=1, No=0
Cost per Round-Trip to Main Water Source per Month (M) in Ghana Cedis	1648	9.16 (11.95)	Continuous/Count 0(Min)-1308 (Max)
Cost per Round-Trip(s) to Other Sources of Water per Month (M) in Ghana Cedis	1648	55.52 (27.32)	Continuous/Count 0(Min)- 1540 (Max)
Saving Behaviour	1648	0.73 (0.45)	1-Yes, 0-No

Type of Variable Name	Obs.	Mean (Std. Dev.)	Variable Description: Type/Codes
Maximum WTP Amount (Ghana Pesewas)	1648	39.86 (21.42)	Continuous 0 (Min)-200 (Max)
Categorical WTP	1648	1.55 (0.61)	Categorical 1 ,2, 3, 4
Lower WTP Amount	1648	31.93 (13.42)	Continuous -5 (Min)-60 (Max)
Upper WTP Amount	1648	52.93 (18.24)	Continuous 20 (Min)-210(Max)
Starting Point Amount	1648	34.95 (11.18)	Discrete 20,30,40,50
Number of Households	1646	4.71 (3.79)	Continuous 1 (Min)-32(Max)
Main Source of Household Water for Drinking Reliability Index	1110	0.03 (0.18)	Dummy Yes=1, No=0
Main Source of Household Water for General Use Reliability Index	1589	0.25 (0.43)	Dummy Yes=1, No=0
Knowledge of Local Environmental Issues	1648	0.55 (0.49)	Dummy Yes =1, No=0
Knowledge of International Environmental Issues	1641	0.61 (0.49)	Dummy Yes =1, No=0
Average Household Expenditure on water/month	1612	52.21 (38.35)	Continuous 4 (Min)- 400(Max)
Residence Fence Type	1648	0.59(0.49)	Dummy 1=Fenced, 0=No Fence

*Hypothesised on WTP

APPENDIX C1.4: FIELD WORK ISSUES

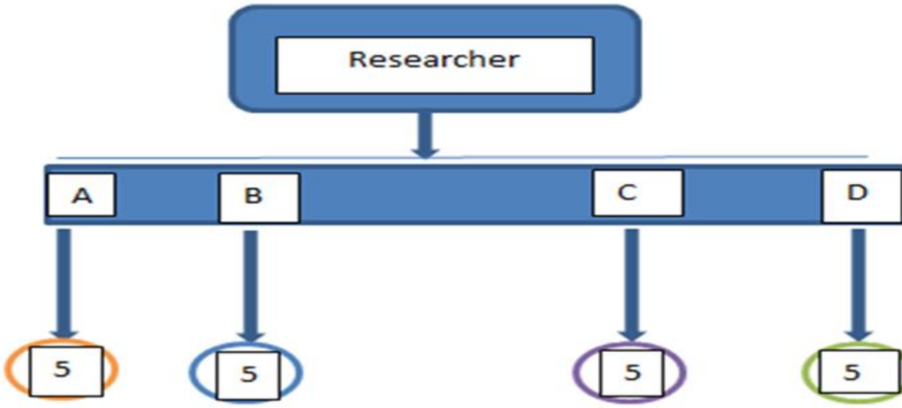

Fig. 3.5: Team Structure for Field Work

Fieldwork Processes	
Process 1	**Process 2**
1. Survey designed 2. Inputs from Supervisors 3. Inputs from individual experts from other Schools 4. Focus group discussion 5. Most comments reviewed 6. Ready for presentation at School's internal seminar 7. Ready for process 2	1. Input from Faculty/School 2. Focus group discussion 3. Training of Coordinators 4. Training of Interviewers **5. 1st Pilot Survey** 6. Signing of field agreement form 7. Pilot survey data analysis 8. Modification of questionnaire 9. **2nd Pilot survey** (on a relatively smaller sample) 10. Analysis of last pilot survey 11. Fieldwork commences

CHAPTER FOUR

Demand for Domestic Water from an Innovative Borehole System in Rural Ghana: Stated and Revealed Preference Approaches

1. Introduction

In the Millennium Development Goals (MDGs), one of the first targets to have been declared met was the Drinking Water Target. However, rural areas across the world especially in developing countries still lag behind in access to clean drinking water. UNICEF/WHO (2014) reports that, 97 out of every 100 people from rural areas in developing countries do not have piped-water, with 14% depending on surface water such as rivers, ponds, or lakes. Sub-Saharan Africa (SSA) needs more attention as it has a worse case relative to other developing regions. It is estimated that only 61% of people in SSA have access to improved water supply relative to over 90% in Latin America and Caribbean, Northern Africa, and large parts of Asia. Indeed, SSA lags behind the other developing regions in terms of development towards water supply targets.

Towards meeting MDG 7 which has further been consolidated into Sustainable Development Goal 6 [1], groundwater is considered a reliable improved source for domestic use in SSA. MacDonald et al. (2002) provide some insights into groundwater as a reliable improved option especially in low permeability areas in Africa. They argue that groundwater is a "well suited" source for rural water supply in SSA. It possesses some resilience to the impacts of drought and is relatively cheap to develop and maintain. One major challenge is the kind of improved groundwater (borehole and wells) being provided. These are generally the traditional manual types, which require a lot of physical strength from water haulers (mainly women and children) to pump and it's mostly without filters hence quality is sometimes compromised because of environmental conditions. The water is further exposed to contamination from the point of access to the point of usage. It is important to acknowledge that recent evidence indicates that many improved water supplies suffer from poor reliability (Hunter et al., 2009), and that not all improved water is safe (Levisay and Sameth, 2006). In the view of MacDonald et al. (2002), some proportion of trace constituents in groundwater can make it unsafe and can give rise to health problems. Yet such sources can erroneously be described as improved or safe sources of water. This, to some extent, brings doubts as to whether what is described as 'improved' by the international community is the same as 'safe[32]'.

In Ghana, the Community Water and Sanitation Agency (CWSA) is the national institution responsible for the provision of safe drinking water and related sanitation services to rural communities. Unfortunately, these communities depend primarily on water from traditional borehole systems which can at best be described as 'improved' but not 'safe'. Another key challenge of the CWSA enshrined in the National Water Policy (NWP, 2007) is how to set tariffs to ensure the sustainability of operations as information on consumers' consumption behaviour is unknown to agents in this market.

In order to avoid future uncertainties regarding the supply of safe drinking water to rural dwellers in a more effective and efficient way, this study primarily aims at estimating household's demand for an innovative borehole system given that piped-water systems are not available. This is a completely new kind of borehole system. It uses water pump and it is connected to a solar source of energy supply. The pump generates and supplies water through a filtered-pipe into a communal water tank, which supplies the generated water through a second filtered-pipe(s) to surrounding homes. Thus, we use cost effective resources such as abundant sunshine and ground water which is properly filtered for the design of this innovative system. Water supply from this innovative system can be described as safer and cheaper water relative to what is currently being offered. It has the advantage of easing the water burden on women and children with its associated consequential benefits. In addition, it is particularly useful in developing countries where water supply infrastructure is a major problem. We propose this innovative system to the rural community and provide information about households' willingness-to-pay (WTP).

The competing independent valuation approaches generally accepted and used in literature for determining the economic value of non-market goods and services are either based on the revealed/indirect approaches (such as hedonic pricing method [HPM], travel cost method [TCM], take-it-or-leave-it method [TIOLI] etc.) or stated preference/direct approaches (such as contingent valuation method [CVM], choice experiment method [CE]) (see Adamowicz et al., 1994). These valuation approaches

[32] "Safe drinking water is water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality" (WHO, 2015@ www.who.int/water_sanitation_health/ mdg1/en). In this study *safe water* is referred to as water supply from piped system or treated borehole water etc., and *improved water* is defined as water supply from boreholes, wells etc. not necessarily treated.

also provide economic measures of social benefits needed to inform policy direction. These methods have been used by prominent institutions such as The World Bank, and applied in both developed and developing countries' contexts (see Briscoe et al., 1990; Bateman et al., 1994; Nauges and Whittington, 2009 etc.). Indeed, it goes without saying that these methods are useful in both settings.

In this paper, we use the CVM through a hypothetical market design, and the HPM using rental values of housing units, to measure different aspects of water supply in the rural Greater Accra Region (GAR) of Ghana. We use the CVM to estimate household's marginal WTP for domestic water supply from the proposed innovative borehole system which captures access to safe water supply whilst the HPM is used to estimate household's marginal WTP for the current service which also captures access to current improved water supply in residences. Results from both methods suggest that, households place higher value on water from the innovative borehole system than the traditional systems. We find that household's monthly marginal WTP estimates are GHS35.90 (US$11.45) and GHS17.59 (US$5.61) in the CVM and HPM, respectively. In line with the MDGs and Sustainable Development Goals (SDGs), this study provides information to assist policy makers locally and internationally in their decisions for rural water supply in Ghana. This will help evaluate the socio-economic and health potential of the project as well as determine appropriate tariffs for rural communities which can help design socially equitable fiscal policies.

The rest of the paper is structured as follows. Section 2 presents the empirical review of literature. Section 3 describes the survey design used in carrying out the research. Section 4 presents results and discussions while section 5 concludes with relevant policy recommendations.

2. Empirical Literature

In this section, we review studies on WTP which relate to introducing innovative or new products in developing countries and shed light on how studies have been empirically conducted using non-market based valuation methods.

Brouwer et al. (2015) assessed urban and rural demand for gravity-driven membrane (GDM) filter for improved drinking-water supply in Kenya. This was a new technology that had not yet been introduced to the market. Respondents had knowledge about other filters and their associated benefits. However, this technology with its benefits were altogether new to respondents. The new technology was based on an extensively tested ultra-low pressure filtration and flux stabilisation technique. This by design does not require filter cleaning, yet it produces sufficient amount of water to meet 10-40 $Lday^{-1}$as required by the WHO and reduces diarrhoea occurrence among children to a maximum of once a year per child. The study combined two stated preference methods namely the CE and the CVM and found the latter to produce conservative and statistically more efficient estimates. The study found that respondents value the new technology positively relative to their current situation. The marginal WTP values in absolute terms were observed to be consistently higher in urban areas than rural areas because of income effect. They concluded that a differentiated marketing strategy is key to a successful introduction of the product in Kenya.

