Household Water Security and Water Demand in the Volta Basin of Ghana

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1 INTRODUCTION

1.1 Background of the study

Water is identified as one of the most important natural resources because it is viewed as a key to prosperity and wealth (Arbués *et al.*, 2003). However, water tables are falling (Brown, 2001) and aquifer depletion is now an emerging problem. It is documented that less than 10 countries have about 60% of globally accessible water (Swaminathan, 2001), suggesting inequitable distribution of water globally and nationally. Lately, global climate change and its impact on rainfall availability and variability in time and space is becoming a concern. Natural factors as well as human actions and inactions are directly responsible for water scarcity problems. Human activities may alter the hydrological cycle in uncertain ways resulting in greenhouse-induced climate changes. Population growth directly or indirectly is expected to shift about 55% of the World's population towards water stress or severe water scarcity over the next generation (Rockström, 2001). Genuine concerns are therefore raised about future water scarcity because of the important role water plays in sustainable development and quality of life. The international conference on freshwater held in Bonn, Germany in 2001 and the third world water forum held in Kyoto, Japan in 2003 are examples attesting to these concerns.

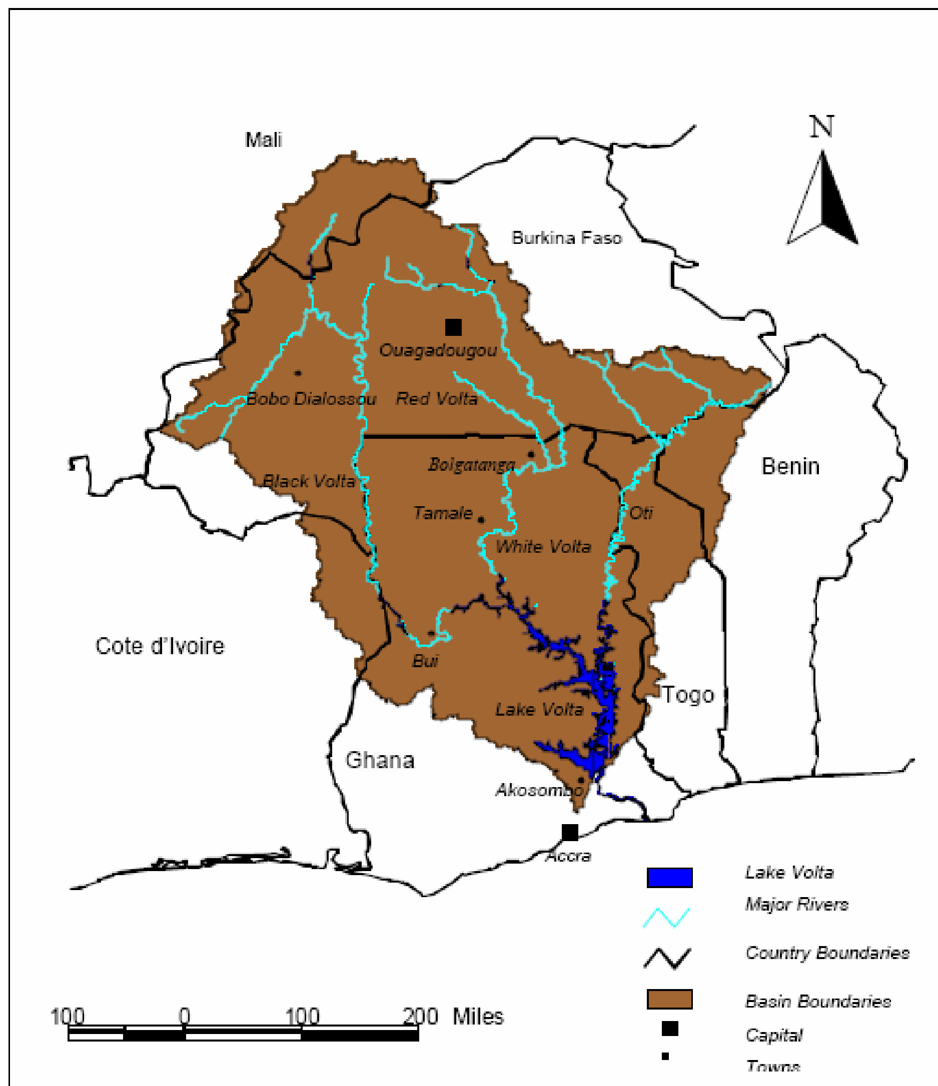
Water scarcity situation is severe in developing countries, with an estimate of about 1.2 billion people in 20 "water-scarce" developing countries without access to "safe water" (WHO, 1998). By the year 2020, up to 30 countries mainly in Africa and Asia would be in this group. The World Commission for Water (2000) estimates that more than 1 billion people in developing countries do not have access to clean water whilst 2 billion lack adequate sanitation. In the case of sub-Saharan Africa, Rosen and Vincent (1999) estimate that about 67% of the rural population (about 250 million people) lack safe and accessible water supply whilst 81% do not have access to sanitation facilities. Estimates show that available water per capita has declined by 40% in Asia and 50% in Africa (Ayibotele, 1992). Africa is noted to be the poorest of the world continents in terms of annual fresh water renewal (World Resources Institute, 1986 as cited by Falkenmark, 1990). Thus, most sub-Saharan African countries facing economic water scarcity are expected to more than double the amount of developed water supplies by the year 2025 if they are to overcome water insecurity.

The Volta River basin in West Africa is characterised by unpredictable rainfall patterns with periodic and perennial water shortages. It covers an area of about 400,000 km^2, approximately the size of Germany. It is one of the poorest watershed areas of Africa (with mean annual income estimated at US$ 800) and the ninth largest river basin in sub-Saharan Africa, traversing 6 riparian countries, namely, Ghana, Togo, Burkina Faso, Côte d'Ivoire, Benin and Mali (see Figure 1 for the six riparian countries in the Volta river basin and Table A1.1 in Appendix 1 for some socio-economic characteristics and water-related information). The basin serves as the home for roughly 18.6 million people, with majority living in rural areas. About 42% of the basin lies in Ghana where the construction of a dam along the Volta River mainly for hydroelectric power generation has resulted in the largest manmade lake in the World, with a storage capacity of 148km^3. However, inadequate rainfall within the entire basin in 1998 gave rise to serious water shortages leading to a lowering of water levels in the Volta Lake and electricity generation was adversely affected. Ghana therefore witnessed serious power shortages during this period. The scarcity and management of 'blue water'[1] in the entire basin appears to be an important issue to contend with. Hence, the GLOWA-Volta project[2] was initiated to address water scarcity issues, among others. It is the Ghanaian part of the basin, covering roughly two thirds of the land surface of Ghana that is the research focus for the first phase of the project. What is not very clear is whether water insecurity problems are the result of physical water shortages, infrastructural constraints, mismanagement, or inadequate human and institutional capacities to tackle the situation. Addressing these concerns is beyond the scope of this study.

[1] This is rainfall available for human use either as groundwater or as surface water.

[2] Under the title "Sustainable water use under changing land use, rainfall reliability and water demands in the Volta basin", the GLOWA-Volta project aims at analysing the physical and socio-economic determinants of the hydrological cycle to develop a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin. The project, based at the Centre for Development Research (ZEF) in Bonn, Germany, is funded by the Federal Ministry of Education and Research (BMBF) and the Ministry for Schools, Science and Research of North Rhine-Westphalia of Germany and is one of five GLOWA projects (Elbe, Danube, Drâa/Ouéme, Jordan, and Volta).

Figure 1.1: The Volta basin and the six riparian countries.



Source: From the GLOWA-Volta project (2003): http://www.glowa-volta.de

1.1.1 Household water security issues: concepts, causes, and definitions

Unlike food security, household water security is a relatively new concept in water demand management literature for both developed and developing countries. This concept encompasses issues of water availability, accessibility, usage, and water quality. It has traditionally envisaged availability as the central focus (Ariyabandu, 2001) although availability alone does not ensure household water security at a given point in time. Water availability is affected to a larger extent by environmental factors that may result from hydrological changes and may have short-term variations. In this case, water is viewed as a natural resource that has to be managed and sustainably used. Hence, the unsustainable consumption of water may have long-term impacts by reducing available water to

communities concerned. Human factors also influence water availability in that available water would have to be harnessed and distributed to ensure adequate and reliable flow.

Water accessibility considers water as a commodity and ensures that households have full or firm control of the available water. Access to this commodity therefore depends on its physical location and timely availability. Water usage relates to "entitlement rights" of households, required for basic needs (i.e., for drinking, cooking, hygiene and sanitation) and other purposes such as watering livestock and backyard gardens. In addition to these, the quality of water is important because households can not be secure from water-borne and water-related diseases when its quality is questionable.

Easy accessibility, reliability and timely availability of adequate safe water to satisfy basic human needs ensure water security (Ariyabandu, 1999). This implies that households are able to obtain the required quantity of suitable quality water for basic needs and other economic activities (Ratnaweera, 1999). The extent to which these factors interact determines water security conditions of households, nations and regions at a point in time. Nevertheless, water insecure households adopt various coping strategies such as the use of multiple water sources and commuting long distances to access water. Coping with seasonal and periodic water scarcity is costly due to investments in water storage equipment, water treatment (i.e., boiling water, purchase of chemicals and filters to purify water) and opportunity costs of time spent fetching water.

Other closely interrelated concepts include water scarcity, water shortage, and water stress. Causes of water scarcity are either natural or induced by the actions and/or inactions of man, resulting in permanent or temporary effects (Falkenmark, 1999; Pereira *et al*., 2002). Several degrees of water scarcity identified include absolute, life-threatening, seasonal, temporary and cyclical water scarcity (Pereira *et al*., 2002). Countries with total water withdrawals greater than 50% of the available water resources are said to experience absolute water scarcity (Secklar *et al.,* 1999; Lanka Rainwater Harvesting Forum [LRHF], 1999) whilst economic water scarcity prevails if projected water demand is less than 50% of its available water resources but more than twice the current withdrawal levels (ibid, 1999). Winpenny (1994) attributes high growth in population and food demand as major causes of water scarcity, alongside human behaviour, social customs, institutions and government policies as influencing factors. Growth in urbanisation especially in developing countries,

industrialisation and irrigation are partly responsible for water demand increases at the domestic, commercial and industrial levels. The contamination of existing water supplies, modifying landscapes and land uses, financial and institutional obstacles, and the failure to manage demand have also been mentioned.

There is no widely acceptable definition of water scarcity such that the term water shortage has been used synonymously with water scarcity. When water scarcity is man-induced but with temporary water imbalance including groundwater and surface water over-exploitation, degraded water quality and often associated with disturbed land use and altered carrying capacity of the ecosystems, it is referred to as water shortage (Pereira *et al*., 2002). Thus, water shortage describes a situation of absolute shortage where low levels of water supply do not meet the necessary minimum requirements for basic needs (ibid, 2002). The inability to sustainably manage water shortage may result in desertification, a permanent situation that is difficult to deal with (ibid, 2002).

Water stress is analogous to the term "drought" (ibid, 2002) and a symptom that points to the presence and consequence of water shortage and scarcity. It manifests itself in growing conflicts among water users (both domestic and industrial), unreliability of water sources, crop failures and food insecurity. Whilst water stress acts as a potentially serious constraint to development (Winpenny, 1994), the Food and Agricultural Organisation (FAO) views water shortage as a major drawback to the socio-economic development and environmental protection.

Winpenny (1994) considers water scarcity as an imbalance between supply and demand under prevailing institutional arrangements and/or prices; an excess of demand over available supply; a high rate of utilisation (expressed as a percentage of total available water resources) compared to available supply especially when the remaining supply potential is difficult or costly to tap. Though water scarcity describes water demand vis-à-vis its availability in time and space, interpretation of "scarcity" as a situation where water is insufficient to meet normal requirements may be unhelpful to policy makers and planners.

To further conceptualise the problem, Kulshreshtha (1993) suggested a comparison of water withdrawals alongside annual availability to give different scenarios of water scarcity situations. Pereira *et al.* (2002) thus defined water scarcity as a situation where water

availability in a country or region is below $1000m^3$ per capita per year whilst an amount below $500m^3$ per capita per year is regarded as severe water scarcity. Internal water resource availability for countries like Kenya, Rwanda, Tunisia and Algeria, for example, are below the $1000m^3$ per head and have water use levels also below this level (ibid, 2002). Kulshreshtha (1993), Engelman and Leroy (1995) and WRI, (1996) add that a more realistic measure of water scarcity should include water inflows from other regions and countries and current levels of water consumption. In most sub-Saharan African countries including Ghana, available water resources per capita is quite abundant where 24% and 5% of the population live in areas with annual withdrawals below $2000m^3$ and $1000m^3$ per capita respective (Pereira *et al*., 2002). This may be attributed to abundant water resources, little or no irrigation development coupled with relatively low levels of water usage. Although these benchmarks may have no absolute significance, water scarcity is considered a relative concept that can surface at any level of supply depending on demand and institutional factors.

A quantitative measure, "criticality ratio", to capture water scarcity stress at the basin level has been suggested by Alcamo, Henrichs, and Rösch, (2000) and Raskin (1997) as cited by Rosegrant (2002). A high ratio of water withdrawals to total renewable water implies more intensive use of river basin water that results in degraded water quality for downstream users. Although subjective, a criticality ratio greater than or equal to 0.4 is considered "high water stress" and 0.8 as "very high water stress" (Alcamo, Henrichs, and Rösch, 2000).

These concepts focus only on a single component of water security, and that is water availability. Household water security as a unique concept has been defined variously by different researchers based on research interests or perceptions. A simple definition is the ratio of water supply to water demand, where security is achieved when the ratio is greater than unity, implying water surplus. Ariyabandu and Dharmalingam (1997) defined household water security as "having adequate domestic water supply, so that the productive life of peasants can be sustained". Thomas (1998) fine-tuned this definition to mean the attainment of both Absolute Water Security (AWS) and Design Water Security (DWS), where AWS is the quantity of water reliably supplied to perform culturally normal life whilst DWS is the quantity of water reliably supplied to achieve the designed daily requirement of water. What determines water security, according to Ratnaweera (1999), is the ability of households to obtain the required quantity of suitable quality water for drinking, personal hygiene, other domestic purposes and other economic activities.

These definitions focus on quantity parameters and ignore qualitative determinants such as accessibility and quality. Incorporating quality issues, Webb and Iskandarani (1998) consider "access by all individuals at all times to sufficient safe water for health and productive life" as constituting water security. This view ignores the timely availability and reliability of supply. The interpretation of the term "safe water" is subjective and therefore debatable as "safe water" could connote cultural safety, clinical safety, and perceptional safety (Ariyabandu, 2001) or even minimum pollutant standard (LRHF, 1999). According to the World Health Organisation (WHO, 1996a), "safe water" includes untreated water from protected wells, springs and wells. A definition by Ariyabandu (2000) expresses household water security as "accessibility, reliability and timely availability of adequate safe water to satisfy basic human needs", leaving the interpretation of "safe water" to individual judgement. Abrams (2001) perceives water security as a situation of reliable and secure access to water over time. This view has the perpetuity of water supply or sustainability in mind although silent on water quality. In the words of Winpenny (1994) "The essence of water security is that societies should have sufficient access to water or that they should have the means to limit the damage caused by shortages".

1.1.2 Global water security

Global water security is emerging as one of the highest priorities on the development agenda. This is evidenced by several efforts to assess the present condition of the resource. Clarke (1993) reports an increase in the global water demand by roughly 2.4 % per annum since the 1970s. A similar view is reported by Cosgrove and Rijsberman (2000) who observe that water consumption has more than quadrupled between 1950 and 1995 for both the domestic and industrial sectors. Although in the developed world water is often taken for granted and viewed as a limitless resource, about 1 billion people worldwide have no access to safe drinking water. The UN comprehensive Assessment of the Freshwater Resources of the World estimate that about a third of the world's population live in countries suffering from water stress where there is shortage of surface water, and are extracting more than 20% of their available water resources (Arnell, 2004).

The above situation may be linked in part to decades of human development in which water has played an important role. Focusing particularly on agricultural use, Secklar *et al.* (1999) mention irrigation as the main user of water and being responsible for the depletion of over 70% of the world's developed water supplies. This view has been supported by Rosegrant *et*

al. (2002) who report that irrigated agriculture accounts for 80% of global, and 86% of developing country water consumption in 1995. Secklar *et al.* (1999) thus attribute the success of the green revolution, especially in developing countries, to increases in irrigated land.