Berry et al. (2012) sought to estimate the WTP for a new product (Kosim filter, a ceramic water filter) introduced to some selected villages in Northern Ghana. This product was not totally new to the entire region as it had been introduced and sold by Pure Home Water[33] to some areas but not the areas understudy. The respondents were randomly assigned to be offered a water filter applying either the Becker-DeGroot-Marschak (BDM)[34] or TIOLI offer. This represented a more typical market transaction because prior to the original survey, demonstrations were made and respondents were further educated about the health benefits of the new product. The respondents saw how the new product worked, tasted the water generated from the new product and asked questions. They were given two weeks to discuss WTP for the new product with their families before participating in the original experiment. The study found evidence that respondents were generally willing to pay for the new product. In addition, they found strong evidence that the WTP implied by the TIOLI was consistently greater than the

[33] A Ghana-based Non-profit Organisation.
[34] BDM is a method for measuring utility by a single-response sequential method. It is considered to be an incentive-compatible procedure used in experimental economics to measure willingness to pay.

BDM mechanism. This was justified on two accounts. First, respondents felt they could influence the future price by bidding low. Second, the TIOLI may anchor respondents to higher valuation bids.

In addition, the absence of bathrooms with flush toilets and its health consequences in rural communities and the need for such new facilities within Northern Vietnam motivated Van Minh et al. (2013) to assess WTP for improved sanitation. The economic valuation technique employed was the CVM. Responses were elicited through the iterative bidding game format which involved two stages. First, a sequence of dichotomous choice questions, second, final open-ended questions. The sample size used was 370 households. The unit of analysis for the survey were people not having toilets in their residences as of the time of the interview, and were primary income earners as well as decision makers of their respective households. The hypothetical market used comprises descriptions of the good in question (bathroom with a flush toilet and possible benefits). The study found that about two-thirds were willing to pay for an improvement in their current sanitation situations. The economic status of respondents (poor or non-poor) and health knowledge of respondents were the principal influential factors of respondents' WTP.

Another developing country study by Clasen et al. (2004) investigated household demand for water filters with the purpose of reducing diarrhoea in Bolivia. In a six-month trial, water filters were distributed randomly to half of the 50 participating households in the community. The respondents were categorised into controlled group and intervention group. The respondents generally use customary practices for collecting, storing, and drawing drinking water. Half of the respondents were given filters at the inception of the study, and the other half six months later. Information on WTP were elicited by means of a questionnaire, and they obtained a sample of the pre-intervention drinking water for their baseline data analysis. Participants were randomly allocated by lottery. Half allocated to an intervention group and half allocated to a control group. The study used the CVM to assess WTP for the intervention. The mean response for the maximum amount participants would pay for the filter, was equivalent to U.S. $9.25.

Most WTP studies on introducing a new product, have generally followed field experiments and/or hypothetical survey (CVM) methods. However, to the best of our knowledge there is only one study by North and Griffin (1993), which used the HPM to estimate willingness-to-pay for rural water supply. These authors further confirmed the paucity of studies in this area by indicating that HPM has not yet been applied to WTP for water sources by rural households.

The main contribution of our study to this literature is that, it is, to the best of our knowledge, the first study that has applied both CVM and HPM to water supply for rural households. Also, as demonstrated by the various authors in this literature, the relevance of proper description of an innovative product is very critical when dealing with non-market goods. To this end, we used both pictorial and oral approaches for proper description of our innovative borehole system. We observed from our fieldwork that combining both pictorial and oral approaches gave better understanding to respondents. This and other methodological issues are presented in the next section.

3. Survey Design

Household survey data from all the seven districts in rural areas of the GAR was used in this study. We used household responses for the CVM, and housing attributes from the same survey data for the HPM. The total population and number of households in the rural areas of the GAR as reported by the 2010 Population census are 379,099 and 86,090 respectively. We used Yamane (1967)[35] sample size approach to compute the sample size. We oversampled this to 610 households for higher representation of the population. One response was dropped due to significant missing responses, hence a sample size of 609 households is used in this study.

Standard non-market valuation requires that relevant sampling issues (such as technique and sample size) are properly addressed. It is widely known that inappropriate sampling technique could lead to biased estimates. However, with the unplanned settlements in rural GAR, a multistage quota sampling technique was applied (see Whittington, 1998). This was achieved by clustering the region into seven districts, then into communities. We listed these communities in each district following the Town and Country Planning list of communities and randomly selected the households from these communities within the districts of the region. We sampled one in every two houses. According to our quota, we interviewed all households in the sample houses within the randomly selected communities in the districts. In sum, we applied the multi-stage quota probability sampling technique in drawing our sample of 610 from the population.

[35] Yamane (1967) sample size determination approach: $n = \frac{N}{1+N(e)^2} = \frac{86090}{1+86090(0.05)^2} = 398$. Where n is the sample size, N is the size of the population, e is the error level or level of precision.

A large fraction of rural households in the GAR reside in compound houses together with other households. Communal living effects (where resources are shared) in such compound houses cannot be completely ruled out yet, individual household decisions are mostly the responsibilities of the respective household heads. We therefore considered the entire household as a sampling unit and interviewed whoever the household considers as the household head or decision maker. By Ghana Statistical Service [36] definition, the household head is one who is economically and socially responsible for the entire household. The unit of analyses were household heads who lived in the district, were 18 years old and above, and of sound mind. They should have worked within the last five years and were employed at the time of the survey. However, we also allowed in our sample those who have not worked within the last seven days of the month of the interview. All potential respondents reserved the right to either accept to participate or decline participation.

The questionnaire was designed based on two standard national survey questionnaires from Ghana and the United Kingdom. This was subsequently reviewed by survey experts, economists and legal practitioners. The questionnaire was pre-tested in a pilot survey on two different occasions during in-person or face-to-face interviews. This made it necessary for additional amendments to be made to the questionnaire to suit what was practically feasible during this period. The final version of the questionnaire after amendment can be categorised into six sections. For brevity, we summarise them under three main headings: *personal data of respondent* which comprises all socio-economic and demographic questions; *general water, sanitation and environmental questions* which includes sources of water supply, water use and reliability, types waste disposal forms, and their general knowledge about local and international environmental issues relating to water supply; and *environmental valuation questions* which consists of the various market designs and WTP questions.

The questionnaire was administered by twenty-five fieldworkers during April-May, 2014, which also includes the training of interviewers and coordinators, pilot survey and data entry.

[36] Government of Ghana, Ghana Statistical Service (2012): 2010 Population and Housing Census, Summary Report of Final Results, Sakoa Press Limited, Ghana.

3.1 Valuation Approaches and Econometric Models Applied

3.1.1 The Contingent Valuation Method (CVM)

According to Portney (1994, p.1), "[t]he contingent valuation method involves the use of sample surveys (questionnaires) to elicit the willingness of respondents to pay for (generally) hypothetical projects or programs". The first CVM survey was designed and implemented by Davis (1963). Unlike the revealed preference methods, the CVM has the advantage of capturing both use and non-use values. The CVM follows the conventional consumer demand theory, which has it that the quantity demanded of a good is a negative function of price, all else being equal. Respondents in our survey, were asked to place value on the innovative borehole system by answering WTP questions. We define respondent's value in line with a standard household utility function which is convenient with cross sectional data. Following Whitehead and Blomquist (2005), we specify a standard consumer's utility maximization function subject to income and prices as:

$$\max_{q} U(q,z) \qquad s.t. \;\; y = z + pq \tag{4.1}$$

Where y denotes the income of respondent, p and q are the marginal price and quantity of water from the traditional borehole system respectively, and z is a composite of all other goods and services. The solution to the maximization problem in equation (1) leads to the indirect utility function, $v(p, y)$. Alternatively, the minimisation of consumer's budget, given their utility constraints is shown in equation 4.2.

$$\min_{q} e(z + pq) \qquad s.t. U = U(q,z) \tag{4.2}$$

Similarly, solution to the problem in equation 4.2 yields the consumer's expenditure function, $e(p, u)$. This can be inverted to obtain the indirect utility function by recognizing that $v = u$, and $e = y$.

We demonstrate the entire impact upon a household's welfare by the Hicksian compensating surplus, which essentially shows the amount of income that an individual would be willing to pay for water from the innovative borehole system and, as a result, continue receiving the level of utility (u^0) received before the changes. Now the change in the borehole system by introducing the innovative borehole system should be seen as an increment in consumer's expenditure, $q^1 > q$. Indeed, WTP for the increment arises, and this is shown in equation 4.3.

$$CS(q, q^1) = WTP = e\big(p, q, v(p, q, y)\big) - e(p, q^1, v(p, q^1, y)) \tag{4.3}$$

We also obtain the compensating surplus function where WTP is a function of some factors,

$$CS(q, q^1) = WTP = e(p, q^1, v(p, q^1, y)) - y \quad (4.4)$$

Equation 4.4 (compensating surplus function) represents a measure of WTP for the innovative borehole system as a function of quantity of water from the innovative system and income of households. Thus, it shows how much each household is willing to sacrifice and yet remain on the same utility level (u^0) before the change. For empirical purposes we rewrite the structural economic function given by equation 4.4 into an econometric function. Here we assume that the WTP function in equation 4.4 takes the following parametric linear form:

$$WTP_i = \gamma + \varphi p_i + \propto q_i^1 + \partial y_i + \varepsilon_i \quad (4.5)$$

We rewrite equation 4.5 assuming that the maximum amount household i is willing to pay for water from the innovative borehole system is posited as WTP_i. The error term is represented as ε_i which follows a normal distribution function with mean zero and standard deviation (σ). In addition to the regressors in equation 4.5, factors such as gender, marital status, and household decision type of respondent have the potential to explain household's WTP for safe/improved water. Furthermore, these factors are more likely to correlate with income and quantity hence omitting them from the model is likely to lead to omitted variable bias. To ensure consistent and efficiency of the parameters in the WTP function we account for these additional factors in our empirical specification. We specify our explicit linear functional relationship as

$$WTP_i = \gamma + \varphi p_i + \propto q_i^1 + \partial y_i + \mathbf{X}_i \boldsymbol{\beta} + \varepsilon_i \quad (4.6)$$

Where **X** is a vector of household characteristics, $\boldsymbol{\beta}$ is a vector of parameters to be estimated. All other variables are as already defined.

Hypothetical Market Description

One essential requirement of CVM studies as outlined by the National Oceanic and Atmospheric Administration (NOAA) is a clear description of the hypothetical market. We describe the innovative borehole system which provides the target commodity as:

Hypothetical Market Scenario:

- Stage 1:

  I would want to find out from you, if you value the provision of an improved water supply system in Ghana particularly the rural part of the Greater Accra Region. By improvement it means you are connected to an uninterrupted supply of safe and sufficient water. We have designed an innovative/modernized borehole that is not manual but powered by solar energy so you do not have to pay electricity bills for water generation. This borehole water is filtered, piped and connected directly to *your residence. Thus, water flows directly into your residence at all times, the quality is up to acceptable national standards. Generally, we know that every good thing comes at a cost. You may be required to pay a permanent amount that will be factored into your water bills to be provided by the Community Water and Sanitation Agency (CWSA).*

- Stage 2 *(Refer to pictorial description for further understanding of oral/written description)*

  In the second stage, a picture representing the scenario described in the first stage was shown and narrated to the respondent (See Fig 4.1). This is also a preferred approach to just describing a hypothetical market (see Whittington and Pagiola, 2012).

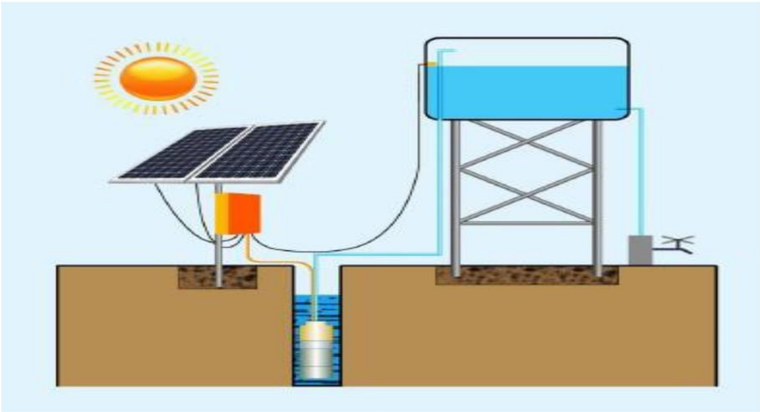

Fig. 4.1: Pictorial Description of Innovative/Modernized Borehole System

In this regard, the two stages were put together and the question asked for the double bound dichotomous choice game was: *"Suppose you are supplied with this innovative/modernized borehole system as orally and pictorially described, how much would you be willing to pay to fetch a 34cm bucket of water from this improved system?"*

3.1.2 Double Bound Approach

The double bound design with open ended approach is used in this study. According to Whitehead (2000, p.2), "Estimation of the double-bounded willingness to pay data with the interval data econometric model improves the statistical efficiency of WTP estimates relative to single bound models". However, this approach is prone to starting point and anchoring effect biases. To correct such biases, Bateman et al. (2002) have suggested the use of randomized card sorting procedure (RCS). In this study, we used randomized questionnaire sorting (RQS) procedure which in principle is very similar in approach to the card sorting method. In a nutshell, this study used the dichotomous choice double-bound format with RQS.

3.1.3 Respondents' Bids

We determined marginal WTP through the maximum amount respondents were willing to pay for safe water from the innovative borehole system. The double bound dichotomous choice format used in this study provides three options. A yes or no response data, an interval data and the maximum amount respondents have stated as their WTP for the good in question. Respondents' responses from the WTP question are used as the dependent variable using different model specifications. The OLS uses the final bid amount stated by the respondent. In the case of the interval regression there were four permutations in the responses from respondents. The yes-yes responses, yes-no responses, no-yes responses and no-no responses. This approach is presented in section 3.1.4 (model 2).

3.1.4 Econometric Models Applied

The double bound dichotomous choice format provides midpoints and interval WTP information. We use two econometric models namely interval regression and OLS regression as robustness checks.

Model 1: The Ordinary Least Squares

In this study, the OLS is applied in both valuation methods namely CVM and HPM. We consider a method in which attention is restricted to the final bid for CVM and monthly rental values for HPM. From a broader perspective, we first consider a multiple regression model, using "i" subscript to index the cross-sectional observations and "n" to denote the sample size. We represent the multiple regression with $k+1$ parameters and present it as:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_k x_{ik} + u_i \qquad i = 1, 2, \dots \dots, n. \qquad (4.7)$$

From equation (4.7), given our variables of interest to represent some population, we represent y_i as the dependent variable for observation i, and x_{ij}, j=1, 2,…… k, are the independent variables. The intercept is β_0, and $\beta_1, \dots \beta_k$ represent the slope parameters in the model. We rewrite equation (4.7) in a full matrix notation and define $\mathbf{x}_i$ as a row vector. We represent $\mathbf{y}$ as the $n \times 1$ vector of observations and the i^{th}element of $\mathbf{y}$ as y_i. Also, $\mathbf{X}$ is denoted as the $n \times (k+1)$ vector of observations on the explanatory variables. Thus, the i^{th}row of $\mathbf{X}$ consists of the vector $\mathbf{x}_i$. With u denoting the $n \times 1$ vector of unobservable errors, we rewrite for all n observations as:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \qquad (4.8)$$

This model assumes u_i to be distributed normally with mean zero and standard deviation(σ). Thus, it is in conformity with the Gauss-Markov[37] assumptions underlying the OLS model. This is estimated in both valuation methods used with different functional forms.

Model 2: Interval Regression

The interval regression model is presented following the double bound dichotomous choice (DBDC) format of individual's WTP which is generally estimated using maximum likelihood methods (Cameron and Trivedi, 2005). This is achieved by first assuming that the WTP function has a linear functional form and is represented as:

$$WTP_i^* = x_i'\beta + u_i \tag{4.9}$$

Where WTP_i^* represents the interval within which the true WTP for individual household i can be found. x_i denotes a vector of explanatory variables and u_i a random term which follows a normal distribution function with mean zero and standard deviation (σ).

The DBDC format suggests that there should be a starting bid (b^o). If the respondent says yes, then a second higher bid (b^h) is offered. For this Yes-Yes option, the lower limit is treated as the second higher bid and the upper limit as positive infinity $(+\infty)$. Also, in the case of Yes-No option, the lower limit is the starting bid $(b^o)$and the upper limit is the second higher bid(b^h). However, if the respondent says no to the starting bid, then a second lower bid is offered (b^l). For this No-No option, the upper limit is the second lower bid (b^l) and the lower limit is zero or negative infinity $(-\infty)$. Also, for No-Yes options, the lower limit is the second lower bid (b^l) and the upper limit is the starting bid (b^o) (See Carson et al. 2003).

[37] For simplified discussions of the Gauss Markov assumptions see Wooldridge (2014, p. 93; 2006)

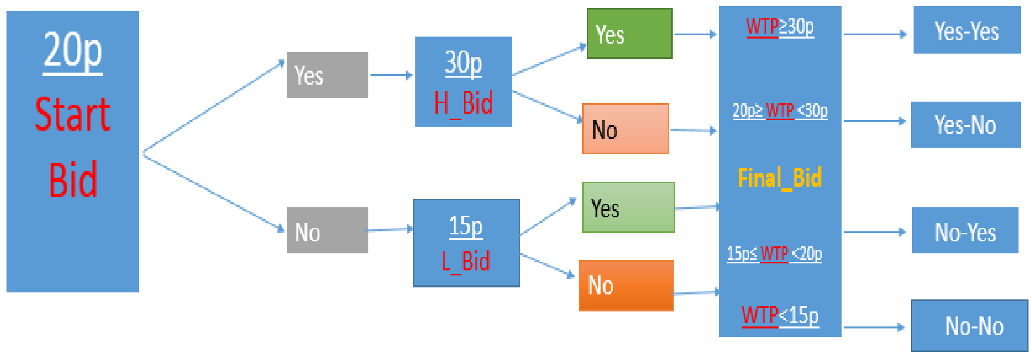

Fig. 4.2: Double Bound Dichotomous Choice Format

The WTP_i^* follows the following definitions. For the:

Yes-Yes option	$WTP_i^* \geq b^h$	i.e. $[b^h - (+\infty)]$
Yes-No option	$b^o \leq WTP_i^* < b^h$	i.e. $[b^o - b^h]$
No-Yes option	$b^l \leq WTP_i^* < b^o$	i.e. $[b^l - b^o]$
No-No option	$WTP_i^* < b^l$	i.e. $[b^l - (-\infty)]$

Taking the cumulative distribution function (CDF) as F, the log likelihood function for the DBDC model is represented in Cameron and Trivedi (2005), and Alberini et al. (1997) as

$$logL = \sum_{i=1}^{n} \log[F(h_i; x_i, \beta, \sigma) - F(l_i\,; x_i, \beta, \sigma)] \tag{4.10}$$

Where h_i and l_i are defined as the upper and lower limits or bounds of the interval around WTP. Equation 4.10 is explicitly formulated and presented for estimation as:

$$wtp_i = f(Y, Age, Male, HH, MS, MSD, R, T, F, Eco, start\_Bid) \tag{4.11}$$

The explicit interval regression model presented in equation 4.11, is used as the preferred model because of the following two reasons. First, after controlling for district specific effects and starting point bias, we found no evidence of starting point bias or anchoring effect in our results unlike the OLS models (see Table 3). Second, the interval regression model relative to the OLS estimated in this study, provides the lowest standard errors which suggest a relatively higher level of precision in our estimates. In addition, the parameters in interval regression can be interpreted same way as in an OLS regression. The "Maximum Likelihood (ML) interval technique in log-linear models is unambiguously more reliable than OLS used on interval midpoints" (Cameron and

Huppert, 1989, P.242). We therefore transform equation 4.11 and present it as an interval regression function.

$$lnwtp_i = \beta_0 + \beta_1 lnY_i + \beta_2 Age_i + \beta_3 Male_i + \beta_4 HH_i + \beta_5 MS_i + \beta_6 MSD_i + \beta_7 R + \beta_8 T_i + \beta_9 F_i + \beta_{10} Eco_i + \beta_{11} lnstart\_Bid_i + u_i \quad (4.12)$$

Where $lnwtp_i$ is a continuous variable that denotes log of the lower bound and upper bound of respondent's WTP per month for safer water from the innovative borehole system, lnY_i is log of household head's take-home monthly income in Ghana cedis, Age_i represents Age in years of respondent, $Male_i$ is a dummy variable representing respondent's gender status, HH_i is the household size of respondent, MS_i is a dummy variable [1, married and 0, unmarried], MSD_i is a dummy variable [1, main reliable source of drinking water is improved source and 0, otherwise], R_i is a dummy variable[1, access to reservoir in respondent's residence and 0, otherwise], T_i is a dummy variable [1, existence/access to toilet facility in respondent's residence and 0, otherwise], F_i is a dummy variable [1, household residence has fence and 0, otherwise], Eco_i is a categorical variable (All the time=1, Sometimes=2, Not at all=3) representing the extent to which respondents use ecologically friendly products. This is used as a proxy to capture respondent's knowledge of environmental issues, $lnstart\_Bid_i$ is log of the starting point bid to test for starting point bias or anchoring effect in the model, and the error term (u_i).

3.2.1 The Hedonic Price Method (HPM)

HPM helps to obtain WTP values through the housing market based on rental values or property sale values and attributes of the property. These attributes are generally presented to include structural characteristics (number of stories, number of rooms, nature of floor space, dwelling age etc.), neighbourhood amenities (distance to public services, distance to work etc.), and environmental amenities (air and water quality or proximity to open space (see Van Den Berg and Nauges, 2012).