Groundwater withdrawals are perceived to be an emerging problem in the 21st century (Secklar *et al.,* 1999; Rosegrant *et al.,* 2002) even though little attention is devoted to it. Brown (2001) mentions the falling of water tables on every continent and aquifer depletion as a potential problem. Countries like Mexico, China, India, Pakistan, as well as North African and Middle Eastern countries have literally exhausted their groundwater resources (Secklar *et al.,* 1999). In India, water extraction from aquifers is already twice the recharge rate (ibid, 1999) leading to a lowering of the water table by 1-3 metres annually and a projected drop of 25% in crop production if this trend should persist (Brown, 2001; Gleick, 2000 as cited by Rosegrant *et al.,* 2002). These developments point to a potentially threatening future for global water availability.

The concerns raised in the above reports have prompted a number of studies on future availability of water. The International Water Management Institute (IWMI) estimates that about 1.4 billion people (equivalent to a one-third of the population of developing countries) live in regions that will experience severe water scarcity in the first quarter of the 21st century (Secklar *et al.,* 1998). They further projected that by the year 2025, about a billion people living in arid zones will experience absolute water scarcity. It is estimated that 348 million people living in regions with sufficient potential water resources, but have to undertake expensive and perhaps environmentally damaging water development projects, will experience severe economic water scarcity (ibid, 1999). With the world population estimated to reach roughly 8 billion by 2020 (UNFPA), Rosegrant (1997) estimates an increase in global water withdrawals for the same period by 35%. Given the *status quo* of water use practices, water withdrawals in developing countries are projected to increase by 27% by 2025.

The effect of climate change and its impact on rainfall cycles and availability is becoming a concern. Arnell (2004) predicts changes in the volumes and timing of river flows and ground water recharge, which will impact on the numbers and distribution of people suffering from water scarcity. Arnell points out that most of the projected national water resource scarcity

studies, for example, by Rosegrant (1997), Secklar *et al*. (1999), World Resources Institute (2000), UNEP (2001), and Alcamo *et al.* (2000, 2003) among others, ignored the effects of climatic changes. Calculating water stress indices at watershed scale (and not at national levels) and using consistent climate and socio-economic scenarios, Arnell (2004) concludes that by the 2020s, between 53 and 206 million people will fall into water-stressed category whilst between 374 and 1661 million people are projected to experience increases in water-stress and that the effect of climate change on water scarcity will largely depend on future water resource management practices.

Given that the single greatest threat to food security, human health and natural ecosystems is water scarcity (Secklar *et al.,* 1999), developing countries need to be proactive in solving water scarcity problems as it requires at least 20 years for the development of substantial water-resource programmes to yield results (ibid*,* 1999).

1.1.3 The GLOWA-Volta project

The GLOWA-Volta project was initiated to primarily address water security issues, among others in a holistic manner by examining how water can be sustainably utilised under changing land use, rainfall reliability and water demands in the Volta basin. Funded by the German government, the project has the primary objective of analysing the physical and socio-economic determinants of the hydrological cycle with the ultimate aim of developing a scientifically sound decision support system that will aid in the assessment, sustainable use, development and the management of water resources within the Volta basin (See Figure A1.1 in Appendix 1 for the structure of the GLOWA-Volta research project).

The achievement of such objectives requires a multidisciplinary team of researchers involving economists, social and natural scientists and anthropologists. The socio-economic component in the project required the implementation of household surveys that has to accommodate the research interests and data needs of other (agricultural) economists and scientists from other disciplines in the project. For example, the soil and social scientists and anthropologists have to be considered so that research findings will touch not only on economic aspects but also on social, demographic and institutional characteristics. As the agricultural economist interviews households on issues regarding water accessibility, usage and water coping strategies for example, the soil scientists may be involved with collecting soil samples from the farms of the same households whilst the institutional analysts may be

concerned with decision making processes, such as participation in water and sanitation projects, at the community or village level.

Four interrelated subprojects broadly address specific objectives of the socio-economic aspects within the GLOWA project. These include the building of a bio-economic household model, water allocation model and population and migration model for households in the basin. A fourth subproject which addresses household water security and water demand issues in the basin is the subject of this study.

1.2. Problem statement

Freshwater is vital for socio-economic development and provision of ecological services but this resource is gradually becoming a scarce commodity in Ghana. In 1955, per capita available renewable freshwater was 9,204m^3. This declined to 3,529m^3 in 1990, representing more than twice the amount defined as the upper limit for water stress (Karikari, 1996)[3]. These macro level statistics classifies Ghana as a water-abundant. However, relying on such information is misleading because of the pervasiveness of seasonal and perennial water scarcity nationwide. The Global Water Project (GWP) forecasts that six West African countries, including Ghana and Burkina Faso, may experience water scarcity by 2025 mainly due to the expected rate of growth in population (Global Water Partnership (2001). Current annual population growth rate of 2.7 % (Ghana Statistical Service, 2000) coupled with expansion in urbanisation suggests future increases in water demand. Already, water demand outstrips supply (Karikari, 1996) and projected per capita renewable freshwater availability by 2025 will further decline to 1,400 m^3 (ibid, 1996), which is within the water-stress range. It is obvious that national level indices of water availability mask sub-national or within-country seasonal and spatial variations in water availability in the entire Volta basin of Ghana.

The link between inadequate access to safe and affordable water and public health problems can not be overemphasised. For example, inadequacy of rural water supply and sanitation coverage has been recognised to be a major contributor to human disease and malnutrition in Ghana. Common diseases such as cholera, typhoid, river blindness, hepatitis and shigellosis and malaria are either water-borne or water-related. It is estimated that about 70% of diseases

[3] Hydrologists consider a country as water-stressed if its per capita annual freshwater availability is between 1000-1667 m^3/person/year and as water-scarce if this amount is less than 1000 m^3/person/year.

in Ghana are the result of inadequate rural water supply and sanitation coverage (The International Fact-Finding Mission on Water Sector Reform in Ghana [IFFM], 2002). As a result, malaria and diarrhoea are rife. In 2000, for example, about 12% of health problems in the form of acute eye infections and skin and diarrhoeal diseases were as a direct consequence of poor water supply or its absence and another 40% of outpatient visits to health facilities were for cases of malaria (IFFM, 2002). The high incidence of malaria can be linked to the poor sanitation and drainage systems that provide breeding places for mosquitoes. These observations may be partly explained by the relatively low public piped connection rate of 76% in urban and 46% in rural Ghana (Ministry of Works and Housing, 1998). The minimisation of these health problems is contingent on the choices made by household's regarding available water supply sources as this has health and agricultural productivity implications. For example, the World Bank (1992) estimates that improvements in water quality, increased availability of water, a combination of these, and proper disposal of excreta would decrease mortality from diarrhoea by 16%, 25%, 37% and 22% respectively.

Water quality perceptions by households may also contribute to household health problems. Water may be consumed from sources perceived to be of good quality. However, in dire situations especially in the dry seasons, households may have no options when most available water sources dry up. In such circumstances, water is consumed with little or no attention paid to its quality thereby influencing household drinking water security.

To further enhance water security, household invest by purchasing storage facilities and by treating water (using chemicals and filters for purification purposes). Although there is no empirical evidence in Ghana (to the best of the authors knowledge) regarding the costs of coping with water insecurity, it is believed that due to the subsidisation of urban water, costs of coping to access a unit of water by rural households are higher than what urban consumers pay for consuming similar quantities of improved water.

Water demand behaviour by rural households amidst seasonal water insecurity still remains a grey area that requires further investigation. Adequate information is therefore needed on the extent and nature of water accessibility and demand in the Volta basin. What is the extent of water accessibility in the Volta Basin of Ghana? Are there differences in time allocation to access water in the forest and savannah zones and does it differ by season? Do households

distinguish water source and usage purpose or do they use multiple water sources for different purposes? Are rural households likely to choose improved (quality) water sources amidst unsafe alternative sources? And if so, what determines their choice and the extent of demand from these sources? Do households consider water as a homogenous commodity and what factors determine rural household water demand? The present study answers these research questions.

1.3. Objectives of the study

The overall objective of this study is to assess the extent of household water security in the Ghanaian part of the Volta basin and to draw policy implications based on the study. The specific objectives of the study are as follows:

1. To examine the extent of household water accessibility and usage patterns in the Volta basin of Ghana.

2. To identify the key factors that influence a household's choice for improved water sources and subsequently examine the determinants of water demand from these sources.
3. To estimate the determinants of household water demand in the basin, specifically to generate price and income elasticities relevant for policy formulation.

1.4. Relevance of the study

It is important to recognise that as the basic amount of fresh water supply by the hydrological cycle does not change, water demand is said to have increased in Ghana (Karikari, 1996). This may lead to water insecurity which can threaten economic sectors, especially irrigated agriculture and hydropower generation. Secklar *et al*. (1999) and Luijtena *et al*. (2001) note that water scarcity represents the single greatest threat to food security, human health and natural ecosystems. Hence, the efficient and sustainable use of water in the basin is very paramount. The need therefore arises to examine the extent of water accessibility and empirically quantify water demand for purposes of structural analyses, forecasting and policy evaluation.

Little is known about the extent and nature of water availability, accessibility and quality in the basin. More attention has rather focussed on the supply and equitable distribution of water to urban populations largely to the neglect of rural areas. The officially quoted figure of 60-

70% potable water accessibility in urban areas and only 35-40% in rural areas are questionable in that a recent study conducted in 2001 indicate that only 40% of the urban population have access to potable water supplied by the Ghana Water Company Ltd (Apoya, 2003). This finding may suggest a deteriorating situation in water accessibility both for urban and rural communities. Assessing the current situation in rural areas is therefore necessary for sound planning.

The connection between water and health and its possible impact on household agricultural productivity makes households' choice for improved water sources an important decision. In this regard, the demand for improved water may be regarded as derived demand that serves as an input for health production. High population growth rates make it expedient to empirically examine present and future water demands for policy intervention purposes in the areas of water resource planning and management strategies. Good insights into water access types and a better understanding of water demand and choice behaviour by households would provide important information for improving water accessibility.

Rural household water demand behaviour is under-researched compared to urban water demand. This study fills that lacuna. As noted by the international fact-finding mission on water sector reform in Ghana, "No single intervention has greater overall impact upon national development and public health than does the provision of safe drinking water and proper sanitation" (IFFM, 2002). As such, Ghana's new Vision 2020 with respect to the water sector seeks to attain 100% safe water supply coverage in all urban areas and over 90% coverage in rural areas. A new target of 85% rural coverage by the year 2009 has recently been set by the Community Water and Sanitation Agency (CWSA, 2003). Achieving such objectives requires relevant information regarding the demand behaviour of households and the factors that influence households' decision to use improved water sources. This study is therefore timely and can contribute to achieving the targets set for rural water coverage by providing relevant household level information.

The quest for reliable research results to a larger extent depends on theoretical frameworks that are consistent with economic theory of consumer demand behaviour and estimation methods. This study applies a consumer demand system model that conforms to fundamental human behaviour to estimate water demand in rural Ghana. According to the author's knowledge, this modelling approach has not yet been applied in the area of urban or rural

household water demand in Ghana and thus pioneers the use of such modelling frameworks in water demand studies in Ghana.

1.5 Organisation of the study

The study is organised as follows. Chapter 2 is devoted to empirical literature review of household water demand studies and water security issues. Data collection methods, starting with the development of a common sampling frame used for the household surveys, survey descriptions and data processing methods are presented in Chapter 3. Chapter 4 presents descriptive statistics of socio-economic and demographic characteristics of households and prevailing water security conditions. An estimation of the price of water based on opportunity costs of time allocated to water collection is also derived in this chapter. Chapter 5 highlights the theoretical framework underpinning the study and methodology followed in modelling household water demand whilst Chapter 6 presents the empirical analysis, discusses the results and policy implications based on the study. Chapter 7 concludes the study with a summary of major findings and contributions to the body of knowledge in empirical water demand studies in rural Ghana. Policy recommendations, limitations of the study and suggestions for future research are also outlined.

2 LITERATURE REVIEW

2.1 Water consumption, access and coping costs

Wide differences exist between water consumption levels in industrialised and developing countries. Average per capita daily water consumption (l/c/d) for Switzerland, the least among industrialised countries, is 110 l/c/d, USA (668 l/c/d) and Japan (342 l/c/d) (World Bank, 1997b as cited by Rosen and Vincent, 1999). In comparison, although at the village level, an average of 11.1 l/c/d is observed for a village in Mozambique with a centrally located standpipe 300 metres away (Caincross and Cliff, 1987 as cited by Rosen and Vincent, 1999). Consumption averaged only 4.1 l/c/d (ibid, 1987) in another village in the same country with similar water source located 4 km away from home. Acharya and Barbier (2002) report an average of 232 litres per day per household or 24 l/c/d for two wetland communities in northern Nigeria. In Madagascar, a survey of 180 households in 8 villages reveals that on the average households consume 31 litres of water daily in the dry season (Minten *et al.,* 2002). No such documented information exists for rural communities in Ghana. What is available is a survey conducted by London Economics (1999) on behalf of the Ministry of Works and Housing (MWH) in major urban areas to justify the introduction of Private Sector Participation (PSP) in urban water sector. They report an average of 105.1 l/c/d for households with tap connections, 68.5 l/c/d for those with yard tap and 33.2 l/c/d for those using other means, with an average domestic water demand estimated at 52 l/c/d for urban sector.

To further enhance water security, multiple water sources are utilised depending on the season and geographic location. Ariyabandu (2001) report that between 2 and 6 sources of water have been used among the rainwater harvesting community in rural Sri Lanka. The burden of domestic water provision by women and children (usually girls) in developing countries is well known (Curtis, 1986 as cited by Sullivan, 2002; Rosen and Vincent, 1999).

Mehretu and Mutambirwa (1992) observe that in the Chiduku communal area in Zimbabwe, approximately 91% of total time devoted to water collection is carried out by women and girls whilst in Arusha, Tanzania, they account for 75% of this time (Makule, 1997). In 8 rural communities in Madagascar, Minten *et al.,* (2002) indicate that women constitute 87% of water carriers and spend an average of 12 minutes (one-way) undertaking this daily activity. Bevan, Collier, and Gunning (1989) give more insight by indicating that in the Central and

Nyanza Provinces in Kenya, younger women generally spend less time than older women in fetching water from the same distance: in the Central Province, women aged 20-29 spend 56 minutes daily; age 30-49 (69 minutes); over 50 years (77 minutes). In a village in Mozambique, Cairncross and Cliff (1987) indicate that about 5 hours is devoted to water collection (return trip) from a public standpipe located 4 kilometres (average of 131 minutes per carrier per day) whilst a similar source located 300 metres takes an average of 25 minutes per carrier per day. Women in Oyo State, Nigeria spend about 58 minutes daily collecting water at an average distance of 537 metres (Sangodoyin, 1992).

Locating improved water supplies within reasonable distances to households saves time and possibly increases total water consumption. Although the World Health Organisation (WHO) considers 200 metres as a convenient distance, Sharma *et al.*, (1996) as cited by Rosen and Vincent (1999) points out that when rural households' perceptions of accessibility is considered, the percentage of households with safe water supply access could substantially reduce and may approach zero in some cases. Huttly *et al.* (1990) find that improving accessibility by constructing boreholes in villages in Nigeria reduced daily water fetching times from 360 minutes to 45 minutes. Through rain water harvesting, women in Sri Lanka saved 2 hours (opportunity costs) daily by a reduction in the number of trips to dug wells and springs from 8 to 3 per day. As a result, rainwater consumption increased in dry and wet seasons between 50 to 70%. Such substantial amount of time saved could improve women's welfare through time and energy availability for education, high-status work and civic activities (WHO, 1995) when it has been estimated that as much as 25% of women's productive time in developing countries could be allocated to this task (Sullivan, 2002).

Studies reviewed by Rosen and Vincent (1999) suggest that time saved by women is channelled into housework (for example, cooking and hygiene), rest, social and personal activities. Others allocated time saved to having quality time with the family whilst a few invested this time into agricultural and cottage income generating activities (Ariyabandu, 2001). Mozambican women, according to Cairncross and Cliff (1987), apportion time saved between housework such as grinding grain, rest and leisure with very little allocated to agricultural production. It must be mentioned that this study was conducted in the dry season where the demand for agricultural labour was low.

In addition to opportunity costs, social and economic costs (related to health problems and energy expenditure) are costs identified with water collection. Dufaut (1988) mention vertebral column injuries among adults, scoliosis among children, and limitation of inflexion and arthritis (degenerative rheumatism) as common injuries. Estimates put energy costs of water collection between 8-10% of daily calorie intake in sub-Saharan Africa (Rosen and Vincent, 1999). For example, Mehretu and Mutambirwa (1992) observe that in the Chiduku communal area in Zimbabwe, an average of 217 calories per day is expended by each water carrier, representing roughly 10% of the carriers' daily intake of calories. Makule (1997) note that women and girls in Arusha, Tanzania expend about 260 calories carrying a container of 20-litre capacity 1 kilometre away from home and this energy expenditure represents about 10% of their daily calorie intake. An earlier study conducted in 12 rural communities in Kenya, Tanzania and Uganda by White, Bradley and White (1972) show that on the average, water carriers utilise 240 calories daily in water fetching. Given an average calorie intake of 2840 calories for Eastern Africa, this value amounts to about 8.5% of the carrier's daily calorie intake.