The HPM was first formalised by Rosen (1974). This method is based on the perfect competition and perfect observability of attributes assumption. This assumption is inapplicable in heterogeneous markets such as the property market. Again, all attributes are assumed unrelated and individually evaluable. For a simple modelling of the property market, we assume that, how much a household is willing to pay in rental values ($\mathrm{P(Z)}$), is conditional on the attributes such as improved source of water in the property. The heterogeneous nature of this market is represented by n attributes. This is presented as:

$$P(Z) = p(z_1, z_{2,} \ldots\ldots z_n) \quad (4.13)$$

We denote z_i as measuring amount of i^{th} attribute in the property, Z. The houses in this market are also assumed to be unique intrinsically (e.g. nature of bedroom, number of bedroom, number of bathroom) and extrinsically (e.g. fence or walls, garden etc.). Estimating marginal willingness to pay for an attribute includes determining implicit prices of attributes associated with the good, summing the implicit prices obtained, and multiplying by the measure of the attribute to yield the market price of the good (see Devicienti et al., 2004).

We re-write Z in an explicit form: $\mathrm{Z = S, N, Q}$ (4.14)

Where **S** represents a vector of structural (or residential) characteristics (access to water in residence(R), access to toilet in residence(T), access to electricity in residence(E), residence with fence (F), number of bathroom facilities(NBF), number of toilet facilities(NTF). **N** denotes a vector of neighbourhood attributes (Water as a district major problem (WDP), distance to nearest hotel or guest or rest house(DNH), distance to commercial transport station(DTS), and $\boldsymbol{Q}$ is neighbourhood socio-economic characteristics (mean district savings (MDS).

In line with Rosen's model, we represent our equations (4.13 & 4.14) as:

$$\mathrm{P(Z) = f(S, N, Q)} \quad (4.15)$$

Where all variables in equation 4.15 are as defined. Choumert et al. (2014) argue that simpler functional forms produce more stable parameter estimates, hence this study uses OLS (see model 1 in section 3.14) with log-log functional form. We re-write equation (4.15) following an OLS approach in a more explicit form and specify the econometric model for estimation as:

$$\ln P(Z) = \beta_0 + \beta_1 R + \beta_2 T + \beta_3 AER + \beta_4 F + \beta_5 NBF + \beta_6 NTF + \beta_7 DFI + \beta_8 WDP + \beta_9 DNH + \beta_{10} DTS + \beta_{10} lnQ + u \quad (4.16)$$

Following the two stage processes of the HPM as presented by Choumert et al. (2014) we determine the implicit marginal price of the different attributes from the aggregate price of the property, $P(Z)$. The partial derivative of the aggregate price function relative to an attribute (z_i), yields the implicit marginal price, p_i, herein referred to as the marginal WTP for the attribute i. In the first stage, we obtain the implicit marginal price by regressing the monthly rental values on the various attributes which include access to improved water supply in residence. In the second stage, we multiply this implicit value by the average house value to yield the marginal WTP for access to improved and safer water supply per month.

4. Results and Discussion

We present the descriptive statistics, results and discussions each from the CVM and then the HPM. Also, we attempt to evaluate whether the two competing methods can be compared.

4.1 CVM Results and Discussion

Here, four different models are estimated for the CVM and all results are presented in Table 4.2. The dependent variable for the: OLS is log of final bid (WTP), interval regression is log of WTP interval (lower and upper limits). The double bound dichotomous choice format provides an interval within a specific range of true WTP. Based on the assumption that respondent's final bid could either be overstated or understated, the interval regression intuitively will provide more information on the Household's WTP relative to the OLS. In addition, as indicated earlier, the interval regression results show no evidence of starting point bias and produced lower standard errors. Therefore, in the CVM, the most preferred model for our study is the interval regression model where the true WTP is assumed to lie within a certain range of monetary values.

In interpreting our results, we ignore the marginal effects as it does not represent the monetary values associated with WTP, and focus on the estimated regression coefficients. Generally, the estimated models (see Table 4.2) are observed to provide quite consistent estimation results especially with respect to signs of the coefficients across all models. The calculated mean VIF values which range from 1.12 to 1.42 provide evidence of the absence of severe multicollinearity in our models. The goodness of fit (LR chi statistic and R-squared/Pseudo R-squared) support our choice of model 4. All variables to be interpreted assume that "all else are held constant".

Table 4.1: Descriptive Statistics on Variables Included in the CVM

Variable	Type	Description	Obs.	Mean [percent]	Std. Dev.	Min	Max	Sign
Household income (Y)	Continuous	Household monthly income in Ghana Cedis (GHS)	583	591.36	655.85	160	4400	+
Age (years)	Continuous	Respondent's Age in years	609	39.31	11.23	21	67	+/-
Male	Dummy	Gender status of respondent	609	0.52	0.50	0	1	+/-
Household size (HH)	Continuous	Household size of respondent	609	4.54	2.28	1	17	+
Marital Status (MS)	Dummy	Marital Status of respondent	609	0.63	0.48	0	1	+
Main Source (MSD)	Dummy	Respondent's main reliable source of drinking water is improved source	553	0.11	0.32	0	1	+
Reservoir (R)	Dummy	Access to water/ reservoir(borehole or well etc.) in residence	609	0.42	0.49	0	1	+
Toilet Access (T)	Dummy	Access to toilet facility in residence	609	0.59	0.49	0	1	+
Fence Access (F)	Dummy	Access to fence in residence	609	0.23	0.42	0	1	+
Eco Product (Eco)	Categorical	Use of ecologically friendly products	609	n/a	n/a	1	3	+
-All the time			229	[37.60%]				
-Sometimes			326	[53.53%]				
-Not at all			54	[8.87%]				
Start Bid	Discrete	Starting point bid	609	25.03 [25% appx][a]	11.24	10	40	+
Lower Limit	Continuous	Lower WTP	609	22.09	11.33	-5	50	n/a
Upper Limit	Continuous	Upper WTP	609	42.40	18.90	10	110	n/a

Mean and Std. Deviation are rounded off to two decimal places. Not Applicable (n/a). [ ] square bracket means figures are reported in percentages. [a]Percent for each of the four bids.

Table 4.2: CVM Results [with (Yes) and without (No) Localization]

	(1)	**(2)**	**(3)**	**(4)**
VARIABLES	OLS (Log-Log)	Interval (Log)	OLS (Log-Log)	Interval (Log)
Household Income (Log)	0.2135***	0.1211***	0.2063***	0.1149***
	(0.030)	(0.020)	(0.031)	(0.021)
Age in Years	-0.0031	-0.0038**	-0.0030	-0.0036**
	(0.002)	(0.002)	(0.002)	(0.002)
Male dummy	0.1045**	0.0587*	0.1313***	0.0770**
	(0.047)	(0.032)	(0.047)	(0.032)
Household Size	0.0099	0.0111*	0.0072	0.0103*
	(0.009)	(0.006)	(0.009)	(0.006)
Marital Status dummy	0.0592	0.0192	0.0685	0.0224
	(0.048)	(0.035)	(0.047)	(0.035)
Main Source of Drinking Water	0.4732***	0.2270***	0.4843***	0.2360***
	(0.079)	(0.053)	(0.075)	(0.049)
Reservoir in Residence dummy	0.0539	0.0171	0.0501	0.0191
	(0.048)	(0.033)	(0.047)	(0.033)
Access to Toilet in Residence dummy	0.0122	0.0796**	0.0093	0.0769**
	(0.046)	(0.033)	(0.048)	(0.033)
Residence Fence-Access dummy	-0.0549	-0.0248	-0.0628	-0.0319
	(0.059)	(0.039)	(0.060)	(0.038)
Use of Eco-product = 2, Sometimes	-0.0451	-0.0161	-0.0642	-0.0252
	(0.051)	(0.036)	(0.051)	(0.036)
Use of Eco-product = 3, Not at all	-0.1425*	-0.1105*	-0.1397*	-0.1057*
	(0.075)	(0.057)	(0.073)	(0.058)
Starting Point Amount (Log)	0.0888**	0.0402	0.0906**	0.0441
	(0.044)	(0.029)	(0.043)	(0.029)
Constant	1.6679***	2.5354***	1.7571***	2.5898***
	(0.220)	(0.159)	(0.215)	(0.156)
District Dummies	***No***	***No***	***Yes***	***Yes***
Observations	521	529	521	529
R-squared[Pseudo R-squared]	0.254	[0.11]	0.294	[0.12]
LR chi(12&18 respectively)		121.11***		136.27***
Mean VIF (1/1- R-squared) [a]	1.34	1.12	1.42	1.14

Dependent Variable: WTP, Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, †Exchange Rate (GHS1=US$0.319 as at 15/10/2014. [a]Pseudo R-squared was used for models 2&4.

We start our discussion with variables capturing the demographic characteristics of respondents. To begin with, the variable *Household monthly income* was found to be positive and highly significant, implying that a one percentage increase in household's income will increase their WTP for safer water supply from the innovative borehole system by 0.1149%. Thus, household's income elasticity is approximately 0.12 with a confidence interval of 0.07 to 0.16. This suggests that the good in question although a normal good, is definitely a necessity. Age was expected to be positive and significant due to experience with different water sources, water use and associated health consequences. However, we found age to be negative and significant. This implies that a one year increase in respondent's age decreases his/her WTP by 0.36%. This suggests that older people are less willing to pay for improved water supply from the innovative borehole system relative to younger respondents. This could be attributed to free rider effect or cohort effect on the part of older people who would expect younger people to pay for them to enjoy. Better still, it may suggest that younger people have different expectation regarding their taste and preferences. This can also be explained by the theory of innovation diffusion where some studies have found that earlier adopters of innovation are younger (Rogers, 1995). Negative effect of age on WTP has also been found by Carson et al. (2001). The variable *Male* was positive and significant. It further shows that males are willing to pay 7.7% more than females in adoption of the new technology. Again, *household size* is found to be positive and marginally significant. Thus, a unit increase in household size, increases WTP for improved water supply from the innovative borehole system by 1.03%. *Marital status* was found to be positive but insignificant.

Next, we discuss variables that are water related. Reliability of the improved main source of drinking water represented as *main source of drinking water* was found to be positive and highly significant. Sachet-water is the main source of drinking water within the study area. An increase in respondent's reliable main drinking water source, increases WTP for safer water supply from the innovative borehole system by approximately 24%. This implies that those respondents who have access to reliable main drinking water source and would still want to have either a safer version or have something similar to what they are used to expressed very high WTP. Stated differently, respondents value what they already have (endowment effect). This inevitable reference point shows how important reliable drinking-water is to the people in rural GAR. *Reservoir in residence* was found to be positive as expected but not significant. *Access to toilet* was positive and significant. An increase in respondent's access to toilet, increases WTP by approximately 7.7%. This implies that those who have access to toilet and know the relevance of reliable water supply in improving their sanitation and health expressed high WTP as compared to those who do not. In other words, higher expectations in improving sanitation through access to safer water supply could explain respondent's WTP. *Residence Fence* determines the extent to which neighbours can easily have access to each other's house. This was found to be negative as expected but not significant.