2.2 Empirical water demand studies

Reviews of empirical literature on water demand show the dominance of residential (urban) over that of rural water demand studies. Single and system of demand equations with different functional forms have been employed to estimate elasticities of water demand with respect to price, income, household characteristics and composition, among others. These studies utilise time series, cross-sectional data or panel data.

Arbués *et al*. (2003) notes the absence of a general consensus regarding the methodology to analyse water demand and this has resulted in different ranges in price-elasticity estimates of water demand. Through meta-analyses of residential water demand studies, Espey *et al*. (1997) as cited by Arbués *et al*. (2003) attribute these differences to the functional form of estimation technique, type of data used, the choice of variables included (in addition to water price) such as income, weather variables, household population, housing characteristics, frequency of billings and tariff rate designs, and indoor versus outdoor uses. Using Ordinary Least Squares (OLS) estimation and marginal price variable, price elasticity estimates range from -0.21 to -1.57 (Howe and Linaweaver, 1967), -0.39 to -3.33 (Lyman, 1992) and -0.04 to -1.24 (Pint, 1999). A combination of OLS and average water prices gives price elasticity estimates from -0.16 to -0.38 (Griffin and Chang, 1990). Using panel-data techniques with

average price variable, Nauges and Thomas (2000) estimate price elasticity at -0.22. Hewitt and Hanemann (1995) employed instrumental variable approach in combination with marginal price and its difference to give price elasticity estimates between -1.57 and -1.63. These results mainly come from developed countries.

In the developing country context, water demand management in general has traditionally focused on supply-side policies (Arbués *et al*., 2003) that aim at improved water supply coverage for the entire population at low tariffs (Atlaf, 1994). This strategy has been shown to produce low service levels (Briscoe and de Ferrenti, 1998) especially in rural areas and therefore unsustainable in that rural water supply schemes have been approached as welfare activities without financial viability considerations (Saleth, 1996). Willingness to pay (WTP) studies through contingent valuation approach has been used to investigate the potential value to consumers of an improvement in water supply. Studies show that households are willing to pay between 0.5% and 10% of the income for improved water services. Although household income is an important determinant of demand, other factors are found to be more paramount in the demand for improved water services in rural areas of developing countries (World Bank Water Demand Research Team, 1993). Garn (1998) mentions differences in cost (or price), water quality perceptions, reliability, and level of service between existing and improved supplies in rural areas as significant in affecting demand.

Empirical findings indicate that rural households demand high level of service (ibid, 1993), are willing to pay more for improved water supply and services and are already spending substantial amounts to circumvent low services (Whittington *et al*., 1990; Mangin, 1991; Brookshire and Whittington, 1993; Atlaf, 1994). In Kathmandu, Nepal, Whittington *et al.,* (2002) find that households' willingness to pay for improved water services is much higher than their current water bills, where unconnected households are WTP a monthly average of US$ 11.67 for private connections. In the case of Ghana, London Economics (1999) find that urban households are WTP ¢13,209 per month for a compound tap whilst this increases to ¢13,432 per month for having in-house pipe connections.

The decision by households to use improved water sources among other alternatives has received attention and has been modelled through a discrete choice approach. Mu *et al.* (1990) approached this choice problem by assuming that the decision to opt for improved water sources is independent of the quantity of water consumed thereof. Merret (2002)

criticises this approach as it ignores the fact that households use multiple water sources for multiple purposes. Asante *et al.* (2002) find that educational level and household income are important in determining the likelihood of households using improved water sources in the Volta basin of Ghana. However, their regression analysis does not include the price of improved water, an important decision variable often used as tool in water demand management strategies. Employing OLS estimation procedure, Iskandarani (2002) finds that per capita household income and water storage facilities are significant determinants of water demand in Jordan whilst the level of education of household head and price of water charged by private water vendors are not significant in explaining total water demand. Income elasticity of 0.30 and 0.29 is observed for Amman (urban) and rural areas respectively. ,

Attention has lately shifted to demand-oriented approach where the price of water is used as the main instrument to regulate demand. Top-down and community-based approaches have been suggested by Parker and Skytta (2000) but without clear distinctions between these approaches. Zekri and Dinar (2003) find price a significant determinant of water demand in rural Tunisia, with a price elasticity of -1.29 (for a private supply arrangement) and -0.24 (for a public supply arrangement). They attribute the observed high absolute price elasticity to high levels of poverty for consumers of private water companies. The study also finds that low water quality (proxied by salinity) significantly reduce water demand whilst household income has no significant effect on quantity demanded. Minten *et al*., (2002) apply OLS estimation and find household size (elasticity of 0.31) and income (elasticity of 0.11), but not distance, as significant factors that explain household water demand in 8 rural communities in Madagascar. The insignificance of distance is attributed to the closeness of the sources (i.e., lakes and rivers with an average of 12 minutes one-way). However, their study presents a serious drawback by excluding water price, a tool employed in water management to regulate demand.

Using seemingly unrelated regressions, Acharya and Barbier (2002) find that in two areas (four villages) in the Hadejis-Jama'are floodplain in northern Nigeria, time devoted to water collection did not significantly explain water demand by households who only collect water. However, time significantly determines water demand by households who both collect and purchase water where a 1% increase in collection time decrease the demand for collected water by 3.19% and increase the demand for purchased water by 1.69%. Whilst the price of water does not explain water demand by this group of households (i.e., those who collect and

purchase water), price of purchased water is significant in explaining demand for purchased water where a 1% increase results in a 166.7% decrease in its demand for purchased water by both groups of households. Household size significantly explains the demand for collected and purchased water for these two groups of households.

System of consumer demand equations have been mostly applied in the area of food, meat and alcohol demand in developed and transition countries. Very few studies employ this theoretically consistent methodology in water demand studies. A notable one is by Pashardes *et al.* (2001) who applied the Quadratic Almost Ideal Demand System (QAIDS) model to estimate residential water demand in Cyprus and to derive welfare implications for changes in the water pricing system. Their results point to water as a necessity with an average income elasticity of 0.32, ranging from 0.25 (lowest income group) to 0.48 (highest income group), indicating that water is more of a necessity to poorer households. Plausible reasons advanced for this unexpected result is the complementary role of water to large houses having swimming pools, large lawn gardens, and other luxury goods such as washing machines purchased by rich households. Another reason is that affluent households use more water and thus pay more under the prevailing increasing block tariff system. They also observe that poorer households are more responsive or sensitive to water price changes (elasticity of -0.79) than wealthier households (elasticity of -0.39). Based on this evidence of decline in water price responsiveness from poor to rich households, the authors suggest the inappropriateness of using price as a water management tool.

Most studies conducted especially in developing countries model water as a homogenous good. Mu *et al.* (1990) acknowledges the heterogeneous nature of water in less developed countries, perhaps due to quality differences, the need to treat water and distances travelled to access this resource. Water demand modelling in this study deviates from the normal practise by considering water as a heterogeneous good with the intention of giving more insight into demand behaviour regarding these goods.

3 DATA COLLECTION METHODS AND SURVEY DESCRIPTION

3.1 Introduction

The nature and scope of the GLOWA-Volta project with respect to the socio-economic component makes the use of a household survey inevitable. This is to aid in the realisation of the broad objectives of four interrelated subprojects within the socio-economic component, namely, building a bio-economic household model, water allocation model and a population and migration model for households in the basin. The fourth objective, which examines the influence of socio-economic and demographic factors on household water demand, is addressed by this study. This begins with a randomly representative sample of households in the basin, implying that cross-sections of households have to be selected and questionnaire-based interviews conducted to generate the required household socio-economic information. To ensure that survey sites selected reflects the interests of each researcher as well as other scientists on the project poses a challenge, but in this way project costs may be substantially minimised. Therefore, striving for the development of some sort of common sampling frame to more or less satisfy each researcher seems to be a laudable approach to pursue.

This chapter comprehensively explains the approaches adopted in building a suitable common sampling frame for some of the subprojects within the GLOWA-Volta project. The multivariate sampling procedures employed in building the common sampling frame that served as observation units for the GLOWA-Volta household survey is described in Section 3.2. The strengths and drawbacks of this kind of sampling frame are also briefly mentioned. Section 3.3 describes both the socio-economic and household water quality surveys conducted separately in 2001 for purposes of soliciting relevant primary data. In order to render the data set fully usable for empirical analysis, some data processing procedures performed on some of the variables are explained in section 3.4 to conclude the chapter.

3.2 GLOWA-Volta common sampling frame

The motive for developing a common sampling frame is to select communities or villages in the basin for enumeration. The GLOWA-Volta household survey benefited immensely from the Ghana Living Standards Survey 4 (GLSS4), a nationwide survey conducted by the Ghana Statistical Service (GSS) in 1998/99 and with assistance from the World Bank. As such, this nationwide survey was used as the foundation for developing the common sampling frame for the GLOWA household survey. The appropriateness of the GLOWA-Volta sampling

frame is very much dependent on the statistical soundness of the methods employed by the Ghana Statistical Service in selecting their observation units for the GLSS4 survey, a rich source of primary data on several aspects of household socio-economic information and community level characteristics. The description of their selection procedure is briefly outlined below.

3.2.1 Ghana Living Standards Survey sampling criteria

The purpose of the GLSS4 survey was to (1) provide information on patterns of household consumption and expenditure disaggregated at greater levels, (2) serve as a database for national and regional planning in combination with the data from the earlier rounds, (3) provide in-depth information on the structure and composition of the wages and conditions of work of the labour force in the country, and (4) provide benchmark data for compilation of current statistics on average earnings, hours of work and time rates of wages and salaries that will indicate wage/salary differentials between industries, occupations, geographic locations and gender (GSS, 1999).

This survey used the list of 1984 population census enumeration areas[4] that considered population and household information as important factors in the selection criteria as their sampling frame. Their sampling design involved stratification according to the three ecological zones, namely, savannah, forest and coastal zones. Further stratification was done in each zone to categorise it as either rural or urban and this was based on the size of the locality. Then in each stratum, enumeration areas were selected based on systematic sampling with probability proportional-to-size criterion. The proportional-to-size criterion simply implies that the higher the population of each stratum, the more enumeration areas are selected. In other words, the number of enumeration areas selected in each stratum is proportional to the size of that stratum. This first stage of sampling resulted in the selection of 300 enumeration areas. The second stage selected 6,000 households in the 300 enumeration areas. This scientific approach led to the selection of a nationally representative sample that contains data at both the household level (6,000 households) and community levels (223 communities).

[4] The Ghana Statistical Service (GSS) defines an Enumeration Area (EA) as a demarcated geographic area consisting of a locality or group of localities with boundary description which usually can be managed by one enumerator.

The 300 GLSS4 enumeration areas also served as sampling units for the GLOWA-Volta socio-economic survey for the construction of a common sampling frame. The first step was to restrict or confine this data to the level of the Volta basin (henceforth called the Volta basin data). This procedure resulted in the selection of 2,240 households, representing about 37% of the total GLSS4 sampled households. Thus, the Volta basin data comprises 2,240 households.

3.2.2 GLOWA-Volta Survey sampling frame procedures

The household survey of the GLOWA used the GLSS4 and for that matter the 1984 population census enumeration areas as sampling units. Multivariate data reducing techniques (i.e., principal component and cluster analysis) were then applied using the Volta basin data, consisting of 2,240 households in 183 enumeration areas in order to select survey sites or communities that will be representative for the basin. Table 3.1 shows the number of enumeration areas in the administrative regions in the basin.

Table 3.1: Number of enumeration areas in Volta basin regions of Ghana

Region	Number of enumeration areas	Percentage of total (%)
Upper West	6	3.3
Upper East	13	7.1
Northern	18	9.8
Brong Ahafo	27	14.8
Volta	28	15.3
Eastern	38	20.7
Ashanti	53	29.0
Total	**183**	**100.0**

Source: GLOWA-Volta field survey, 2001

3.2.2.1 Principal component analysis (PCA)

The initial step in the development of the common sampling frame was the provision of a list of variables of interest from other subprojects to be utilised in a Principal Component Analysis (PCA). Principal component analysis (PCA) is a standard mathematical procedure that aims at transforming a large set of variables that are possibly correlated into a smaller number of uncorrelated variables called *principal components*. The uncorrelated variables are linear combinations of the original variables. In this way, dimensionality or redundancy in the data set is reduced while at the same time retaining as much information as possible in the newly identified underlying variables. The first principal component is a combination of variables that account for the maximum variability in the data set. The second principal

component accounts for the next highest amount of variation that is not explained by the first component. Subsequent components account for as much of the remaining variability as possible and there can be as many principal components as there are variables.

The variables included in the analysis ranged from household incomes and expenditures, fishing and farming activities (crops and livestock), irrigation practices, water expenditures and accessibility, kinds of employment, community participation, and migration to climatic factors such as temperature, rainfall levels and evapo-transpiration. In all, 22 variables were of major importance, implying that there could be as many as 22 principal components. Table 3.2 gives the variable definitions whilst Table 3.3 presents the univariate descriptive statistics of the variables. It must be pointed out that some of the categorical variables were converted into continuous variables by taking percentages of them.

The statistical programme called SAS was used to perform the Principal Components and Cluster Analyses. The principal component procedure first computes a correlation matrix[5] using all the 22 variables and the 84 observations (or sample size)[6] to construct this new set of variables called eigenvectors, each with its own distinct eigenvalue. The value of each eigenvalue indicates the contribution of the new component to the total variation in the dataset.

Applying the latent root criterion on the number of principal components to be extracted suggests that 8 factors or components should be extracted as their respective eigenvalues are greater than one (Table 3.4). The first principal component accounted for 20% of the total variance whilst the second principal component, being orthogonal to the first principal component, explained 18% of the remaining variation not explained by the first component. The cumulative proportion of variance criterion, which says that the extracted components should together explain at least 50% of the variation, shows that the 8 extracted components cumulatively explained 71.1% of the variation in the data set. Scores are numbers that express the influence of an eigenvector on a specific sample (observation).

[5] Principal components analysis can also be performed on a covariance matrix but the correlation matrix is usually used.
[6] These observations are the enumeration areas (EA's) used in the analysis.

Table 3.2: Principal component variable definitions

Variables	Definition
S1Q4	Migration in and out of community
S2Q12	Major source of community drinking water in dry season
S2Q22	Distance to nearest periodic or daily market
Healthprob	Health problems
Fetcth	Average water fetching time per head per month
S7DQ1GoodBad	Proportion of households with improved water supply
Watexph	Total water expenditures per head per month
Healthexph	Per capita health expenditure
Invcropsl	Per acre household crop investments
Invanish	Per capita household livestock investment costs
Dassetsh	Household durable assets per head
Dsaveh	Per capita household savings
land	Amount of land under share cropping
S11DQ2	Contributions to self-help projects
Shland	Acres of land owned
Incomh	Per capita household income
Expenh	Per capita household expenditure
Activity	Agricultural employment among 5 most important occupation
Modern	Proportion of households with modern fishing inputs
Temp	Annual average temperature
Rain	Annual average rainfall
Petann	Annual potential evapo-transpiration

Source: Data from the GLSS 4 survey 1998/99

Table 3.3: Descriptive statistics of variables used in the Principal Component Analysis (PCA)

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
S1Q4	84	18.5	15.2	0.0	75.0
S2Q12	84	26.4	28.6	0.0	95.0
S2Q22	84	11.4	55.4	0.0	480.0
Healthprob	84	46.1	17.5	25.0	75.0
Fetcth	84	3.56	2.1	0.3	12.9
S7DQ1GoodBad	84	0.4	0.4	0.0	1.0
Watexph	84	79.3	317.8	0.0	2371.3
Healthexph	84	1625.1	1867.1	70.8	13040.0
Invcropsl	84	15450.1	31613.8	0.0	115952.8
Invanish	84	4498.3	18292.7	0.0	152549.7
Dassetsh	84	339891.3	738541.8	13275.6	5420333.3
Dsaveh	84	18675.6	72872.7	0.0	600000.0
land	84	3.2	4.7	0.0	26.4
S11DQ2	84	4396.1	7707.4	0.0	54900.0
Shland	84	0.2	0.9	0.0	7.0
Incomh	84	416193.3	292178.7	70861.5	1453540.1
Expenh	84	753422.8	427463.1	207564.5	2667677.8
Activity	84	0.8	0.2	0.1	1.0
Modern	84	0.3	0.4	0.0	1.0
Temp	84	26.9	1.2	25.0	28.5
Rain	84	1165.3	207.3	800.0	1550.0
Petann	84	1672.7	196.1	1425.0	2025.0

Source: Data from the GLSS 4 survey 1998/99

Table 3.4: Reported eigenvalues (correlations) from data set

Component	Eigenvalues		
	Total	Percentage of variance (%)	Cumulative percentage (%)
1	4.381317	0.1992	0.1992
2	2.575963	0.1171	0.3162
3	2.164285	0.0984	0.4146
4	1.622959	0.0738	0.4884
5	1.381617	0.0628	0.5512
6	1.268371	0.0577	0.6088
7	1.181148	0.0537	0.6625
8	1.063256	0.0483	0.7109
9	0.964213	0.0438	0.7547
10	0.874630	0.0398	0.7944
11	0.801693	0.0364	0.8309
12	0.729827	0.0332	0.8641
13	0.590432	0.0268	0.8909
14	0.565842	0.0257	0.9166
15	0.478495	0.0217	0.9384
16	0.383786	0.0174	0.9558
17	0.324262	0.0147	0.9705
18	0.196703	0.0089	0.9795
19	0.152539	0.0069	0.9864
20	0.134859	0.0061	0.99 26
21	0.096055	0.0044	0.9969
22	0.067748	0.0031	1.0000

Source: Calculated from GLSS 4 data set.

The next stage involves examining the presence of any complex structure among the variables. A complex structure is said to be present when a variable has a factor or component loading (or correlation) greater than 0.40 on more than one component. Loadings express the influence of each original variable within the component. A minimum factor loading of 60% on a principal component is recommended. Table 3.5 shows the factor loadings of each variable on the principal component. Three of the 22 variables (i.e., healthprob, fetchth and activity) appear to have a complex structure. However, these variables were maintained because they did not "overload" on several components: they loaded on only two components, hence not considered a serious problem in this case. Moreover, the loadings seem not to be significantly different from 0.40 and as such were not categorised as having a strictly complex structure.

After checking for complex structure in the variables, the factor loadings are again examined, but this time to check for components that have only one variable loading on them. A check on Table 3.5 shows that all 8 components had more than one variable loading on them, thus resulting in the keeping of all the 8 components. This formally concluded the principal component analysis.

What remains is the interpretation of the 8 principal components extracted. It is instructive to note that the original 22 variables have been summarised into 8 new uncorrelated variables that explain 71.1% of the total variance in the variables included on the components. This often is the challenge posed by this analysis as the combinations of variables that load high on a component are difficult to interpret. For example, the first principal component (PC1) in Table 3.5 reported high factor loadings for the climatic variables, i.e., 93% for annual rainfall, 88% for annual temperature and 86% for annual potential evapo-transpiration. This component is easy to interpret as a climatic variable. On the second component for example, per capita household expenditure loaded 73%, followed by household per capita health expenditures (70%). Although household durable assets per capita loaded 64% and that of total water expenditure per capita per month was 60%, this component may be interpreted as the household expenditure variable. With some level of difficulty, the following interpretations can be attached to the other 6 new variables or components: third component (livestock investments costs per capita), forth component (source of drinking water), fifth component (crop investments costs per capita), sixth component (amount of owned land under share cropping), seventh component (per capita household savings), and the eighth component (distance to nearest market). These new variables will now serve as original variables for Cluster Analysis, the next analysis to be performed in pursuit of a common sampling frame.

3.2.2.2 Cluster Analysis (CA)

As all the 183 enumeration areas in the basin could not be surveyed, there was the need to reduce this number by grouping them into homogenous groups based on some characteristics common among them. This requires the application of a technique to classify enumeration areas with similar characteristics into a cluster. Cluster analysis, a multivariate analysis technique or an exploratory data analysis tool was used to solve such classification problems. It aims at sorting items or cases into groups or clusters such that the degree of association between members of the same cluster is strong whilst the degree of association between members of different clusters is weak. In other words, this method organises information about variables so that relatively homogenous groups called "clusters" can be formed, implying that members in each cluster are similar to one another on some specific characteristic whilst other clusters external to it are highly heterogeneous with dissimilar characteristics.

Table 3.5: Factor loadings of variables on Principal Components

Rotation Correlations (Structure)

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
S1Q4	-0.049460	-0.324773	0.038554	0.005583	-0.060703	0.112274	0.537923	-0.386080
S2Q12	-0.122109	-0.034842	0.170056	**0.887700**	0.074374	0.075241	-0.027683	-0.004965
S2Q22	-0.007310	-0.108774	0.038373	0.001512	-0.016689	-0.085104	-0.068583	**0.865398**
healthprob	*0.123464*	*0.099474*	*0.210768*	*-0.177408*	*-0.426611*	*0.082608*	*0.500422*	*0.055133*
fetchth	*-0.187907*	*0.188530*	*-0.138781*	*-0.456784*	*-0.088060*	*0.284124*	*0.157330*	*0.477022*
S7DQ1GoodBad	-0.046153	-0.028071	-0.003326	**0.746095**	-0.311054	0.131607	0.019036	-0.021030
watexph	-0.068716	**0.600685**	0.362385	0.287647	-0.196552	-0.049964	0.054886	-0.009283
healthexph	-0.226424	**0.702566**	-0.082971	-0.161953	-0.130595	0.054725	-0.080780	-0.161086
invcropsl	-0.161601	0.051566	0.074260	-0.069214	**0.773359**	-0.133134	-0.166011	-0.170787
invanish	0.057371	-0.017238	**0.929565**	0.136619	-0.043277	0.018614	0.077850	0.027548
dassetsh	0.111279	**0.646274**	0.060958	-0.068091	0.315440	0.229910	-0.124846	0.020832
dsaveh	0.153273	-0.010101	-0.017434	0.077889	0.028627	-0.090252	**0.600042**	-0.019107
land	-0.117165	0.016249	0.198922	-0.045503	-0.078689	**0.852413**	-0.125101	-0.072599
S11DQ2	-0.123223	0.214512	**0.888034**	0.036784	0.050586	0.078371	-0.030529	-0.032934
shland	-0.128870	0.182758	-0.109867	0.252896	0.065750	**0.709660**	0.155462	0.012222
incomh	-0.129666	0.338075	-0.014764	-0.222888	0.373481	0.103374	0.538381	0.150933
expenh	-0.329011	**0.733998**	0.185988	-0.111714	0.242454	0.111862	0.260760	0.140880
activity	*0.517104*	*-0.409648*	*-0.276475*	*-0.257073*	*-0.035850*	*0.213871*	*-0.115873*	*-0.040284*
modern	-0.140692	0.050766	-0.044988	-0.109939	**0.693300**	0.111473	0.232054	0.129162
Temp	**0.877816**	-0.101566	0.002915	-0.041399	-0.182031	-0.255455	0.112234	0.036970
Rain	**-0.928796**	-0.042020	-0.064339	0.005910	0.024207	0.010869	-0.046545	0.019467
Petann	**0.858375**	-0.282171	-0.103893	-0.059193	-0.191845	-0.127173	0.096214	-0.064775

Note: Variables in italics are those that appear to have a complex structure
Factor loadings in bold indicate loadings more than 60% on a principal component

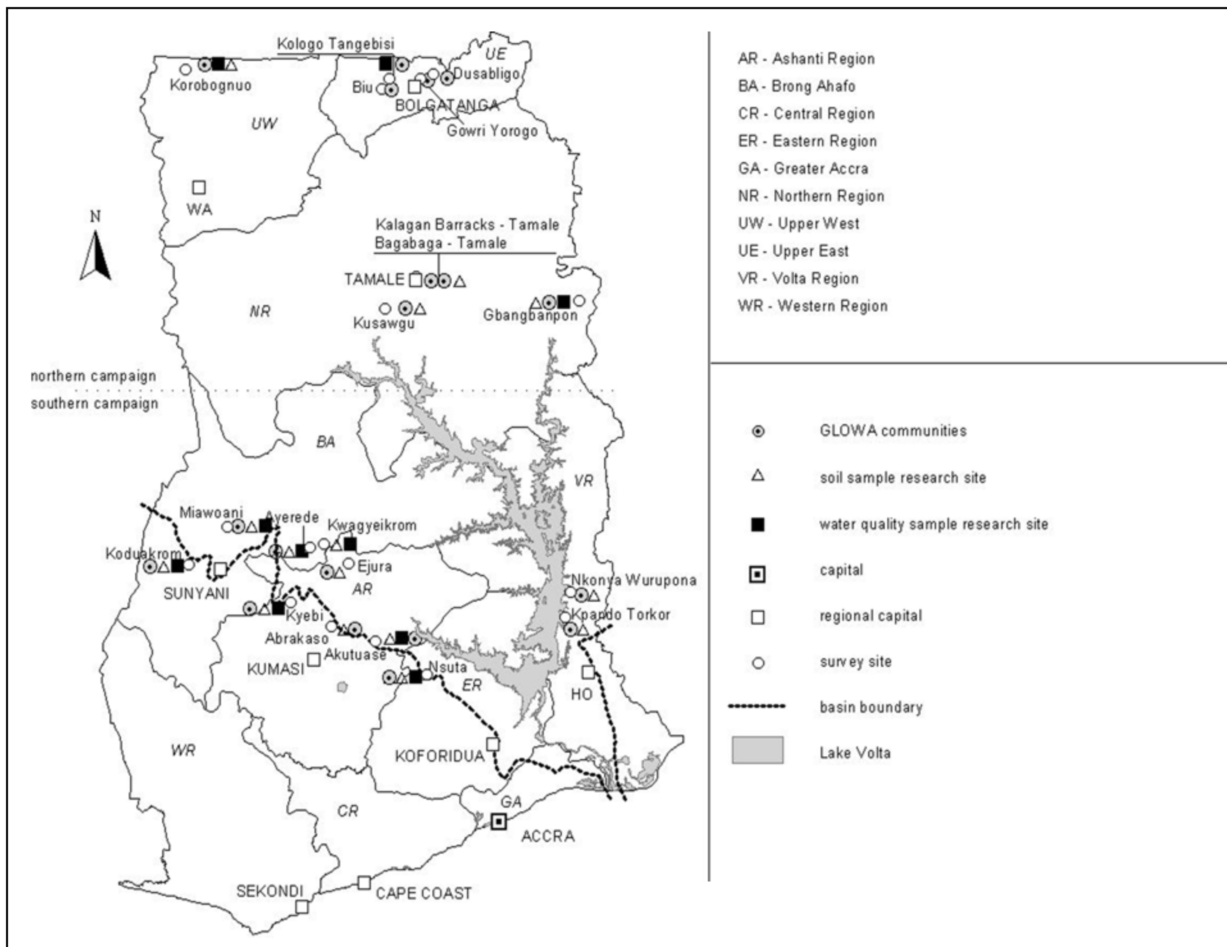
Clustering of the enumeration areas was the last stage to the selection of survey sites that will reflect the interests of each subproject. The eight retained principal components now serve as clustering variables for the analysis. That is, the 183 enumeration areas in the basin were clustered based on the 8 components. The FASTCLUS command in SAS employed the centroid hierarchical clustering procedure. Being circumspect of project resources, time and logistics ten clusters were deemed adequate for the entire basin. For each of the ten clusters, the enumeration areas closest to each clusters centroid were selected, leading to the selection of 10 enumeration areas. However, 6 additional survey sites had to be purposefully added to ensure an overlap of subgroup interests in the project because (1) these sites were either considered GLOWA-Volta "hot spots" due to special research interests in these areas and were not originally part of the GLSS4 sampling frame and (2) the sites were of special interest to other subgroups but were not selected by the clustering technique. With the decision by the project to survey 20 communities, four additional enumeration areas were selected based on its proximity to the centroid. Coincidentally, each of the 7 administrative regions in the basin was represented by at least one of the selected enumeration areas. Figure 3.1 shows the communities selected for the socio-economic and water quality surveys. Soil sampling was also carried out in some of the selected communities.

3.2.3 Common sampling frame- advantages and disadvantages

An advantage afforded by the common sampling frame lies in the fact that the selection of survey sites common to all may considerably reduce project cost. In the case of the GLOWA-Volta household survey, transportation and accommodation costs of researchers and enumerators were reduced because the field survey was conducted simultaneously. The need for the researchers to undertake their separate enumeration in the same communities was avoided. Thus, interdisciplinary team work by researchers is enhanced. In addition, the per capita cost of training enumerators or field assistants was reduced by avoiding multiple training sessions. Another merit of this common sampling frame approach for the GLOWA-Volta project lies in the fact that research findings at different survey sites in the basin can be extrapolated for the whole basin using appropriate weighting factors because of the underlying statistical procedure employed in selecting randomly representative samples. In this case, conclusions can be made at the basin level and with some assumptions at the national level as well. This will then feed into policy making. This procedure outweighs purposefully selected samples, the results of which may qualify as case studies.

Agreeing on the selected survey sites, which is the outcome of the common sampling frame came at a cost. First, much time was invested at the beginning stages of discussion on the selection of appropriate variables of interest used in the multivariate data reducing analyses. Second, as the common sampling frame procedure was more or less a new idea at least for the project members, questions and uncertainties were voiced out regarding the desired benefits of this approach meeting their expectations. These concerns may lead to another potential demerit where other research groups may be unwilling to contribute to this procedure because of the likelihood of this random selection missing their sites of interest. This was particularly exemplified in the institutional subgroup which looks for specific issues to study.

Figure 3.1: Map showing communities selected for the household, water quality and soil sampling surveys in the Volta basin of Ghana



Source: GLOWA-Volta project, 2001

3.3 Household survey description

Two separate surveys were conducted in the 20 selected survey communities. The first was a socio-economic household survey conducted between the periods of May and September 2001. This solicited information on several issues of interest to the interdisciplinary research team as discussed earlier. The second was a household water quality survey conducted between March and July 2002 in 10 of the 20 selected communities in the basin.

3.3.1 Survey coverage

The household survey covered 7 of the 10 administrative regions of Ghana that cuts across 16 of the 110 districts. The regions excluded were, namely, Greater Accra, Central and Western region. The common sampling frame adopted resulted in the selection of 20 communities spanning 2 ecological zones (Table 3.6). Five hundred and one (501) households were interviewed: 196 located in the forest zone spanning 8 communities and 305 households in 12 communities in the savannah zone. The reason behind selecting more households in the forest zone was due to the probability proportional-to-size principle inherent in our GLSS4 sampling frame used for the survey. The number of households per community ranged between 23 and 27.

Table 3.6: Surveyed communities in the Ghanaian Volta basin

Region	District	Ecological zone 1=Forest 2= Savannah	Community/village	Number of respondents
Ashanti	Afigya Sekyere	1	Abrakaso	26
	Asante Akim North	1	Akutuasi	25
	Ejura	1	Ejura	24
	Offinso	1	Kyebi	24
Brong Ahafo	Nkoranza	2	Ayerede	24
	Nkoranza	2	Kwagyeikrom/Bredi	24
	Sunyani	1	Koduakrom	24
	Wenchi	2	Miawoani	25
Eastern	Kwahu South	1	Nsuta	26
Northern	Cheriponi/Saboba	2	Gbangbanpon	26
	Tamale	2	Bagabaga	24
	Tamale	2	Kaladan Barracks	24
	West Gonja	2	Kusawgu	24
Upper East	Bolgatanga	2	Dusabligo	27
	Bolgatanga	2	Gowrie	27
	Kassena Nankana	2	Kologo Tangabisi	27
	Kassena Nankana	2	Biu	26
Upper West	Jirapa/Lambussie	2	Korobognuo	27
Volta	Jasikan	1	Nkonya Wurupong	24
	Kpando-Torkor	1	Kpando Torkor	23

Source: GLOWA field survey, 2001

3.3.2 Household data collection method

The socio-economic household survey utilised questionnaire-based interviews to solicit information. The strategy was to conduct the survey in two rounds. The first round covered regions in the southern part of the basin (mainly in the forest zone) whilst the second round concentrated in the northern savannah regions.

This approach was necessary for two reasons. The manner in which the selected survey communities were dotted across the basin obviously required a split for convenience. Second, due to the wide ethnic diversity across the basin, the medium of communication became very important. In order to clearly understand questions posed, respondents in these rural communities would be more comfortable in responding to questions in their local languages. Conducting these interviews in the English language was not likely to yield desired results due to the level of illiteracy. For this reason, two groups of enumerators, one for the southern campaign and the other for the northern campaign, who hail from these localities or speak these languages were selected and trained for this purpose. The designed questionnaires were then pre-tested using the two groups of enumerators. Problematic and ambiguous questions were rephrased and the time concerns of respondents were noted. A final version of the questionnaire prepared served as the survey instrument to solicit information.