Furthermore, the degree of environmental knowledge is generally important in determining WTP for natural/environmental resources. *Use of Eco-product* which is a categorical variable (all the time [reference category], sometimes, and not at all) was introduced to capture the degree of environmental knowledge. One would expect that respondents who are environmentally informed would express a high WTP to access safer water supply from the innovative borehole system due to health concerns. We found that respondents who do not use ecologically friendly products, express approximately 0.11% lower WTP values relative to those who use ecologically friendly products all the time.

We further introduced log of the starting point amount in the model to capture for possible existence of starting point bias or anchoring effect. We found this to be positive but insignificant in our preferred interval model. This implies that this bias is less important in this model, however, it is important in the OLS model. In short, our preferred model is not being influenced by the randomised starting point amounts used. As shown in Table 4.3, we proceed to determine the marginal WTP for improved water supply from innovative borehole system per month using the predicted command in Stata 13.

Table 4.3: Predicted WTP Measures for Reliable Water from an IBS†

Measures	Max. WTP for a 34 cm bucket of water from a *IBS†* (GHp)	Max. WTP reliable & sufficient water from a *IBS†* (GHS)	Max. WTP for reliable & sufficient water from a *IBS†* (GHS)/Month
Mean [95% CI]	29.92 [29.44-30.39]	1.20 [1.18-1.22]	35.90 [35.33 - 36.47]
Median [95% CI]	28.88 [28.35-29.36]	1.16 [1.13-1.17]	33.50 [32.89-34.06]
% of HH Income [95% CI]		0.20%	6.07% [5.97%-6.17%]

Note: Computation used the Mean Household (HH) Income of 591.36 *and a CI of* [538.01-644.70].
**0.2992×4×30(days) †IBS implies innovative Borehole System.*

4.2 HPM Results and Discussion

We now turn to the HPM. We estimate WTP for improved water supply from housing units with current borehole/well system as an attribute using OLS under the assumption that improved water supply has a perfectly inelastic demand in all the districts within the study area.

We first present the summary descriptive statistics of the HPM in Table 4.4 and the regression results in Table 4.5. In the latter case, we present four different models. In model 4 (Table 4.5), the R-squared and the adjusted R-squared are about 32.4% and 30.3% respectively, higher than all the other models. In addition, the mean VIF value of approximately 1.5 for all models show the absence of severe multicollinearity. We admit that the models are different, nonetheless, apart from controlling for district specific heterogeneous effects, the coefficient of variation and the mean VIF values make model 4 our preferred model.

We also observed that all the explanatory variables had the expected signs. However, except for three variables: *Access to toilet in Residence*, *Access to Electricity* and *Distance to Transport Station (KM)*, all estimated coefficients are found to be statistically significant at various levels of significance. In interpreting our variables, we further assume that “all else are held constant”.

Table 4.4: Descriptive Statistics on Variables Included in the HPM

Variable	Type	Description	Obs.	Mean	Std. Dev.	Min	Max	Sign
Mean District Savings (Q)	Continuous	Neighbourhood socio-economic characteristics (mean district savings)	609	33.10	10.52	10.28	50.92	+
Transportation(KM)	Continuous	Distance to nearest commercial transport station	576	1.22	5.26	0.005	60	-
Hotel (KM)	Continuous	Distance to nearest hotel	543	6.13	14.84	0.001	120	-
No. of Toilets (NTF)	Continuous	Number of toilet facilities in residence	609	0.74	0.73	0	4	+
Bathrooms (NBR)	Continuous	Number of bathrooms in residence	609	1.36	0.74	1	7	+
District Problem (WDP)	Dummy	Water as district major problem	609	0.79	0.41	0	1	-
Reservoir(R)	Dummy	Access to water/ reservoir(borehole or well etc.) in residence	609	0.42	0.49	0	1	+
Toilet Access (T)	Dummy	Access to toilet facility in residence	609	0.59	0.49	0	1	+
Fence Access (F)	Dummy	Access to fence in residence	609	0.23	0.42	0	1	+
Electricity (E)	Dummy	Access to electricity in residence	609	0.91	0.29	0	1	+
Rent/Month	Continuous	Rental rate per month	609	61.23	42.56	10	200	n/a

Mean and Std. Dev. Are rounded off to two decimal places. Not Applicable (n/a).

Table 4.5: Hedonic Regression Results [with (Yes) and without (No) Localization]

	(1)	(2)	(3)	(4)
VARIABLES	Lnmonth-rent	Lnmonth-rent	Month-rent	Lnmonth-rent
Access to Water in Residence_dum	0.2390***	0.2439***	21.3914***	0.2525***
	(0.048)	(0.048)	(3.741)	(0.047)
Access to Toilet in Residence_dum	0.1221	0.1356*	4.4465	0.1013
	(0.076)	(0.077)	(6.044)	(0.078)
Water as a District Major Problem_dum	-0.1493**	-0.1592***	-10.2999**	-0.1501***
	(0.059)	(0.059)	(4.465)	(0.058)
Access to Electricity_dum	0.0778	0.0744	1.8761	0.0919
	(0.085)	(0.086)	(6.042)	(0.086)
Residence Fence-Type_dum	0.2187***	0.2213***	17.1129***	0.2038***
	(0.059)	(0.059)	(4.875)	(0.060)
Number of Bathroom Facilities	0.0490	0.0441	4.2062	0.0666**
	(0.034)	(0.033)	(2.649)	(0.033)
Number of Toilet Facilities	0.1356**	0.1398**	9.9502**	0.1315**
	(0.056)	(0.056)	(4.951)	(0.059)
Distance to nearest Hotel (KM)	-0.0053***	-0.0055***	-0.4154***	-0.0061***
	(0.001)	(0.001)	(0.095)	(0.001)
Distance to Transport Station (KM)	-0.0052*	-0.0053*	-0.4507*	-0.0025
	(0.003)	(0.003)	(0.232)	(0.003)
Mean_District_Savings	0.0072***			
	(0.002)			
Mean_District_Savings(Log)		0.1266*		
		(0.069)		
Constant	3.3807***	3.1924***	55.3405***	3.8047***
	(0.141)	(0.268)	(8.103)	(0.111)
District Dummies	***No***	***No***	***Yes***	***Yes***
Observations	529	529	529	529
R-squared	0.285	0.277	0.286	0.324
Adjusted R-squared	0.271	0.263	0.264	0.303
Mean Variance Inflation Factor(VIF)	1.49	1.49	1.48	1.48

Dependent Variable: Rent per month in Ghana cedis, Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Our discussion is presented under water related Residential and Neighbourhood characteristics, other Residential/Structural characteristics, and other Neighbourhood characteristics. The water related explanatory variables presented in our model include: *Reservoir in Residence, Access to toilet facility in Residence, Water as a district major problem.* The other Residential/Structural characteristics include: *Access to Electricity*, *Residence Fence*, *Number of Bathrooms, and Number of Toilet Facilities*. Lastly, the other Neighbourhood characteristics include: *Distance to nearest hotel (KM)*, *Distance to Transport Station (KM)* and *Mean_District_Savings*.

In a broader sense of our discussion, the study finds that regarding the water related variables, all of them had the expected a priori signs. To discuss these variables individually, we begin with *Access to Water in Residence* which was proxied with *Reservoir in Residence*. There is a strong evidence that *Access to Water in Residence* has a significantly positive effect on rental values relative to residences without access to water in residence. This is true for all estimated models. The preferred model 4, suggests that houses with *Access to Water in Residence* pay 25.52% more in rent relative to those without. Moreover, *Access to toilet in Residence* is found to be insignificant. This could be attributed to the fact that a lot of people in rural GAR do not have toilets in their residences but rather depend on publicly used and other forms of toilet facilities. Evidence is provided by Apt and Amankrah (2004) who report that 43.5% of households in rural areas of the GAR do not have toilets in their homes. Also, the study provides evidence that the variable *Water as a district major problem* has a negative and highly significant effect on rental values relative to districts within the region with water not as a major problem. Thus, households located in districts with water supply as a major problem pay 15.01% less in rental values relative to districts with water supply not as a major problem.

Next is the Residential/Structural characteristics. The study finds that all the variables in the preferred Model 4 (Table 4.5) relating to Residential/Structural characteristics had the expected a priori signs (see Sirmans et al. 2005). First, *Access to Electricity* is found to be positive albeit insignificant. This could be explained by the fact that 79% of rural people are without access to electricity in their homes (ibid). Second, *Residence Fence* was introduced to capture possible free-riding effect in areas characterised by communal living. This provides a positive and very high statistically significant effect on rental value. That is, fenced residences pay 20.38% more in rental values relative to unfenced residences. Third, *Number of Bathrooms* had the expected positive sign on rental values. Although this is seen not to be significant in the other models except the preferred model 4. The result suggests that if the number of bathrooms in a residence increase by one, households will pay 6.66% more in rental values. In addition, *Number of Toilets* is positive and significant in all estimated models. It therefore implies that if the number of toilets in residence increase by one, households will pay 13.15% more in rental values. In effect, better residential characteristics evidenced by quantity and quality of residential characteristics are seen to increase rental values.

The quality of neighbourhood characteristics is expected to affect rental values. For example: *Distance to nearest hotel (KM)* which captures some degree of prestige, environmental quality, security, affluence etc. definitely will increase rental values. This variable is seen to provide evidence of a negative and highly statistically significant effect on rental values. This implies that residences that are located within a kilometre range, closer to a hotel, increase rental values by 0.61%. More so, we find *Distance to Transport Station (KM)* variable to be negative and significant in all models except in our preferred model.

To further evaluate the potential effect of district wealth heterogeneity on rental values, we introduced the *Mean_District_Savings* variable models 1&2 as a proxy for income and wealth. This could not have been included in models 3& 4 because of severe collinearity with district dummies. We find evidence of a positive and significant effect of the *Mean_District_Savings* on rental values in both models. It can be inferred that districts with high income and savings (or wealthy households) tend to pay more in rental values. This satisfies the scope sensitivity test commonly found in valuation studies.

We now turn our attention to the computation of the marginal WTP for having access to reliable water supply which is proxied with access to improved water supply in residence. Given that the variable of interest is dummy, we compute the relative change in rental values with results from Table 4.5 (Model 4) using the delta method. This study finds that the average amount households will be prepared to pay per month for access to water in residence is GHS 17.59 which constitutes 2.98% and 2.68% of the mean-district-income and mean-household-income per month respectively (see Table 4.6). According to Bartik (1988) and Choumert et al. (2014), this should be interpreted as upper bound values because the utility dummy may include unobserved attributes and utilities.