In the absence of a household list in the 20 selected survey communities, each community was divided into blocks as deemed fit. In each block, houses were selected by a systematic random sample. As the target was to have approximately 500 households or respondents, at least 24 households in each community were selected and the household head interviewed. In the absence of the head, the spouse was interviewed. However, depending on the type of question posed, the appropriate member of the family responded to that question. For example, the question on the quantity of water used daily for various household chores was answered by the spouse (assumed to be a woman) and not the male household head because she is mainly involved with water collection.

In situations where the selected house had more than one single household, the household head willing to be interviewed was selected. In cases where all household heads were willing to be interviewed, one is simply picked at random. In the event where there were no members to be interviewed in a selected household because of their busy schedules or were unqualified (they lacked the knowledge on these questions), the next household was then picked. A

household is defined in this study as a group of people who live together in the same dwelling and share meals together for at least six months prior to the time of the interview.

3.3.3 Water quality data collection method

The selection of communities for the water quality survey followed a similar pattern as described for the socio-economic survey in terms of the selection of households in the communities. Ten of the 20 surveyed communities were selected randomly for this purpose (See Figure 3.1). The number of communities had to be reduced because of time and especially financial constraint involved in acquiring bacteriological water quality testing kits. This survey aimed at investigating the quality of water consumed by households and also to examine water quality differences at the source. The existence of water quality differences between the source and home signals possible contamination at home. Water quality differences were also investigated between rainy and dry seasons, requiring two rounds of surveys.

Water quality considered only the bacteriological quality and not the chemical quality. Total counts of *Escherichia Coli* (*E. coli*) and faecal *streptococcus* in water are normally used as water quality indicators. A technician from the Water Resources Institute (WRI), one of the projects collaborating partner institutions, was part of the survey team to handle this aspect. Water samples were taken from the most commonly used sources in each community. This is mainly because financial and time costs did not permit us to take samples from all sources used. The water collected was then tested for the presence of *E. coli* and the number of bacteria present in 100ml of water was recorded. At the household level, water samples were taken from water storage facilities that households usually drink from. This ranged mainly from barrels in the forest zone to clay pots in the savannah zone. Drinking water was targeted because of the importance of drinking water security.

3.4 Data processing procedures prior to estimation

Primary data collected first requires that the data be cleaned or processed to render it usable for empirical analysis. Accordingly, missing data and possible outliers would have to be dealt with. This section describes how some economic variables were processed.

3.4.1 Water quantities

The study revealed that Volta basin households use multiple sources of water for various household chores. Both improved and unimproved water sources were identified. Information was solicited on the quantities of water consumed from each of these sources on a weekly basis. In addition to this, a distinction was made between quantities consumed in a typical week in the dry and rainy seasons. It must be emphasised that all quantities of water consumed by households in this study are based on households' recall of quantities consumed in a week. In other words, such quantities indicated could be considered as estimates, suggesting that these amounts could be overstated or understated and therefore subject to errors. Nevertheless, care was taken by probing further when an unrealistic quantity of water was reported by households. Moreover, women and children who are the main water carriers were the ones asked to divulge this information.

The computation of quantities of water consumed annually was derived by multiplying the weekly amounts by 52. This approach makes the implicit assumption that households' utilise, on the average, equal quantities of water on weekly basis. Given the yearly water consumption by season, the average annual water consumption on per household basis was generated by taken the yearly average of water consumed in the dry and rainy season. No missing data on water consumption was reported.

3.4.2 Water prices

The price of water used in this study is not the actual amount of money paid for consuming a unit of water from any source. Instead, water prices are imputed prices based on the opportunity costs of time spent in water collection by women and children. Some reasons advanced for preferring the opportunity costs approach is that majority of rural households use unimproved water sources and no actual price per unit is associated with its consumption. Because of long distances commuted in sourcing water, time devoted to this activity is quite enormous and must be accounted for because that time could potentially be devoted to income generating activities. Second, although some improved water sources like boreholes attracted flat rates on a per unit, monthly or yearly basis, such water tariffs as gleaned from the study appear to have little or no variation in data. Using such water price data in empirical analysis may not separate or reflect the actual influence of price on water consumption (Elsner, 2001). Moreover, not all households utilise improved water sources in communities where both sources exit therefore employing data of this nature implies a reduction in sample

size (which may be costly) and the possibility of a sample selection bias may result. Appropriate value is placed on household time spent on water fetching. Based on the average quantities of water consumed daily per household, opportunity costs per litre of water consumed are computed. Estimating opportunity costs using different approaches of valuing household time is detailed in chapter 4.3.2.

A distinction is made between water used for drinking and cooking and water used for other indoor purposes such as bathing and washing. They are viewed as two different goods because of different water storage and treatment practices that household's exhibit. In the first place, water used for drinking and cooking is stored separately from water used for other purposes. Second, water meant for drinking and cooking are treated or purified to render it more hygienic for human consumption. This means adding value to this good, thus placing it in a different category. This distinction is necessary for purposes of achieving one of the studies objectives of modelling household water demand. Subsequently, two sets of prices are also estimated for these goods.

The following assumptions were made in calculating the prices for these two goods. Two treatment methods were identified: water filtering and boiling. It was assumed that households devote 15 minutes in boiling a litre of water whilst 5 minutes is spent filtering water. These assumptions factored in time needed to assemble the necessary items or materials before the proper treatment procedure begins (e.g. including fetching of firewood or preparing a piece of cloth for filtering). An appropriate value is then placed on time allocated to these activities to generate the daily opportunity costs (refer to similar procedures in chapter 4). The cost of filtering and boiling a litre of water were then calculated separately by dividing the daily opportunity cost of undertaking these activities by the daily average amount of water used for drinking and cooking. These two costs are then summed up on a per household basis to derive the cost of water treatment per litre. This treatment cost represents opportunity costs. Households also spend money to treat water, for example, purchasing chemicals such as chlorine to purify water. This money expenditure on water treatment per litre is added to the opportunity cost per litre to derive the total water treatment cost per litre per household.

The final step in obtaining the price of water used for drinking and cooking is to add the total cost of water treatment per litre component to the already computed per litre price of water.

Water meant for other indoor purposes, comprising dish washing, bathing and hygiene, laundry and housecleaning does not include the water treatment cost component. Thus, the important difference worth noting between the two sets of prices is that the price per litre of water assigned for drinking and cooking is the same as that of water used for other purposes, the only difference being that the former accounts for actual expenditures and opportunity costs of water treatment. These imputed costs of water serve as proxies for water price and are used as explanatory variables in explaining household water allocation expenditures. The price of improved water later to be used in a Heckman two-stage model is also derived using the opportunity cost of time approach. It is the quantity of improved water consumed per unit that is considered for the analysis.

3.4.3 Water expenditures and budget shares

The imputed water prices for the two goods multiplied by the respective quantities consumed gives the expenditure on that good. A summation of the two expenditures equals total household water expenditures. Therefore, the share of water used for drinking and cooking (or budget share) in total household water expenditure is the expenditure on this good divided by the total household water expenditure. The budget shares are used as endogenous variables in the total water demand model.

3.4.4 Replacement of missing data

Missing data is usually a problem in time series and especially cross-sectional data. The imputed prices for water had missing data as well. When no technique is employed to generate acceptable values to replace missing data, they may lead to significant reductions in sample size. In some cases, replacements can be generated whilst in other cases this might not be possible. In such circumstances, the only solution may be to discard the missing data and to perform the analysis on the remaining observations.

One common practice is to replace missing data with the mean of the variable in question, disregarding the standard deviation (or variance) of that variable. If the variance is quite large, its usage may be inappropriate and perhaps the sample median may be the best choice. In replacing missing data for opportunity costs of time (not all households had woman wage income, see also Chapter 4.3.2) this study did not use the overall mean or median. Since households in each community are likely to have similar characteristics, for example, distance to the most important water source, it is more appropriate to utilise the mean or

median water prices of communities for this procedure. After finding the variable mean as satisfactory, the means were computed per community and then used as replacements for missing values.

4 HOUSEHOLD WATER SECURITY IN THE VOLTA BASIN

Macro-level data indicate that Ghana is abundant in water resources. However, periodic water scarcities especially in the dry seasons have eventually become a perennial problem. This suggests the need for disaggregated analysis that may reveal seasonal and spatial variations in water availability in the Volta basin. One of the problems identified is inadequate water accessibility particularly by rural households. This is partly due to insufficient water supply points at the community level and the high connection costs involved in channelling piped water into homes. Considerable distances commuted to secure water attests to difficult water accessibility and thus a hindrance to household water security. For example, a national water supply and sanitation survey conducted in 1993 showed that only 46% of the rural population had access to potable water while the urban population had 76% coverage (Ministry of Works and Housing, 1998). Many households therefore depend on multiple water sources, including rainwater for multiple uses. Because in rural areas most of the water used comes from unimproved or traditional sources, their level of quality is questionable. Households cope with these prevailing conditions by undertaking water storage measures, which have time and financial implications.

This chapter basically gives insights into prevailing household water security conditions in the Ghanaian Volta basin. Socio-economic characteristics of respondents and households are described, followed by a description of prevailing water insecurity conditions at the household level with regards to water consumption, accessibility, quality, usage patterns and costs of coping. Finally the price of water, a major determinant of water demand, is estimated using different approaches.

4.1 Household socio-economic characteristics

4.1.1 Household composition and major characteristics

The household survey comprises 4805 persons living in 501 households. The proportion of males to females is about equal indicating a gender balance in the sampled population (Table 4.1). More than 50% of the population is related to the household head as biological or adopted children, suggesting that more members stay with their parents or guardians. The age structure follows a normal distribution (see Table A4.1 in Appendix 4) with the economically

active population (age 18 to 59 years) being the dominant group representing 50% of the population. A sizeable number (32%) fall within the adolescence age group (age 5 to 17).

The level of educational attainment in the Volta basin is low. About 44% are illiterates without formal or informal education. Approximately 31% have secondary education whilst less than 2% have tertiary education (see Appendix 4 Tables A4.2 and A4.3 for the socio-economic characteristics by ecological zone and at the community level). It is instructive to note that the data further show a slight bias against female education for two reasons. First, sizeable proportions (57%) of those without any form of education are females. Second, a further examination of those currently schooling indicates that 56% are males and 44% are females. Hence more attention through appropriate policies should be focused on female child education. Christianity represents the dominant religion (63%) and this is quite close to the 68.8% reported for the year 2000 national population census (Republic of Ghana, 2000). Adherents to non traditional religion constitute 16% and Islam 15%. Majority of sampled households are Akans constituting 38% (see Figure A4.1 the ethnic group composition of sampled households).

4.1.2 Demographic characteristics

The average age of a household head is 51 years and about 70% of them fall in the economically active population (ages 18-59). Majority of household heads (52%) have no formal education. This declines to 45% when household heads and their spouses are considered. Household heads on the average have 5 years of formal education. Male-headed households constitute 80%. The average net household size is 8.5 persons per household (Table 4.2), thus excluding members who reside outside the household for more than 6 months. On the average, there are more adults than children.

4.1.3 Household income sources and employment

Without information on specific occupations of household heads, their income sources may suggest whether they are employed in the agricultural or non-agricultural sectors. Table 4.3 reports mean annual incomes from agricultural and non-agricultural sources for sampled households who reported positive incomes. The computation includes imputed food and animal products since home produced goods, when sold, would generate additional income for households (see Table A4.4 in Appendix 4 for annual incomes that excludes imputed income).

Table 4.1: Household socio-economic characteristics

Variable	Percentage (%)
No. of persons	4805
Sex (%)	
Female	49.44
Male	50.56
Relation to household head (%)	
Wife/husband	12.03
Child/adopted child	50.75
Grandchild	9.23
Father/mother	2.34
Sister/brother	5.75
Other	9.18
Age composition (%)	
Age(less than 4 years)	9.83
Age (from 5-17 years)	31.84
Age (from 18-59 years)	49.75
Age (+ 60 years)	8.58
Marital status (%)	
Married	37.35
Divorced	1.43
Separated	1.04
Widow/widower	3.56
Single	56.61
Education (%)	
No schooling	43.95
Elementary	17.89
Secondary school	12.58
Vocational	0.98
Tertiary	1.45
Still in school	20.20
Other	2.95
Religion (%)	
Christians	63.12
Islamic	14.58
Traditional	16.47
No religion	2.48
Other	3.35

Source: GLOWA field survey, 2001

Table 4.2: Household demographic characteristics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Total household size	500	9.48	4.49	1	37
Net household size	500	8.48	4.41	1	23
No. of females	501	4.79	2.85	0	25
No. of males	501	4.70	2.64	0	15
Babies (<6 years)	501	1.21	1.37	0	8
Children (6 - 17 years)	501	2.79	1.97	0	10
Adults (>= 18 years)	501	5.42	3.21	1	21
No. of rooms in dwelling	486	5.23	4.09	1	35
Household head					
Sex	500	1.80	0.40	1	2
Age	500	50.80	15.09	16	105
Formal education (years)	495	5.13	5.39	0	15

Source: GLOWA field survey, 2001

Agricultural activities contribute 77% to household income with an annual mean income of ¢8.5 million whilst the remaining 23% comes from non-agricultural sources, indicating the importance of agriculture in the rural economy. Crop production and livestock sub-sectors contribute 95% and 5% respectively towards agricultural income. This high dependency of households on agriculture should not be misconstrued to imply profitability in this sector because any form of agriculture dependent on the vagaries of the weather is likely to be unprofitable. Agriculture in rural Ghana is mainly rain-fed with virtually no serious irrigation practices to balance crop-water availability. The dependency of majority of the rural population on agriculture for their livelihoods suggests the lack of opportunities in the non-agricultural sectors and the absence of an enabling environment necessary for agricultural and rural development. Such situations may compel some members or heads of households to out-migrate to other communities with the hope of better agricultural prospects.

In the context of the subsequent analysis related to water pricing, it would be interesting to know the contribution of women to agricultural and non-agricultural income. This distinction is necessary to shed more light on income disparities between males and females. It is documented that gender wage differentials exist due to biases against women in accessing credit for agricultural activities, land and technology (Larson and Frisvold, 1996; Prah, 1997). Unfortunately, such a breakdown is not available for agricultural activities. What is readily available is the contribution of women towards non-agricultural income and this represents roughly 24%. This observation suggests that men are the main contributors to household income, giving an indication of fewer income generating opportunities for women (i.e., less opportunity costs). It may also imply that women allocate more of their time undertaken other important household activities that generate no monetary value and may explain why, apart from their traditional roles of house keeping and child-raising, women are mainly involved in water collection. This in no way suggests that women do not undertake any form of agricultural activities. The absence of data prevents us from making a case on their agricultural income contribution.

Sources of non-agricultural income include off-farm income, remittances and assistance from friends and relations, actual and imputed rent and non-farm self employment income (Figure 4.1). Self employment income comprises activities such as the sale of firewood, poles charcoal, handicrafts, dairy products, sheabutter, and petty trading. Undisclosed sources of non-agricultural income are as high as 84%. This is followed by off-farm income (7%) and

self employment (6%). Remittances and rental income together contribute no more than 3%. The high contribution of other non-agricultural income sources towards rural livelihoods may imply that either households are unwilling to declare all their non-agricultural income sources or the survey was deficient in data collection in this regard.

Table 4.3: Mean annual household income by sector (in ¢ millions)

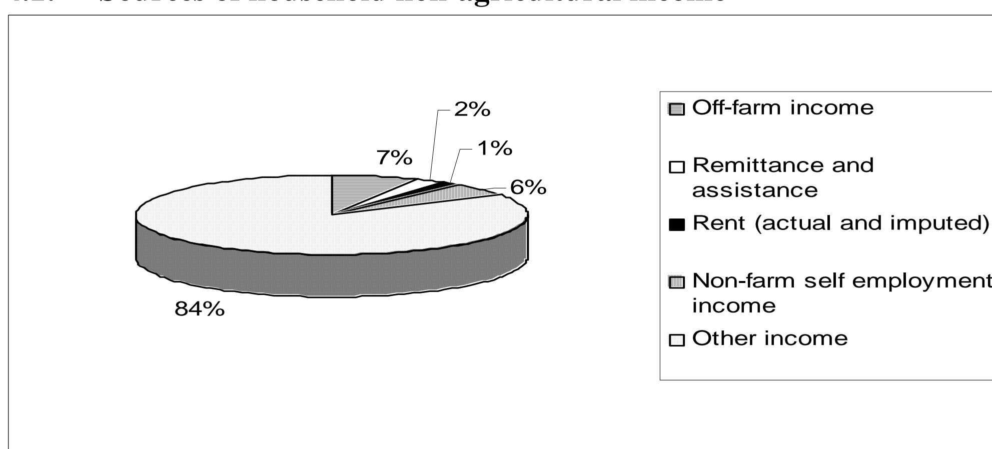
Source of income	Observations	Mean	Standard Deviation	Minimum	Maximum
Agricultural	488	8.5	12.9	0.0009	119.0
Crops	485	8.0	12.8	0.0009	119.0
Livestock	298	0.7	1.1	0.0060	8.0
Non-agricultural	410	2.9	7.4	0.002	112.0
Non-agricultural (women)	262	1.1	1.9	0.004	19.0
Total income	497	10.8	14.3	0.053	123.0

Source: GLOWA field survey, 2001

Note: Non-agricultural income of women excludes remittances, assistance, pensions, gifts and rents from buildings. Total income is the sum of agricultural and non-agricultural income. Their mean values may not add up to total income indicated in the table because the latter is derived from the sample and not from the table.