Table 4.6: Predicted Increase in the Value of a House with Access to Water Supply

Marginal implicit house value per month(GHS)	Current average HH expenditure on water per month (GHS)	Increment as a % of monthly district-income	Increment as a % of Monthly Household Income
Mean[38]	Mean	Mean[39]	Mean[40]
17.59 [10.34-24.85]	41.554 [39.41-43.69]	2.98% [1.75%-4.20%]	2. 68% [1.58%-3.79%]

[.] Denote confidence intervals estimated at 95%.

38 Relative change (water dummy)×Average House Value=0.28724×61.23064=17.59≈GHS18 per month
39 Marginal Implicit house value/Average district- income=17.59/591.3551=0.0298×100=2.98%
40 Marginal Implicit house value/Average Household income=17.59/655.85=0.0268×100=2.68%

4.3 WTP Estimates: Can we directly compare our estimates?

The CVM and HPM are valuation methods employed to estimate WTP for improved supply of rural water. However, it needs to be pointed out that in application, they could capture different things yet provide relevant estimates that are worthwhile for policy purposes. The estimated results presented in in Tables 4.3 and 4.6 are summarised in Table 4.7. In Table 7, the results are presented in both Ghana Cedis (GHS ¢) and in United States dollars (US$) for easy understanding.

Table 4.7: A Summary of CVM and HPM Estimates.

Method	WTP(GHS)/M*	95% CI	WTP US$/M*	% of Income Index
CVM	35.90	[35.33 - 36.47]	11.45	6.07%
HPM	17.59	[10.34 – 24.85]	5.61	2.68%

*Note: CI denotes Confidence Interval. *M=Month (GHS=US$0.319 as at 15/10/2014)*

From Table 4.7, it is important to acknowledge that the CVM used here seeks to measure how much respondents are willing to pay per month for improved and safer water supply from an innovative borehole system. The values captured by this method include use values of an improved system over what is currently being used. In the case of HPM, it seeks to measure the economic value of improved water supply from an amenity (reservoir i.e. traditional borehole or well) in residence per month through house prices, or how much households with access to water are willing to pay per month. Stated differently, the HPM provides estimates of the additional amounts households with access to water supply in residence are willing to pay per month in rental values. This captures only the use values of the current service only. Therefore we expected the CVM to be greater than the HPM. The results show that CVM estimates are much more precise than the HPM at 95% confidence interval.

The HPM estimate of GHS17.59 (US$5.61) per month and the CVM of GHS35.90 (US$11.45) per month constitute approximately 3%-6% of household income. Paying this by potential beneficiaries represent a sensible trade-off that people might make towards policy implementation (See Carson, 2012). However, it is important to reiterate that these estimates are capturing entirely different things and cannot be directly compared in our case. According to McPhail (1993, p.1), "…most utilities and donors assume that, as long as the cost of potable water to the household falls below 5% of household income, then it is "affordable" and the household will make a connection to the system and be able to pay the subsequent recurrent charges". Similar assertions have also been made by Whittington et al. (1990) to that effect. In view of this, we may conclude that our estimates are within a reasonable range of affordability and that respondents have shown a positive attitude towards the services.

5. Policy Implications and Conclusion

Towards achieving MDG 7(now consolidated into SDG 6), this study focuses on providing information on household's WTP for sustainable, safe rural water supply in Ghana. This study is important against the background that unsustainable planning and management have largely been attributed to absence of information on consumer's WTP for water supply services.

Indeed, policy makers are not fully informed about consumer's WTP to have access to their current state of water supply as well as improvement in water supply. This has triggered a myriad of studies in this area with the primary motive of contributing to policies relevant to sustainable safe water supply. To this end, we use the HPM to capture WTP for the current service, and CVM to also capture WTP for improvement in the service through introduction of an innovative borehole system. We therefore provide policy recommendations as follows:

We recommend that to achieve SDG 6(1) of *safe and affordable drinking water supply*, either an innovative and affordable system with relevance to women and children like this should be considered. Alternatively, the GWCL and CWSA should consider using our estimates for a cost benefit analysis of this project to extend piped water services to the rural areas. Also the estimated WTP may be used to encourage households to adopt such safe appliances across the country and elsewhere.

Currently, the world is full of praise for meeting access to improved water target as enshrined in the MDGs 7. However, we argue following Hunter at al. (2009), and Levisay and Sameth (2006) that not all improved water supply are safe. In order to ensure that the current SDG is achieved with safe water for rural Ghana, this study proposes an innovative borehole system and estimate the demand for water from this system. This is achieved by using the HPM to capture the economic value of an existing system (i.e. marginal WTP for access to improved water from the traditional borehole and well) in residences and CVM to capture the same for improved and safer water from the innovative borehole system. Our results suggest that households support the improvement in their water supply and are willing to pay about 3%-6% of their income.

In short, we present one of the first estimates of the economic values for rural water supply using both the HPM and CVM to capture for current service (*improved water*) and improvement in current service (*safer-water*) through a proposed innovative borehole system in a developing country. These results may be applied to other developing countries with similar characteristics without any loss of generality.

APPENDIX D

APPENDIX D1:1 QUESTIONNAIRE

Interviewer: ……………………………….

Supervisor…………………………………..

Region: ……………………………………….

Metropolitan Area……………………..

Locality………………………….............

Interview date :…………/…………/ 2014

Start Time: Hrs.……../Min………

End Time: Hrs..……../Min……….

TOPIC: Demand for Domestic Water from an Innovative Borehole System in Rural Ghana: Stated and Revealed Preference Approaches

District………………………………

House Number……………………….

Respondent's ID…………………….

Survey Price Draw

Yes[ ]	No:
No[ ]	Thanks

Language used in the survey:

11. English	
12. Twi	
13. Ga	
14. Ewe	
15. **Other**	

A BRIEF BACKGROUND OF STUDENT

My name is [Give Name] from Central University College [show I.D] and I'm part of a team headed by Anthony Amoah, a PhD student from the School of Economics, University of East Anglia, UK. He is conducting a survey of people's opinions about the water situation in Ghana.

I humbly wish to request your kind participation in this research, which aims at estimating the economic value of domestic water supply in Ghana. The research does not probe into your private affairs but we are interested in your personal perception and experience of water supply in Ghana. Your answers will only be used for empirical analysis in the framework of this research**.** Your information will not be shared or used for any other purpose. It will be treated as ***strictly confidential.*** Nevertheless, you still reserve the right to refuse or indicate don't know to questions where necessary. Completing this survey automatically enters you into a free rechargeable mobile credit draw (if you wish) where you could win one of the ten GHS10 mobile credits.

Thank you very much for your kind cooperation.

NB. Please tick [✔], underline or write where appropriate.

SECTION A: Personal Data of Respondent (Household Head)

A.6. Respondent's household status:
1. Head **4.** Parent of Head
2. Wife of Head **5.** Child of Head
3. Husband of Head **6.** Other: If other, specify……….

A.7. Gender:
1.Male
2.Female

A.8. Year of birth (If provided skip A.4):

A.9. Age range (Age in completed years):
1.18-29 **3.** 40-49
2. 30-39 **4.** 50+

A.10. Marital Status:
4. Single **4.** Separated
5. Living with partner **5.** Divorced
6. Married **6.** Widowed

A.5 Which of the following life-cycles describe your household?
1. Single Adult **4.** Family with Teenagers
2. New Couple (≤1yr) **5.** Family with launching(ready for self-dependence) children
3. Family with Children **6.** Family in later life (Retired i.e. ≥60 with or without children)
7. Several Adults living together (with or without children)

A.6 a. Number of people in your household?

b. Number of household's in your residence?

A.7 Highest level of educational qualification achieved/completed:
5. None **4.** Professional
6. Primary/Middle/J.S.S **5.** Second Degree
7. Secondary/Vocational/Technical/Training College. **6.** Doctorate (PhD)
8. First Degree/Diploma **7.** Others (specify)…........

A.8 What is your employment status?
1.Unemployed (during the last 7-days)
2. Full time employee of private firm **7.** Apprentice
3. Full time employee of public firm **8.** Domestic employee
4. Self-employed without employee(s) **9.** Contributing family worker
5. Self-employed with employee(s) **10.** Retired
6. Casual worker 11**.** Other (specify)…………….

A.9 What is your monthly take-home income in Ghana cedis (GHS):
1. <160 **2.**160-599 **3.**600-999 **4.**1000-1399 **5.**1400-1799 **6.**1800-2199 **7.**2200-2599 **8.**2600-2999 **9.**3000-3399 **10.**3400-3799 **11.**3800-4199 1**2.**4200-4599 **13.** 4600-5999 **14.** ≥6000 **15.** I don't know **16.**I won't tell you

A.10 How much do you save per month? (GHS)

A.11 Are there other people in your household who work?
1. Yes **2.**No

A.12 If yes, how much on the average is their monthly take-home income in GHS: **1**. <160 **2.**160-599 **3.**600-999 **4.**1000-1399 **5.**1400-1799 **6.**1800-219 **7.**2200-2599 **8.**2600-2999 **9.**3000-3399 **10.**3400-3799 **11.**3800-4199 **12.**4200-4599 **13.** 4600-5999 **14.** ≥6000 **15.** I don't know **16.**I won't tell you

SECTION B: General Water Supply and Environmental Questions

B.30. Which of the following water systems is installed in your residence?
2. Piped water **2.** Non-piped water **3.** None
(NB: Skip B.2 if None)

B.31. Is the installed water in your residence reliable?
(*Reliability means it flows or you can fetch at least once a day*)?
1. Yes [ ] **2.** No [ ]

Select any of the **SOURCE DESCRIPTION CODES** to answer questions **B.3 and B.5**

01…………Indoor plumbing
02…………..Inside stand pipe
03…………Water truck/tanker service
04………… Water vendor(gallons)
05…………Pipe in neighbouring household
06………… Private outside standpipe
07………… Public Stand pipe
08…………Sachet/bottled water/packaged
09……………Borehole
10……………Protected well
11…………….Unprotected well
12……………..River/Stream/lake/dam
13…………..Rain water/spring
14…………...Dugout pong
15..……….. Other (specify)…………

B.32. What is the main source of water supply for your household?

(Use source description codes)

DRINKING ☐ GENERAL USE ☐

Select any of the **TIME UNIT CODES** for **B.4 and B.6** to answer questions **B.4 and B.6**

1………………..Daily
2………………..Weekly
3………………..Monthly
4………………..Quarterly
5………………..…Half Yearly
6………………..Yearly
0………………..Not Applicable

B.33. How frequently (regular) do you receive drinking water supply from your main source?