The study further examined household income contributions by ecological zone to shed more light on zonal (regional) differences by sector in income contribution. Contrary to *a priori* beliefs, savannah zone households contribute about ¢12 million annually (59%) whilst 41% comes from forest zone households (Table 4.4). In terms of agricultural incomes, households in the savannah zone again dominate by contributing an average of ¢10.3 million annually (66%), of which crops and livestock production constitute 66% and 34% respectively.

Figure 4.1: Sources of household non-agricultural income



Source: GLOWA field survey, 2001

Table 4.4: Mean annual household income (including imputed food) by agro-ecology (in ¢ millions)

Source of income	Observations	Mean	Standard deviation	Minimum	Maximum
Forest zone					
Non-agricultural	155	3.8	10.3	0.002	112.0
Non-agricultural (women)	98	1.7	2.6	0.020	19.0
Agricultural	189	5.2	5.8	0.014	45.9
Crops	187	5.0	5.8	0.014	45.9
Livestock	84	0.7	1.3	0.015	6.7
Total income	193	8.5	12.2	0.109	123.0
Savannah zone					
Non-agricultural	255	2.5	4.8	0.011	48.0
Non-agricultural (women)	164	0.8	1.5	0.004	11.6
Agricultural	298	10.3	15.1	0.001	119
Crops	297	9.8	15.1	0.001	119
Livestock	214	0.7	1.0	0.006	8.0
Total income	304	12.2	15.3	0.053	119.0

Source: GLOWA field survey, 2001

The pattern changes in favour of forest zone households when non-agricultural sources of income are considered. It accounts for 60% (¢3.8 million) of annual household income whilst the remaining 40% is contributed by savannah zone households (see Table A4.5 in Appendix 4 for such a breakdown by ecological zone that excludes imputed income sources). These findings suggest that households in the forest zone seem to have more non-agricultural income generating opportunities or that they are more entrepreneurial by running small businesses and enterprises compared to savannah zone households, who major in agricultural activities.

Women's contribution towards non-agricultural income is also greater for forest zone households, contributing two times more than women in the savannah agro-ecology. In general, women's income contribution from non-agricultural sources is low, representing only 5.5% of total annual household income. This could probably be attributed to their commitment to traditional roles of home keeping and child bearing. In particular, women in the savannah zone appear to have fewer opportunities in the informal sector in terms of contributing to household income. A possible implication from these observations is that agricultural activities in the forest zone may dwindle in the medium to long term due to profitability in petty trading and small businesses, which seem less burdensome compared to the perennial problems and risks associated with rain-fed agriculture. High illiteracy rate and fewer opportunities for women in the savannah zone suggest educational and employment inequalities between the forest and savannah zones.

4.1.4 Household poverty status

Heterogeneity of income across households qualifies its use as a socio-economic variable to explain consumption behaviour (Chern *et al.*, 2002). Household income also serves as an indicator of household poverty status despite the fact that poverty is sometimes defined in terms of household expenditure (Förster, 1994). This study uses household income as an indicator of household poverty and adopts the relative approach of measuring poverty[7] which simply compares a households' income to an average value of the population concerned. Thus, this approach considers household income (or poverty) as low or high relative to incomes of the rest of the population.

Two methods are employed to capture this relative concept. First, a low income line is set at a certain bottom percentile of an income distribution where households falling below the specified percentile of equivalent income are regarded as poor. The second method is through the economic distance approach where low income is define as a percentage of median or mean income of the population concerned (OECD, 1994). Fifty percent of the median income is usually chosen as the economic distance below which households or families are considered poor (ibid, 1994).

Due to the possibility of economies of scale, it is expedient to adjust household income with household size in order to place households on an equivalence scale. A scale of 1 is assumed for the first household member, 0.7 for the second person and 0.5 for all other household members[8]. These scales are summed up for each household and then used to adjust for household income. The resulting household income, called adjusted equivalence income, is what is used for poverty comparisons in this section, and henceforth simply referred to as income. The study views low income households as falling in the bottom quintile (20%) of adjusted equivalent income.

In addition to income, other important demographic variables such as age composition, household size, and educational level may explain consumption patterns. For example, households with similar income levels but with diverse age structure, gender composition and

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[7] Two other approaches used in literature to measure poverty are the absolute and subjective approaches. For details of these approaches, see Förster (1994)

[8] This is the scale applied to OECD countries. The assumption is that as resources needed per household member increase but less proportionately with increase in household size, it is reasonable to think that such economies of scale would apply in the context of a developing country such as Ghana.

educational levels may have different structure of consumer demand in terms of type, quality and extent of demand. Expenditure pattern may also shed light on household poverty levels as it is expected that poorer households would spend less on goods except for inelastic goods, such as water, where an increase in price increases household expenditure. Table 4.5 shows the pattern of annual household income by income and age groups of household heads. Four age groups are considered. The first group are 24 years and below (young group), followed by ages 25 to 39 years (young adults group), then ages 40 to 59 (adult group) and finally those above 60 years (old group). The young adult and adult groups could be referred to as the economic active population or middle age group.

Table 4.5: Mean annual household income (¢ millions) by income and age groups of household heads

Age group (in years)	Income level					Mean of total
	1 (lowest)	2	3	4	5 (highest)	
<=24	3,181,503	3,085,750	5,332,591	7,713,669	16,251,160	9,768,327
25-39	2,059,899	4,673,976	7,728,205	10,169,584	21,445,467	10,576,700
40-59	2,093,667	4,697,512	7,725,729	12,523,909	32,130,092	10,582,563
60+	2,371,473	5,344,785	8,058,569	9,960,679	30,155,387	10,975,579
Mean of total	2,185,599	4,918,149	7,761,547	11,034,940	27,599,891	10,676,981

Source: GLOWA field survey, 2001

In general, the older the household head the higher the annual household income (last column). This applies to the poorest 60% of the population (first to third income quintiles) and such a pattern is not unexpected. The reason being that older household heads in rural communities generally have less years of education (Table 4.7 below) and may have been engaged in various income generating activities long enough to gain experience to profit from the trade. This may partly explain why old household heads (age 60 and above) are generally wealthier than the young and economically active population. This trend does not hold for the wealthiest 40% of the population, where the economic active population (ages 25 to 59) earn higher annual incomes compared to old household heads. An unexpected finding is where the "young" group of household heads in the lowest income group being the highest annul income earners. A plausible explanation may be that such young household heads have relatively large families or dependants and may have to sustain the family by perhaps working off-farm and on-farm to earn more income. This assertion is confirmed in Table 4.6 below where in general, poorer households have larger families.

Table 4.6: Mean household size by income and age groups of household heads

Age group (in years)	Income level					Mean of total
	1 (lowest)	2	3	4	5 (highest)	
<=24	18.0	8.0	6.0	5.6	4.2	6.2
25-39	9.1	9.4	8.6	6.4	5.2	7.5
40-59	9.9	8.9	9.5	8.4	6.7	8.8
60+	10.6	10.4	9.7	7.0	6.3	8.9
Mean of total	10.1	9.6	9.3	7.4	6.0	8.5

Source: GLOWA field survey, 2001

It is often stated that poorer households have the tendency of having larger families for several reasons, some of which include the need for more family labour to work on family farms and children serving as security for parents during old age. Table 4.6 reveals such a pattern where household size declines with higher income levels (last row), suggesting that wealthier households show the tendency of having smaller families. Another observation is that older household heads seem to generally have larger families (last column). This may be attributed to their wealth (Table 4.5) and may be in the position to support larger families.

Table 4.7: Mean number of years of education of household heads by income and age groups of household heads

Age group (in years)	Income level					Mean of total
	1 (lowest)	2	3	4	5 (highest)	
<=24	10.0	10.0	5.5	6.6	8.3	7.5
25-39	4.9	6.6	6.8	6.7	6.5	6.4
40-59	6.8	5.3	3.9	6.6	6.1	5.7
60+	3.2	1.9	3.9	3.8	3.0	3.1
Mean of total	5.5	4.3	4.5	5.9	5.4	5.1

Source: GLOWA field survey, 2001

The a priori expectation is that younger household heads (middle age group) in general would have more years of formal education compared to older households heads. This is confirmed in Table 4.7 (last column). However, no clear pattern emerges amongst various income groups (last row). On the average, household heads in the highest and lowest income quintiles have equal years of schooling. This may imply that the number of years of formal education by household heads may not significantly determine household wealth creation. In other words, more years of formal education of household heads may not necessarily translate into higher incomes. Factors such as the combination of petty trading with agricultural income generating activities to escape the poverty trap, among others, may explain wealth accumulation by rural households.

Household income level vis-à-vis household expenditures are expected to be positively correlated; it is expected that wealthier households will spend more than poorer ones on consumer goods. For example, diets could be enriched daily with more protein (i.e., meat and eggs) or allocate more budgets to renovating homes and purchasing durable items such as televisions. However, as shown in Table 4.8, annual household expenditures rather fluctuate with no consistent trend across income groups. However, a comparison between the poorest and wealthiest 20% of households indicates that the former spend more, implying a negative relation between income and expenditures.

Table 4.8: Mean annual household expenditure (¢ millions) by income and age groups of household heads

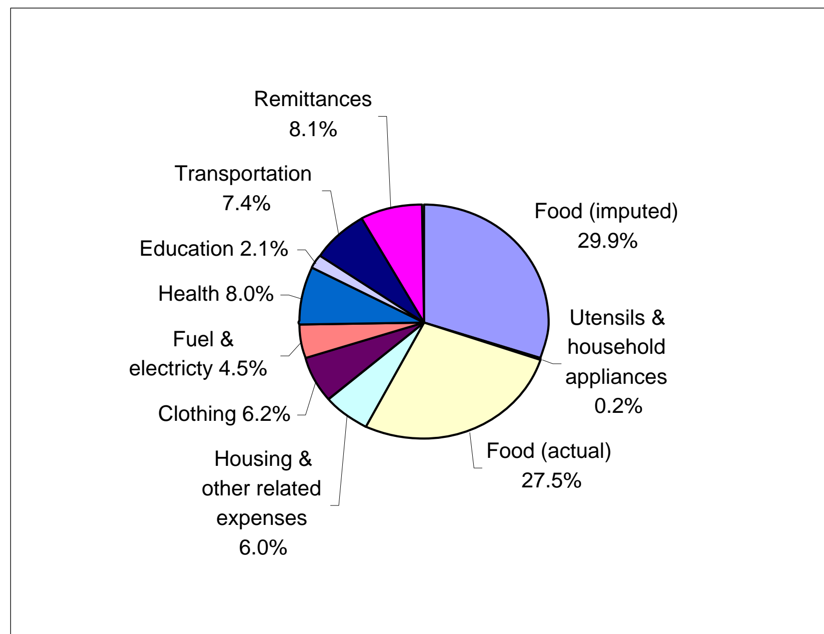
Age group (in years)	Income level					Mean of total
	1 (lowest)	2	3	4	5 (highest)	
<=24	8,855,000	4,692,000	10,996,500	7,702,000	11,804,100	9,505,036
25-39	12,901,320	7,643,967	8,953,053	6,054,804	11,623,759	9,350,473
40-59	7,366,183	7,279,420	7,923,611	6,574,373	6,052,809	7,126,461
60+	9,843,109	7,744,108	8,281,277	8,743,827	6,887,847	8,272,932
Mean of total	8,979,189	7,504,284	8,269,966	7,085,535	8,228,214	8,017,263

Source: GLOWA field survey, 2001

What the various income groups spend on is not exactly known. Information available is the proportion of household annual budget allocation to various expenditure items, as presented in Figure 4.2. With the exception of imputed food, a greater percentage of household income is allocated to food (27%). Health expenditures are quite substantial, taking about 8% of annual household income, suggesting the need for more education and awareness creation on preventive health care in addition to improved public health facilities.

In summary, poorer households generally have larger families. They also spend more on summer goods than wealthier households, implying that income alone may not explain expenditure levels of households. A relevant question worth investigating is how poor households finance their expenditures to smoothing consumption. This question can not be answered by this study although this possibility cannot be ignored especially where the expenditure levels of the poorest 20% of sampled households is comparable to other higher income groups.

Figure 4.2: Annual household expenditure (¢ millions)



Source: GLOWA field survey, 2001

4.1.5 Type of housing and energy sources

The design, size, number of rooms and the materials used for roofing gives an indication of the wealth of households. Table 4.9 indicates that 57% of the sampled population live in single storey compound houses[9] and 61% use iron sheets as roofing material. Iron roofing sheets give an indication of household welfare status. About 39% of households use thatch for roofing. It is the most common roofing material for rural households in Northern Ghana and typical farming communities in southern Ghana. Some households use a combination of these roofing materials.

About 77% of surveyed households are not connected to the national electrification grid with a greater proportion (85%) located in the forest zone compared to 73 % in the savannah zone. Although 95% of the surveyed communities already have in place the infrastructure to tap electricity into the homes, financial constraints prevent them from doing so due to high initial connection charges and subsequent monthly bills. If electrical power supply is limiting, then what energy sources do households patronise?

[9] These are houses with several detached structures that are linked to one another by walls and that are usually inhabited by more than one household.

Table 4.9: **Type of housing and energy source (% of household)**

Variable	Percentage (%)[a]
One storey, single family	40.70
Multi-storey, single family	1.24
Single storey compound	57.44
Multi storey, multi-family	0.62
Household roofing material	
Mud	15.99
Thatch	39.27
Wood	6.88
Iron sheet	61.26
Cement/concrete	1.62
Asbestos	1.01
Electricity connection	
Yes	23
No	77
Household energy source for cooking	
Gas	1.60
Electricity	0.80
Charcoal	27.80
Firewood	82.20
Others	10.20
Source of firewood	
Buy from market	14.71
Cut from bush	81.38
Other	3.91

Source: GLOWA field survey, 2001
[a] Some percentages may not add up to 100 because of multiple uses of items by households.

An obvious alternative would be to seek other energy sources from nearby forests and family farms. As indicated in Table 4.9, approximately 82% of households rely on firewood, 29% on charcoal as fuel wood, with less than a percent using electrical energy. The practice by most households is to combine these energy sources, especially charcoal and firewood. It should therefore not be surprising that 81% of households deforest to get firewood by commuting an average of 5.9 kilometres accessing this energy source (GLOWA-Volta household survey, 2001). Fifteen percent purchase firewood on the open market whilst 4% get them from other sources probably from neighbours.

4.1.6 Migration status

In this study, a migrant is a person who has lived in another village, town or in a foreign country for at least 6 months before finally settling in the present homes. Based on this working definition, the survey revealed that a large percentage of household heads and their spouses are migrants (Table 4.10). About 52% of household heads are migrants whilst 45%

are non-migrants. Several reasons were cited as important factors determining the decision to migrate to their current abode and these differ between household heads and their spouses.

The single most important determinant of out-migration by household heads is the prospects of engaging in profitable agriculture (27%). The marriage contract was the major reason (43%) advanced by spouses of household heads for migrating, which is quite tenable. Thus, the decision by most spouses (mainly females) to migrate is mainly tied to that of household heads decisions (mainly husbands), followed by their own decision to out-migrate for better agricultural opportunities.

Table 4.10: Migration status of household heads and spouses

Variable	Percentage (%)
Migrants	
Household head	52.00
Spouse	36.00
Non-migrants	
Household head	45.00
Spouse	45.00

Source: GLOWA field survey, 2001
Note: Percentage may not add up to 100% because of reported missing cases.

Table 4.11: Reasons for migration by household heads and spouses

	Frequency (%)	
Reasons for migrating	**Household head**	**Spouse**
Parents moved	8.7	5.9
Schooling	1.5	1.1
Marriage	7.2	43.3
Look for work	6.4	5.3
Start a new job	6.4	5.9
Better possibilities for doing agriculture	27.5	15.5
Disease	2.3	0.5
Other	40	21.9
Total	100	100

Source: GLOWA field survey, 2001

When prospects of better job opportunities materialise migrants remit home, the effect of which may increase household welfare. On the other hand, out-migration has the potential to stifle developmental efforts in rural communities as it is the economically active that leave in search of better living conditions, resulting in what may be called "community brain drain". Another implication is the possibility that community level participation, for example, in community water development projects may be adversely affected. Living conditions need to

be improved in rural communities, for example, by the establishment of rural industries to create jobs.

4.2 Water Security at the household level

Household water security revolves round issues of water availability, accessibility, usage and quality. Availability of water in a region mainly depends on the climate (which in turn depends on rainfall availability and its variability in time and space, humidity and temperature), topography and geology (UNESCO, 2002). The availability and location of natural water sources and the siting of water supply points in communities determine the ease of accessibility, which may influence quantities consumed and for that matter, usage patterns. The type of water source also reflects its quality level. For example, rivers and streams are often poor in quality (bacteriological quality) whilst boreholes usually are of good quality. This section examines the extent of household water security in rural communities to give insights into prevailing situations for policy intervention if necessary.

4.2.1 Water sources and quantities consumed

Although abundant in water resources, its distribution across the Ghanaian basin is uneven resulting in seasonal and spatial variations in water supply. Augmenting supply with investments into water systems at the community level requires huge financial outlays and it takes time. In the absence of such investments, rural households use available water sources for various consumption needs. The survey found that water from multiple sources is usually used for several purposes. Sources of domestic water supply used by households in the basin are shown in Table 4.12. These range from public pipes to the harvesting of rainwater. Rainwater is the commonly used traditional water source by 64% of households. Another 57% rely on water from rivers, streams and ponds, 43% depend on boreholes and 19% depend on hand dug wells. Water from rivers and streams is the most important water source for 42% of respondents whilst 61% mention rainwater as the second most important water source.

Water consumption levels show significant seasonal variations and across administrative regions. The Volta region records the highest per capita water consumption in the rainy and dry seasons (Table 4.13) whilst regions in the savannah zones (for example, Upper East, Upper West and Northern regions) show the lowest daily per capita water consumption levels. Generally, more water is consumed in the rainy than in the dry season.

Table 4.12: Water supply sources used by sampled households (in % of households) in the Ghanaian Volta basin, 2001

Water sources	Source used	Most important source	Second most important source
Piped water in the house and compound	2.6	2.6	0.5
Public Tap /standpipe	7.8	5.4	1.0
Private water vendor	5.4	1.4	2.0
Water from neighbours	3.0	2.2	1.0
Hand dug well	18.6	12.0	7.4
Borehole	42.7	32.5	8.4
River, streams and ponds	57.1	42.1	18.8
Rain water	64.3	1.2	60.5
Other	0.8	0.6	0.5

Source: GLOWA field survey, 2001

Note: The second most important water sources indicated by households may not necessarily be used. Moreover, percentages of sources of water used by households may not add up to 100 percent because households use multiple water sources for various purposes.

Average daily household water consumption in the basin is 219 litres per day in the rainy season and 181 litres per day in the dry season (Table 4.14). An average of 32 litres per capita per day (l/c/d) is consumed in the rainy season compared to 25 l/c/d in the dry season. These quantities exceed the World Health Organisation (WHO, 1996) estimated minimum amount of 20 l/c/d of safe water needed for metabolic, hygienic and domestic purposes. Note that the basis for the WHO standard has been questioned by Rosen and Vincent (1999). Gleick (1998) estimates 50 l/c/d as adequate: 25 l/c/d for drinking and sanitation and another 25 l/c/d for bathing and cooking. Taking Gleick's estimates as given, quantities of water usage by households in the basin, regardless of the season, are insufficient for healthy lifestyles. A possible reason for the low consumptions levels may be inadequate water supply options, as exemplified in rural Ghana, thus resulting in water consumption levels not equating demand (London Economics, 1999). Moreover, most of the water used comes from traditional or unsafe sources (see Table 4.12).

Table 4.13: Average water consumption by region and season in the Volta basin, 2001

	Monthly water consumption (litres)		Water consumption per day (litres/day)		Water consumption per capita per day (litres/capita/day)	
Region	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
Ashanti	7,720.0	6,721.2	275.75	240.07	36.03	30.24
Brong Ahafo	5,046.1	3,476.2	180.24	124.17	32.62	22.23
Eastern	4,896.5	3,702.6	174.89	132.25	35.88	25.92
Northern	6,976.3	5,982.5	249.15	213.66	30.67	20.73
Upper East	6,068.8	5,637.8	216.77	201.38	24.38	22.75
Upper West	5,118.0	4,744.7	182.81	169.48	17.69	16.39
Volta	8,092.9	5,911.7	289.07	211.16	47.20	34.49

Source: GLOWA field survey, 2001

Table 4.14: Average water consumptions (in litres) by season and household income categories in the Volta basin, 2001

	Income level					
	1 (lowest)	2	3	4	5 (highest)	**Mean of total**
Rainy season						
Per capita/day	35.3	26.6	26.7	29.8	39.9	31.7
Daily	273.8	215.1	209.1	200.4	195.2	218.8
Monthly	7,668.0	6,023.9	5,855.1	5,612.5	5,467.2	6,127.2
Dry season						
Per capita/day	25.7	22.4	22.6	23.9	30.6	25.0
Daily	211.6	185.3	181.3	161.9	165.5	181.0
Monthly	5,925.1	5,190.7	5,076.4	4,534.5	4,635.0	5,068.8
Yearly	13,087.21	11,214.6	10,826.8	10,147.0	10,722.3	11,196.5

Source: GLOWA field survey, 2001

Levels of water consumption by household income categories shows consistent pattern for daily, monthly and yearly water consumption levels, where consumption declines with rising incomes, suggesting that the poor consume more water than the more affluent. This is an unexpected finding in this study. Larger household sizes by the poor may explain higher consumptions levels[10] (see Table 4.6). On per capita daily basis, the trend generally reverses where water consumption increases with higher income levels, corresponding to *a priori* expectations: the wealthiest 20% (highest quintile) are the highest water consumers followed by the poorest 20% (poorest quintile). What remains unexplained is the observation that the poorest 20% are the second highest water consumers. It may be the case that poorest 20% of households devote more time to water collection and possibly have more available water carriers undertake this activity.

4.2.2 Water usage patterns and storage

Water is usually collected from multiple sources for different uses. Little or no distinction is made between water source and usage purpose. With the exception of bottled water (which for obvious reasons would not be for bathing and laundry), water from all available sources is used for drinking, cooking, sanitation and hygienic purposes. Because rainwater, rivers and boreholes are important sources to households, they consume more from these sources (Table 4.15). Most households use river water for laundry. It is assumed that the quantity consumed depends on household characteristics such as household size, gender composition, number of water carriers and season. It indirectly depends on amounts needed for domestic activities such as bathing, cooking, dish washing and domestic hygiene. Water from private vendors is

[10] Water vending is not a usual practice in rural communities hence may not explain higher levels of water consumption by the poor.

considered an option mainly in dry seasons when water accessibility is difficult. Delivery of vended water is through private water tankers or government institutions at specified fee per unit and wealthier households usually patronise this source.

Irrespective of the season, households on a weekly basis use more water for bathing and hygienic purposes (Figure 4.3). Although laundry is the second highest water user, this activity is sometimes undertaken in rivers and streams. Roughly 110 litres is consumed weekly on drinking and cooking whilst dish washing consumes about 54 litres per week. Quantities consumed per activity show little or no seasonal variation.

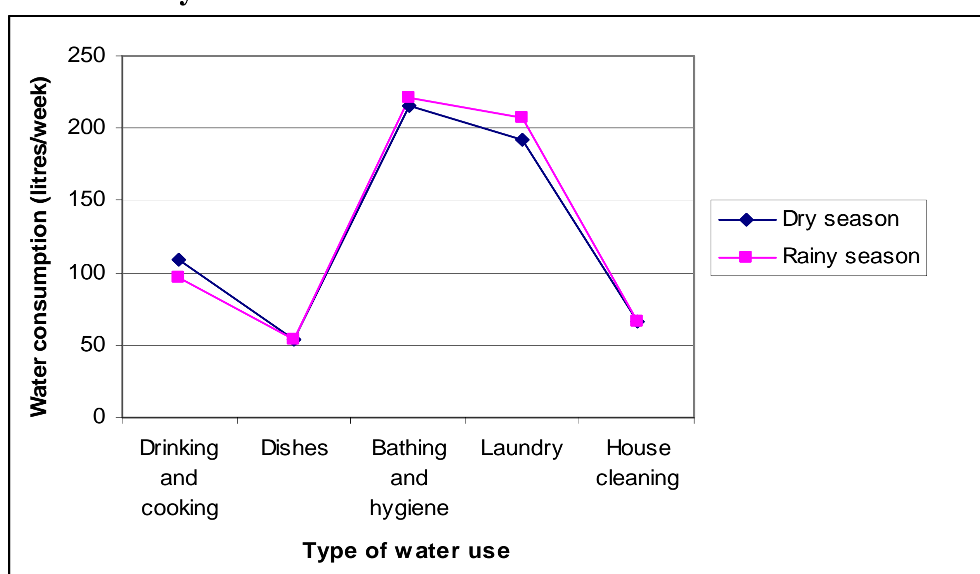
Table 4.15: Water sources by type of household usage (in % of households)

Water source	Drinking and cooking	Bathing and hygiene	Laundry
Piped water in the house and compound	2.61	2.41	2.21
Public Tap /standpipe	6.83	6.46	6.43
Private water vendor	4.22	4.22	4.22
Bottled water	1.00	0.00	0.00
Water from neighbours	3.01	2.81	2.81
Hand dug well	14.86	16.87	16.87
Borehole	40.36	37.35	36.55
River, streams and ponds	47.99	52.61	53.41
Rain water	53.32	53.32	52.92
Other	0.80	0.80	0.80

Source: GLOWA field survey, 2001

Note: The percentages do not add up to 100 percent because households use multiple water sources for multiple purposes and not just a single water source for a single purpose or activity.

Figure 4.3: Average weekly household water consumption (in litres) by type of activity and season



Source: GLOWA field survey, 2001

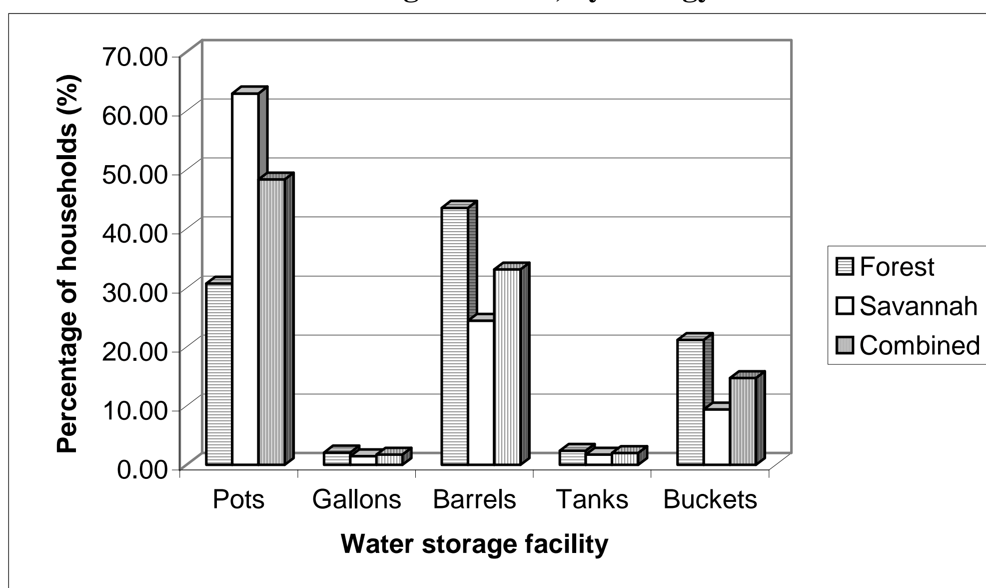
4.2.2.1 Water storage

Water storage is a coping strategy to enhance continuous water availability and reliability. About 95% of respondents store water from all sources in various storage facilities. Rainwater is the prominent source of water stored by 54% of households followed by river water (46%). The cistern (pot) is generally the most important water storage facility used by 48% of households in the Volta basin (see Figure 4.4). It is the commonest facility for 63% of households in the savannah zone whilst the barrel features prominently (44%) in the forest zone. Tanks used by households are either roof or underground tanks. Smaller vessels like cooking utensils are used in some communities during dire situations. The "gallon" is the least preferred due to its small storage capacity of roughly 4.5 litres. Farmers often drink from them whilst working on their farms.

4.2.2.2 Water reuse

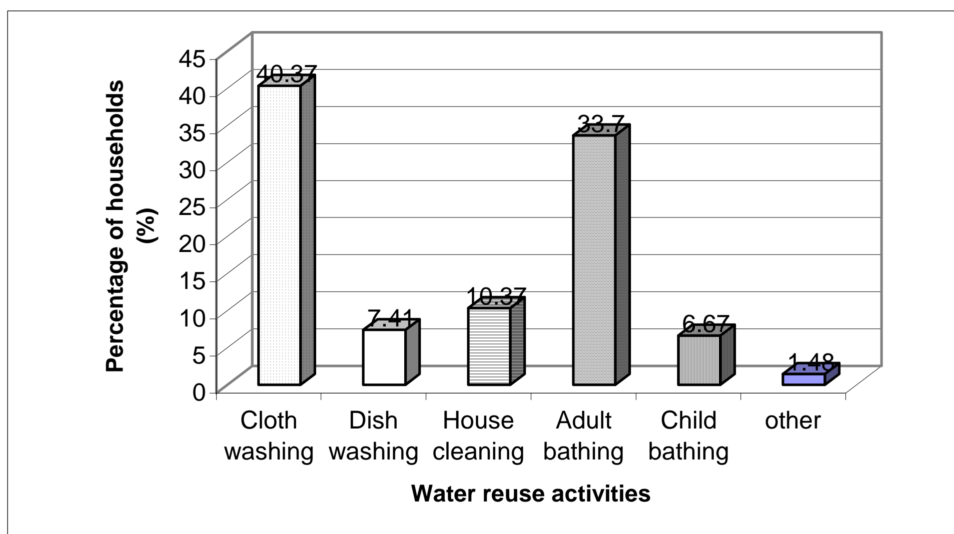
Water is reused with conservation in mind. At least 55% of respondents intentionally reuse water by compromising on good hygienic practices. From this percentage, 40% use less water for washing clothes and 34% economise on the desired amount necessary for adult bathing (Figure 4.5). Using less water for important domestic needs such as personal hygiene may be a recipe for water-washed diseases that results in many diseases of the skin and eyes (Rosen and Vincent, 1999).

Figure 4.4: Household water storage facilities, by ecology zone



Source: GLOWA Volta field survey, 2001

Figure 4.5: Water reuse by type of activity



Source: GLOWA Volta field survey, 2001

4.2.3 Water accessibility

Time allocated to water collection would differ among households and communities depending on its location (distance to source), ease of accessibility (i.e., the terrain), and household characteristics such as number of water carriers and gender. Table 4.16 shows time allocations and distances commuted by households in communities to access the most important water source in the dry and rainy seasons.

Households generally allocate more time travelling long distances in the dry than in the rainy seasons. An average round trip distance of about 0.9km is commuted in the dry season to access water from rivers, which corresponds to an average round trip time of 0.87 hours per carrier. Significant differences however exist in time allocations and distances commuted among the communities. In some communities, such as Bagabaga in the savannah zone, more time is spent collecting water in the rainy season than in the dry season. Difficult terrain in accessing water from waterlogged arrears may explain this reversal of trend. In general, time serves as a major input to water consumption for rural consumers. A t-test (assuming unpaired variances) performed to investigate differences in time allocated to daily water collection from rivers indicate a statistical difference at the 1% level between (Table 4.17). An average of about 2.5 and 1.6 hours per day is allocated to water collection from rivers in the dry and rainy seasons respectively.