Time unit (see **time unit codes**) ☐ Number of times ☐

B.34. What is (are) the other source(s) of water supply for your household?

(Use source description codes)

DRINKING ☐ GENERAL DOMESTIC USE ☐

B.35. How regular (reliable) is your water supply for GENERAL domestic use?

Time unit (see **time unit codes**) ☐ Number of times ☐

B.36. If NOT piped water, why do you use these other sources of water supply?

3. No access to private piped water 3. Other sources are more reliable
4. Other sources are less expensive 4. Other (specify]……………….....

☐

B.37. Do you have any home water treatment system?

1.Yes **2.** No ☐

NB: If No, skip question B.9

B.38. Identify the rate at which is it cleaned/repaired/replaced?

1. Frequently **2.** Sometimes **3.** Not at all **4.** don't know ☐

B.39. In your last five years, which of the following is true? After purchase of water for other sources, you can…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use ☐

B.40. In your last five years, which of the following is true? After purchase of water for drinking, you …..…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use ☐

B.41. In your last five years, which of the following is true? After purchase of water for general domestic use (not including drinking), you….…

1. Use immediately **2.** Treat (Chemical, settling, boiling, filtering etc.) before use ☐

B.42. Have you ever felt the need to have had an improved quality of the water you use?

1. Yes
2. No ☐

NB: If No, it means you are satisfied with the quality of your domestic water. Please skip question B.12, B.13 and B.15.

B.43. What could you have done to improve it?

1. Apply Chemicals. Identify the type of chemicals
2. Allow water to settle. How many minutes would it take to get settled?
3. Boiling. How long would it take to be ready?
4. Filtering. How long does it take to filter your water?
5. Other. Specify and indicate how…..

B.44. In the last five years, which of the following have you done before to improve water quality before use?

1. Boiling- On the average, how many minutes does it take?
2. Applying chemicals- How much do you spend on this per month?
3. Allowing debris to settle- On the average, how many minutes does it take?
4. Filtering. How much do you spend on filters per year/ how long does it take?
5. Other- Specify and identify either the time or amount spent on it………………

B.45. How much would you spend or do you spend on average to make this source potable for use per week?

B.46. How much do you spend (on average) on water per month irrespective of source?

B.47. Who is mainly responsible for ensuring that your household has enough water? **1.** Husband **2.** Wife **3.** Children

B.48. Do you promote good environmental practices? (e.g.: promoting good sanitation, cleaning environment, weeding compound etc.)

1. Yes
2. No (**If No, Skip question B.18**)

B.49. If yes, rank the extent of your promotion to the indicators listed in the table below. (Yearly(Y) , Monthly(M), Weekly (W), Daily(D) Every Purchase(E))

Factors/Indicators	**All the time**	**Some-times**	**Not at all**
Green Environment/ afforestation e.g.: planting trees (M)			
Cleaning of Environment (D) e.g.: sweeping			
Efficient Water use by preventing waste(D)			
Indiscriminate waste disposal(D)			
Use of Eco-product (E) :Identify as Eco-product before purchase			
Good sanitation(W) e.g.: regular collection of refuse			
Other…………………			

B.50. If No to **B.17**, briefly give your reason(s) …………………………..
……………………………………………………………………………………..

B.51. Which of the following international environmental issues do you know of?

5. Global warming/Green House Effect [Yes] [No]
6. Climate Change[Yes] [No]
7. Kyoto Protocol [Yes] [No]
8. I don't know any

B.52. Mention any National/District/Local environmental law/practice you know of?
……………………………………………………………………………………………
……………………………………………………………………………………………

B.53. How important is protecting the environment to your household?
1. Very Important **2.** Important **3.** Fairly Important **4.** Not important

B.54. Is your locality dusty enough to pollute your water? **1.** Yes [ ] **2.** No[ ]

B.55. In your view, is water a major problem in your district? **1.** Yes [ ] **2.** No [ ]

B.56. How is the water supply system operated and managed?

1.Self **2.**Community operated and managed
3.Community Watered Sanitation Agency **4.**NGO
5. Ghana Water Company Ltd **6.**Other (Specify) ………
7. Not Applicable **8.** Don't know

B.57. In your view, which of the following are some of the water problems in your district?

1. Cost **4.** Poor quality
2. Lack of flow **5.** Poor Management
3. Difficult to access **6.** Other [ ] If other, specify……………………………….

B.58. In your view, who in your district is mainly responsible for your water problems?

1. Colonial Administration] **2.** Government **3.** GWCL **4.** Consumer
5. Don't know Give reason for your choice? ……………………………………………………………………………

SECTION C: Hedonic Valuation Questions

C.2. Who owns your residence?

1. You **2.** An Organisation (Property Company)
3. Landlord **4.** Your employer
5. Government(Municipal, District, Local, Assembly)
6. Other (If other, specify)………………………………

C.15. Nature of residence?

1. Compound house 5.Shanty town/slum
2. Separated house 6. Flat/Apartment
3. Duplex 7. Other [ ] Specify………
4. Traditional (mud/hut/wooden)

C.16. Residence outer wall (fence/ boundary/perimeter) type

1. No wall **5 .**Stone
2. Mud bricks/Earth **6 .**Cement/Concrete
3. Wood **7 .**Bamboo/Palm leaves/thatch (grass)
4. Metal sheet/slate/asbestos **8 .**other. Specify…………………..

C.17. Residence Roofing type

1. Mud/Mud bricks/Earth **5.** Slate/asbestos
2. Ceramic/marble/Vinyl Tiles **6.** Cement Concrete/Terrazzo
3. Wood **7.** Bamboo/Palm leaves/thatch (grass)
4. Metal/Aluminium sheet **8.** other. Specify………………….

C.18. Complete the number, size and nature of the facilities in your residence provided below:

Facility	Number	Average Size(Square feet)
Bathroom Toilet Garage Storeroom Kitchen		
Bedroom		
	Nature: cemented/ wool/ rubber/ tiled/paved/ grass /none	
Plot or floor space of your residence	**Size**(Sq. ft)	Nature: cemented/tiled/paved/grass/none

C.19. Do you have access (at least electricity within the last one month) to electricity in your residence?

1. Yes [ ] **2.** No [ ]

C.20. . What is the main source of lighting for your household?

1…………………….National Electricity Grid
2…………………….Kerosene
3…………………… Gas lamp
4……………Candles/Touches (flashlights)
5……………………Solar energy
6……………………Generator
7……………………No light
8……………………Other

C.21. If Electricity, what type of electricity bulbs do you use?

1. Energy saving bulbs **2.** other (such as incandescent light bulbs)
3. Both

C.22. Do you have access to a toilet facility in your residence? Yes [ ] No [ ]

C.23. Do you have a poly tank (reservoir) in your residence? Yes [ ] No [ ]

C.24. **Question for non-owners only:** How much did you pay as rent last month

GH¢……………………

C.25. **Question for Owners only:** If you are the owner of the house, assuming you decide to leave your residence for a new residence. How much would you charge if you were renting your old residence out per month?

GH¢............

C.26. What is the distance (measured in meters) from your residence to the following:

9. School [ ]

10. Coal tar road [ ]

11. Financial Institution]

12. Health centre [ ]

13. Market]

14. Transport Station [ ]

15. King's Palace [**]**

16. Hotel [ ]

C.27. In making your current residential decision how important were the following factors?

Determinants	On the scale of 1 to 5 where ***1=very important*** *and* ***5 =Very unimportant***					***Don't Know***
Rental rate	1	2	3	4	5	
Water Supply	1	2	3	4	5	
Electricity Supply	1	2	3	4	5	
Family and Friends	1	2	3	4	5	
Workplace Proximity	1	2	3	4	5	
Security	1	2	3	4	5	
Public Services	1	2	3	4	5	
Prestige	1	2	3	4	5	
Noise pollution	1	2	3	4	5	
Air pollution	1	2	3	4	5	

***DK means Don't Know or DR means Don't Remember**

SECTION D: Travel Cost Questions

D.3. Do you need to spend some time looking (hauling) for water in your district?

4. All the time
5. Sometimes
6. None of the above

D.4. If NONE, does that mean you have no problem with potable water from Ghana Water Company Limited (GWCL)?

True	
False	

D.7. How far is your household's **main** source of water supply from your dwelling?

NUMBER(see water codes in page 3) DISTANCE UNIT (Meters)

DRINKING

GENERAL USE NUMBER(water code) DISTANCE UNIT(Meters)

D.8. How far is your household's **other** sources of water supply from your dwelling?

NUMBER(see water codes in page 3) DISTANCE UNIT (Meters)

DRINKING

GENERAL USE NUMBER(water code) DISTANCE UNIT(Meters)

D.9. Indicate in the table below the of mode water is transported to your household

Mode of water transportation	Number of round trip per household/ week		Travel cost per round trip(Gh¢)	
	Main Source	Other Sources	Main Source	Other Sources
Walking				
Private car				
Commercial car/bus/truck				
Commercial manual truck				
Tanker services				
Other				

D.10. Are you satisfied with the following:

5. Source of water? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].

6. Quality of water? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].

7. Mode of transporting water to your residence? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].

8. Number of trips made for water to get to your residence? Yes [ ] No [ ]. If No, would you want a change? Yes [ ] No [ ].

E. SANITATION QUESTIONS

E1. How does your household dispose of refuse?	E2.Does your household pay for the disposal of refuse?
1…………………Collected **2**…………………Public Dump **3**…………………Dumped elsewhere **4**…………………Burned by household **5**………………..Buried by household **6**………………..Other specify	Yes ……………………………………… 1 No …………………………………….. 2 >>> >>SKIP >>E4

TIME UNIT CODES **1**………………..Daily **2**………………..Weekly **3**………………..Monthly **4**………………..Quarterly **5**……………..…Half Yearly **6**………………..Yearly **0**………………..No Applicable	E3. How much does this household pay for refuse? Amount in GHS and P GHS [ ] p [ ] Time Unit [ ] see codes
E4. What type of toilet is used by your household? **1**…Flush Toilet **2**….Pit latrine **3**…KVIP **4**…………Pan/bucket **5**…………Public toilet(flush, bucket, KVIP) **6**…Toilet in another house **7**. .No toilet facility (bush, beach) **8**……other , specify [ ]	E5. The last time your youngest child under 5 years passed stools, what was done to dispose it? **1**……...Child used toilet latrines **2**……...Put/rinsed into drain or ditch **3**……...Thrown into garbage **4**…………Buried **5**………Left it in the open **6**. ……..…Other , specify _______ **7** ………...Don't know **8**. No child under 5 years in Household [ ]
E.6 Does your household pay for the disposal of refuse? [ ] Yes ………………………………………. 1 No ……………………………………….. 2 >>> >>**SKIP E.7 to E.8**	E.7. How much does your household pay for the use of the toilet facility? Amount in GH¢ and P GH¢ [ ] P [ ]
E.8 Are you aware of any water borne disease? [ ] **1.** Yes [ ] **2.** No [ ].If yes, specify…………	E.9. Which of these sicknesses was last experienced by any member of your household? **1.** Malaria [ ] **2.**Cholera [ ] **3.**Diahorrea [ ] **4.** Typhoid [ ] **5.** Diabetes [ ] **6.**None[ ] Other [ ] If other, please specify……………………………………………………
E. 10 Do you think toilet or/and refuse gets into your domestic water? 1. Yes 2. No. [ ] Briefly explain your answer in E.10………………………………………	
E. 11 What are the likely HEALTH effects of unclean domestic water on your household?	

SECTION F: Contingent Valuation Questions

F.5. Assuming the associated cost of an improved water service in Ghana is manageable.

Would you like an improved service in Ghana's water service delivery?

3. Yes

4. No

(**If yes, continue with hypothetical market scenario**).

F.6. If no, give reason(s)……………...

……………………………………………………………………………………………
………………………………………….…………………………………………**End**

Hypothetical Market Scenario:

- I would want to find out from you, if you value the provision of an improved water supply system in Ghana particularly the Greater Accra Region. By improvement it means you are connected to an uninterrupted supply of water. We have designed an innovative/modernized borehole system that is not manual but powered by solar energy so you do not have to pay electricity bills for water generation. This borehole water is filtered, piped and connected directly to your residence. Thus, water flows directly into your residence at all times, the quality is up to acceptable national standards. Generally, we know that every good thing comes at a cost. You may be required to pay a permanent amount that will be factored into your water bills provided by the Community Water and Sanitation Agency (CWSA).
- Refer to pictorial description for further understanding of oral/written description

Willingness-To- Pay Questions

Would you prefer another medium of payment other than CWSA monthly bills?

Yes [ ] No [ ] If yes, how would you want to pay it? ……………

A: Willingness-to-pay (WTP)

F.7. Suppose you are supplied with an innovative/modernized borehole system as orally and pictorially described, how much would your household be willing to pay to fetch a 34cm bucket of water from this system?" Would your household be willing to pay

- GHS………… (for the household **not** entire residence) YES [ ] (**if yes, skip to B-WTP**)
- If NO, What about GHS …………………………………………...? YES [ ]
- If No, please specify amount which you would be willing to pay less than GH¢………..…

- Briefly explain why……………………………………..

……………………………..………………………………………………………………………

………….………………………………………………………………………………..**END**

B: Willingness-to-pay (WTP)

If yes, continue….

- GHS……………………. per month, YES [ ]

If yes, it means you will be willing to pay more. Please state how much you would be willing to pay which is more than the GHS…………………

GHS ………………………………

If no, it means you will be willing to pay less. Please state how much you would be willing to pay which is less than the GHS…………………

GHS ………………………………

E.6. How did you find the survey questions?

1. Very difficult

2. Difficult

3. Easy [ ]

4. Very Easy

5. Don't know

6. Refuse

THANK YOU FOR YOUR ASSISTANCE!

GENERAL CONCLUSION

In this thesis, we acknowledge that Ghana is a resource rich country, however, key utilities such as electricity and water supplies have for some time now been a major challenge affecting both firms' efficiency and households' wellbeing.[41] The challenges over the last decade have grown from bad to worse with 24-hour supply being a miracle. Almost every sector in Ghana today has had a fair share of this menace with its obvious negative impact on economic growth. For example, Ghana's annual GDP growth rate rose up to 14.05% in 2011, one of the best growth rates recorded worldwide. However, severe challenges associated with our key utilities may be explained to be a major causal factor of the downward spiral in Ghana's economic growth rates which slowed for the fourth consecutive year to an estimated 3.4% in 2015 (see World Bank, 2016). Several attempts have been made towards combating this menace but desired results are far from reached. A fundamental cause of this problem is the imbalance between operational cost and revenue from these sectors. Some experts have proposed a full cost recovery programme for such sectors. However, holistic empirical evidence to support policy decisions is lacking.

The challenges to the utility sector can be addressed either from the demand side or the supply side. The thesis principally focuses on demand side management as a panacea to the major challenges confronting the utility sector in Ghana.

The thesis consists of four main chapters (or papers), two on the subject of electricity demand, and two on water demand. The main objective of this thesis is to apply a variety of established techniques to estimate demand for energy (electricity) and residential water in Ghana. We address this objective by applying a myriad of macro (ARDL) and micro (CVM, HPM, TCM) techniques. Regarding the macro technique, we first modelled energy demand and disaggregated it by energy type. We estimated the elasticities for these types which includes electricity. Focusing on only electricity, we find an income elasticity of 2.7. This is consistent with existing studies.

Also, regarding our micro technique applications, we first used the CVM only on a household survey data to determine WTP for a 24-hour supply of electricity in Ghana.

[41] Firms' efficiency: Firms' machines, man-hours, and water and electricity dependent production are either lost or at best come at a huge cost. Households' wellbeing: Apart from losing out on quality leisure hours, households' appliances constantly break down because of electricity crisis. In addition, absence of water forces households to waste man-hours trying to access water and also compromise on good hygiene and healthy living.

This is achieved in line with providing evidence to address highly debatable issues such as hypothetical bias, WTP & WTA disparity, and scope sensitivity.

Our study finds no evidence of hypothetical bias, yet there exist an evidence that satisfies our scope sensitivity test. Thus, contrary to our macro estimates with income elasticity being elastic, our micro level (household survey) data also shows that income elasticity is inelastic. This difference can be explained by the fact that households are not as responsive to electricity changes because of income constraints unlike other agents such as firms who may budget for shocks and uncertainties. In response to WTP & WTA debate, several tests were conducted to establish a convergence or divergence between WTP & WTA estimates. Based on our evidence, we cannot be conclusive and requires a further test (convolution test) on the entire distribution which our sample does not permit at this stage. The main findings show that households are willing to pay between 7% and 15% of their income to have a 24hour supply of electricity in the GAR of Ghana. However, our cost & benefit analysis shows a deficit of GHS567.52million ($146.97million) per annum. This suggests that a complete removal of subsidies on electricity tariff in Ghana will be very disastrous to household's electricity consumption especially lower income brackets.

The second micro level application used the CVM, HPM and TCM to estimate demand for piped-water supply in Ghana. This chapter provides the first developing country's study to compare three economic valuation methods in a water related study. The purpose of this chapter was to provide robust estimates to influence policy. Standard practices were followed throughout the design stages, data collection and application of econometric techniques. We surveyed 1,648 urban households and find that the average amount that households are willing to pay per month is GHS 44.73 or US$14.27 (Hedonic Price Method), GHS 22.72 or US$7.25 (Travel Cost Method) and GHS 47.80 or US$15.25 (Contingent Valuation Method) respectively. We find our estimates to be equivalent to 3%-8% of households' income. Evidence from our cost &benefit analysis show a positive net benefit of GHS1,333,638.19 (US$426,010.29) per day or GHS486.78million (US$155.49million) per annum. Similar positive net benefit results are found in Briscoe et al. (1990), Whittington et al. (2002), and Soto Montes de Oca (2003). We still find evidence of net benefit for both urban and rural households cost together at the same expected revenue. This evidence shows the economic viability of the sector which supports the proponents of full cost recovery for the water sector in Ghana. Thus, an initiative towards the complete removal of subsidies should be considered rigorously irrespective of past practice.

The third micro level application which focuses on rural water supply, designs an innovative borehole system and elicit household's WTP for improved and safe water from this system. We surveyed 610 urban households and applied both CVM and HPM in this single study. Interval regression and OLS are applied to investigate the determinants of WTP. We find that monthly WTP are GHS35.90 (US$11.45) and GHS17.59 (US$5.61) in the CVM and HPM, respectively. These values constitute approximately 3%-6% of household monthly income which is consistent with existing studies.

In short, this thesis presents the first cost and benefit analysis study for key utilities in Ghana to inform policy direction towards addressing critical problems currently bedevilling the country's electricity and water sectors. In general, the results of this thesis provide the first evidence from Ghana regarding households' willingness to pay for improved utility services such as electricity and water. Moreover, our results suggest that households are positively inclined toward having improved utility services in Ghana. We may infer public support gearing towards a privatization plan that would improve utility supplies and require all participants to pay regular and relatively higher monthly bills. Our estimates provide the needed information that may help persuade policymakers of the economic viability of private sector involvement and guide the design of a new tariff structure.

Summary of Key Findings and Policy Recommendations.

1. Our results show that energy prices, income, urbanization and economic structure are significant demand drivers of the different energy types in Ghana with varying estimated elasticities. We find that there is high degree of responsiveness of electricity demand to income changes by mainly the industrial sector relative to households. This provides evidence of a clear link between national income and demand for electricity by the industrial sector for their growth prospects. Indeed, this study recommends that policy makers should ensure that long-term sustainable renewable energy sources are harnessed to sustain Ghana's industries because of the nexus between industries energy demand and national income growth.

2. The net cost of electricity supply in Ghana is GHS567.52million ($146.97million) per annum. Thus, we discourage any policy towards the complete removal of subsidies on electricity tariff in Ghana. We recommend that any move towards

privatisation of the sector should not be sanctioned if removal of subsidies will be immediately considered.

3. Also, the net benefit of piped-water supply for urban households in Ghana is GHS486.78million (US$155.49million) per annum. Interestingly, extending the cost to include the rural households still yield a net benefit of GHS1.13million (US$363,824.73) per annum. This provides evidence for proponents of full cost recovery programme in the water sector to consider its implementation. This study recommends that a regulated private sector should be considered within the context of proper due diligence before carrying out full implementation plan.

In sum, any policy attempt at removal of subsidy especially for lifeline consumers in Ghana for now, is not recommended by this study. This is mainly attributed to the fact that removal of subsidy from the electricity sector will hurt both poor and non-poor. Also, implementing a full cost recovery programme in the water sector looks more ideal and we highly recommend this. That is, a regulated private provision of water supply could be a better option. This recommendation should be implemented with recourse to proper due diligence.

Directions for Further Research

1. A holistic welfare analysis that is not limited to only economic cost & benefit is recommend for further studies.
2. We provide evidence of WTP for an innovative borehole system for rural communities, however, we fail to provide the entire cost estimates of the entire system due to several technical aspects that need to be considered first. We recommend further research into the cost of the innovative design. We further recommend an appraisal of the cost of connecting piped-water to rural areas in Ghana. Evidence from the appraisal will be very useful to the private sector.
3. Based on our recommendation that government should provide the needed incentives towards household use and management of their own renewable sources of energy, we recommend further cost benefit analysis research into renewable sources of energy in Ghana as done in other countries.

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