Table 4.16: Average distance and time allocation by communities to access water from rivers and streams

Community	Average distance (meters)		Average time (round trip) (minutes) [11]	
	Dry	Rainy	Dry	Rainy
Abrakaso	442.9	442.9	37.1	28.1
Akutuasi	566.0	580.0	61.8	58.8
Ejura	595.3	660.7	35.6	34.8
Kyebi	525.0	500.0	22.5	20.0
Ayerede	1441.7	1437.5	48.3	47.5
Kwagyeikrom/Bredi	443.5	426.1	79.3	39.1
Koduakrom	1585.7	491.3	81.4	25.0
Miawoani	1510.0	689.6	77.6	49.2
Nsuta	472.4	401.4	36.7	42.9
Gbangbanpon	857.7	694.2	52.7	38.3
Bagabaga	1375.0	1500.0	42.6	44.0
Kaladan Barracks[a]				
Kusawgu	1073.9	1073.9	61.5	61.5
Dusabligo	550.0	466.7	20.3	16.7
Gowrie	721.0	931.5	26.7	33.5
Kologo Tangabisi*				
Biu	700.0	700.0	37.0	37.0
Korobognuo	1200.0	1200.0	55.0	45.8
Nkonya Wurupong	783.3	700.0	38.3	28.3
Kpando Torkor	680.6	702.9	28.9	30.1
Average	**911.0**	**736.3**	**52.3**	**39.5**

Source: GLOWA field survey, 2001

[a] *This community does not have access to rivers/streams*

* *This community does not use river or stream water even in the rainy season because they have access to boreholes that are closer to their homes. Moreover, the stream does not flow always and not reliable*

The analysis split into ecological zones further confirms significant time expenditure both in the dry season and in the savannah zone (see Appendix 4 Table A4.6). However, when average time spent collecting water from all available sources by ecological is examined, a different situation emerges. An average of 1 hour is spent in the forest and savannah zones collecting water in the rainy season. However, dry season water collection times are higher for forest zone households (Table 4.18). This finding may not be obvious because of the expectation that the savannah zone have drier climates with difficult water availability and accessibility.

A plausible explanation why savannah zone households spend less time in sourcing water in the dry season may be the fact that these communities have received intervention by Non Governmental Organisations (NGO's) through the provision of boreholes in almost every community, making accessibility much easier.

[11] Distance travelled and time budgets are based on recall (estimations) by the household head, the spouse or the water carriers depending on the situation.

Table 4.17: T-test for mean water allocation times (in hours) by season

Variable	Observations	Average time	Standard error	Standard deviation
Dry season	245	2.47	0.19	3.00
Rainy season	241	1.56	0.13	2.03
Combined	486	2.02	0.11	2.60
Difference		0.91	0.23	

Satterthwaite's degrees of freedom: 430.15
H_o: mean (dry season) - mean (rainy season) = diff = 0

H_a: diff < 0	H_a: diff ~= 0	H_a: diff > 0
t = 3.91	t = 3.91	t = 3.91
P < t = 0.9999	P > t = 0.0001	P > t = 0.0001

Table 4.18: Average time (in hours) spent daily per household collecting water from all sources, by ecology zone and season

Ecological zone	Season	Number of observations	Average time
Forest	Rainy	189	0.57
	Dry	189	0.98
Savannah	Rainy	278	0.58
	Dry	278	0.75

Source: Derived from the GLOWA Volta field survey, 2001

4.2.4 Water quality and treatment

In addition to water availability, accessibility and usage, water quality plays an important role in determining water security. The quality of water consumed determines the drinking water security and subsequently health and agricultural productivity status of households. In this regard, household perceptions on water quality are crucial in determining household health production and water treatment decisions. Table 4.19 presents households water quality ratings by source.

About 91% indicate their satisfaction with rainwater, an important water source to households whilst about 40% are satisfied with the quality of rivers and streams in the rainy season, dropping to 24% in the dry season. Although rivers are the most important water sources for the sampled households, about 60% and 76% expressed dissatisfaction with its quality in the rainy and dry seasons respectively. These responses, depending on the community, may imply the absence of alternative water sources. Borehole, an improved water source was rated high in both seasons: rainy season (94%) and dry season (88%).

Table 4.19: Household water quality ratings by source and season

Water source	Household water quality ratings (%)							
	Rainy season				Dry season			
	Fully satisfied	Rather satisfied	Rather not satisfied	Not satisfied	Fully satisfied	Rather satisfied	Rather not satisfied	Not satisfied
Piped water	25.0	41.7	25.0	8.3	25.0	25.0	8.3	41.7
Private water vendor	11.1	38.9	38.9	11.1	4.6	41.0	36.4	18.2
Public Tap	37.1	37.1	25.8	0.0	44.1	23.5	29.4	3.0
Neighbours	29.4	52.9	5.9	5.9	25.0	50.0	12.5	12.5
Borehole	59.7	34.7	4.2	1.4	49.6	38.6	8.2	3.6
Hand dug well	26.2	45.5	18.2	9.1	27.0	41.6	18.0	13.4
River, streams and ponds	4.6	35.2	29.2	31.0	5.8	18.1	29.0	47.1
Rain water	46.4	44.6	7.3	1.4*				

Source: Derived from the GLOWA Volta field survey, 2001

** Some of the percentages may not add up to 100 because of the "don't know" response not shown.*

When factors that are likely to influence households' dissatisfaction with the quality of water were examined for four most important water sources, it was observed that large proportions of households were not content with the quality of unsafe or traditional water sources in both seasons. With respect to river water, households express much water insecurity with the presence of particles (94%), colour of water (93%) and fear of infection (95%) in the dry seasons. These ratings are slightly lower in the rainy seasons. Although over 90% of households are generally satisfied with rainwater in the rainy season, the presence of particles is a major for 50% of households whilst 41% are worried about contracting infections from this source. In general, households are very much bothered with the presence of particles, fear of contracting infectious diseases, the smell and taste of important water sources. The major problems that households encounter with borehole are with its taste and salinity, especially in the dry seasons.

Table 4.20: Water characteristics that worry households, by season

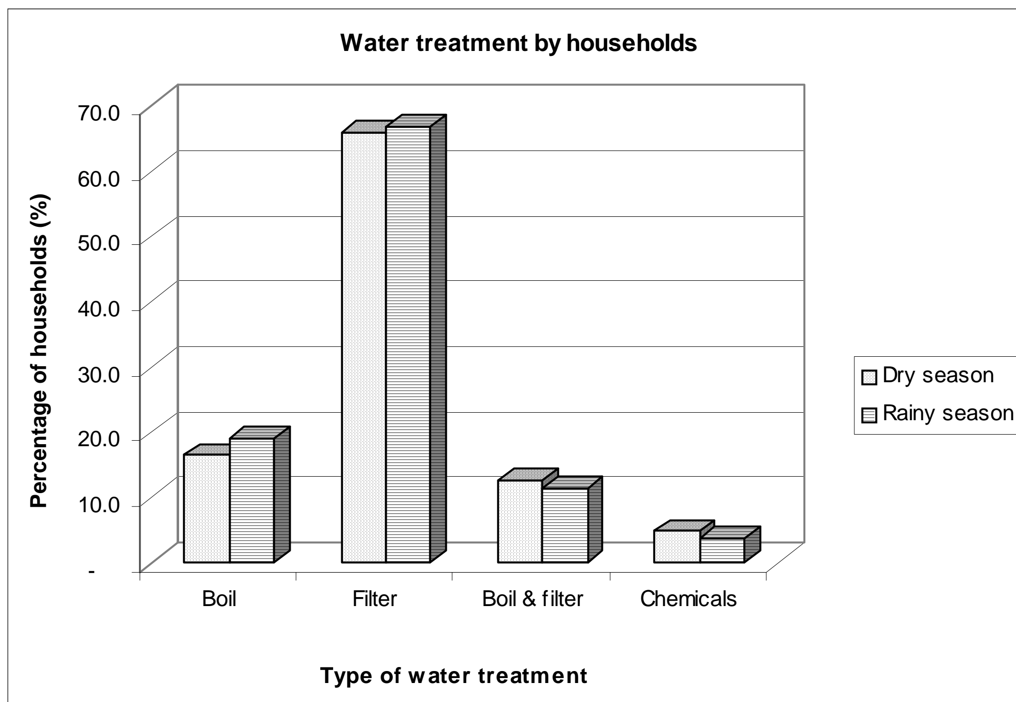
Important water sources	Water characteristics (% of households)					
	Particles	Colour	Smell	Taste	Salinity	Fear of infections
Rainy season						
Borehole	5.3	3.1	0.0	8.0	8.1	3.2
Hand dug well	40.4	40.4	9.1	14.2	11.6	40.0
River, streams and ponds	79.2	73.3	46.6	18.0	5.8	81.4
Rain water	49.6	22.0	1.7	16.1	3.4	41.2
Dry season						
Borehole	9.2	12.2	6.0	13.2	11.2	2.5
Hand dug well	50.0	37.5	16.7	19.0	6.3	43.4
River, streams and ponds	93.9	93.0	84.0	62.0	20.0	94.8

Source: GLOWA Volta field survey, 2001

The decision to treat water may also depend on household income and not only on water quality perceptions. Households treat or purify water, either by filtering, boiling or the addition of chemicals to make it more secure or safe. Approximately 27% of sampled households treat water perceived to be unhealthy for consumption. The cost of chemicals (for example, chlorine) and filters and cost of boiling water constitute water treatment cost.

Methods for treating water from rivers are presented in Figure 4.6. For those who treat water, over 60% filter in both seasons. Slightly more households filter or boil water in the rainy than in the dry season probably due to turbidity of river water. The use of chemicals is the least preferred treatment method either because these chemicals are scarce or because of financial burden. If treatment is mainly by filtering and not by boiling to eliminate disease-causing organisms, then little is done in reducing the effect of micro-organisms on human health. Such treatment methods do not enhance household drinking water security. On the average, more households (76%) treat water in the dry season compared to 57% in the rainy season.

Figure 4.6: Household methods of treating river water by seasons



Source: GLOWA Volta field survey, 2001

4.3 Water price estimation approaches

The price of water is an important determinant of water consumption and one of the major concerns in this study is finding an appropriate price for water consumed by rural households.

This is because most of the water consumed comes from traditional sources such as rivers and streams and hand-dug wells with virtually no financial costs. For example, about 57% of households depend on rivers and streams and it is free of charge without any financial costs attached. Another 19% of households use water from hand-dug wells and about 43% utilise boreholes. Water from communal wells and boreholes in some communities attract flat rates on monthly or yearly basis. Over 64% of sampled household utilise rainwater, a major water source.

The challenge is to estimate the price per unit of water consumed in a situation were water is not a tradable good and water costs are in some cases a composite of costs, but mainly consist of opportunity costs for household labour. Hired labour is not used for water collection by sampled basin households. This section first estimates the amount of time households allocate to water collection on a daily basis. Different approaches are then employed to compute opportunity cost of time, based on (1) universal minimum wage rate, (2) agricultural incomes of households and (3) non-agricultural income of women in a household. The strengths and weaknesses inherent in each approach are then discussed. This section ends with a highlight of other cost components that could potentially be an integral part of the price of water.

4.3.1 Time spent on water collection

Several water containers of varying sizes and capacities are used for water collection. These are basically basins and buckets, with the former having an average capacity of 45 litres and the latter 18 litres (size 34 is the commonest size). It is assumed that a water carrier, usually women, on the average carry 45 litres of water per return trip. The survey revealed that households collect an average of 210.4 litres of water per day. Hence, the average number of trips per household is the ratio of the average amount of water collected per day to the average capacity of 45 litres, yielding a daily average of 5.6 trips per household. The survey also revealed that households on the average devote 0.61 hours per trip collecting water from all available sources. In the context of water collection, rural households may not value this time because it is an integral part of their daily activities that must be done at all costs with little or no option available to them.

One option is to have piped water connections in the homes. For financial reasons, this may not be a viable option at least in the short term for rural households. The only feasible alternative is having water delivery points closely located within a few meters radius that can

be accessed in no time. In the absence of this, households on the average allocate 3.42 hours to the task of water collection on a daily basis (multiplying 0.61 by the average number of trips). Table 4.21 gives this information based on agro-ecology zones. Generally, households in the savannah agro-ecology spend more time sourcing water.

Table 4.21: Average time devoted to water collection by agro-ecology

Variables	Unit	Forest	Savannah	Mean time
Number of trips	Day	5.00	6.02	5.60
Round trip time	Hours	0.56	0.64	0.61
Water collection per day	Hours	2.79	3.85	3.42

Source: Calculated from the GLOWA-Volta field data, 2001

4.3.2 Opportunity costs of time

Time is also an important resource for rural households as evidenced from the proportion of household income earned through agricultural activities especially food crop production (see Table 4.3). It may be therefore untenable not to assume that time allocated to water fetching could generate some level of income. The question then arises as to whether employment generating opportunities exist in rural communities. First, it has to be pointed out that availability of such opportunities will vary from one community to the other and the severity of this situation may sometimes warrant migration to other communities. Churchill (1987) indicated that rural women do have income-generating opportunities such as food processing and petty trading. Ocloo (1997) makes a similar argument, for example, by indicating that about 30% of Ghanaian women engage in petty trading and food processing. Moreover, time could also be used productively to generate human capital (e.g. especially through female child education). Nevertheless, the argument advanced in this study is that rural folks may have something doing, either on their own farms, as casual labourers, trading or taking care of children at home, or even leisure. This suggests that time spent on water collection could be and should be valued in monetary terms. It is upon this basis that the opportunity cost, based on different valuations of women’s time devoted to water collection is estimated to derive the price of water.

4.3.2.1 National daily minimum wage approach

In rural Ghana, over 70% of the economically active population (age 15 and above) are employed in the agricultural sector (GSS, 2000). Since our survey communities are basically rural, it seems practical to use rural agricultural wages to put a value on the opportunity cost

of time collecting water. Therefore, in computing an appropriate wage to value women's time, this approach draws on the employment data of the Ghana Living Standards Survey fourth round (GLSS4) conducted in 1998/99. Specifically, this approach relies on the average basic hourly wage of women in 1999 to value their time allocated to water collecting.

In 1999, the average basic hourly wage was ¢381 for women and ¢598 for men. For the same period, the national daily minimum wage was set at ¢2,900. This increased to ¢5,500 in 2001, representing an annual growth rate of 37.7%. In order to have a corresponding figure for the hourly wage of women for our household survey period 2001, the annual growth rate was used for extrapolation purposes[12], resulting in a value of ¢722.5 per hour. This implies an average hourly and daily opportunity cost of ¢722.5 and ¢1,831.4 respectively. The daily opportunity costs gives an idea as to what a water carrier would earn through employment if government, donor agencies or private firms are to intervene with water projects that will considerably enhance water accessibility within a reasonable period of time.

It must also be pointed out that such interventions in the rural water sector are not entirely free, especially when potable water is being provided by the private sector, generally seen as the engine for growth and efficiency in the provision of goods and services in Ghana. The contracting of private firms, Non Governmental Organisations (NGOs), Community Based Organisations (CBOs) and individuals by the Community Water and Sanitation Agency (CWSA) to deliver services ranging from the drilling and construction of boreholes, hand-dug wells to capacity building (Water and Sanitation Project-AR, 2002) suggests at least the need to recover costs, if not having profit motives. In effect, although these interventions may lead to time and possible costs savings, they also impose some degree of financial burden on households. In the final analysis, whether such interventions improves or worsens the welfare of households or communities would call for further research to determine the effect of the intervention.

From the survey, households on the average consume 210.4 litres of water daily (GLOWA-Volta household survey, 2001). Taking this as given, the estimated price of water using this

[12] The applied formula, $W_t = W_{t-1} (1 + g)^t$, was used in calculating for the annual growth rate, where W_t denotes women's wage in the current period t, W_{t-1} denotes their wage in the previous year and g is the growth rate between the two periods.

approach amounts to ¢9.7 per litre (¢9,694.7/m^3) (This is derived by dividing the mean daily opportunity cost by the mean household daily water consumption).

4.3.2.2 Agricultural income approach

Total agricultural income constitutes 77% of total household income whilst non-agricultural income takes up 23%. Using agricultural incomes to estimate opportunity costs of time for calculating the price of water would give additional insights. Agricultural income as reported in the survey values the time of both men and women. Hence no specific information on female agricultural income is available. Nevertheless the result can be compared to the other approaches.

Further examination of the data indicates a 77% correlation between male adults working on farms and the total number of males in a household. This correlation is only 1% higher for the case of adult females contributing to agricultural labour and the total number of females in the household. These statistics suggest an almost equal likelihood that a male or female adult will be engaged in agricultural activities. It further supports the rational for adopting this approach as well because agriculture provides equal opportunities for male and female adults to earn income. This then serves as proxy to measure opportunity costs.

On the average, households earn about ¢8,476,478.0 annually and ¢7,233.1 daily from agricultural activities (daily estimate is based on the actual number of days worked in a year). This is equivalent to an average of ¢892.4 an hour, assuming 8 hours of daily work and it connote the opportunity cost of an hour of water collection. Given that 3.42 hours on the average is devoted to this activity, the daily opportunity cost amounts to ¢2,316.0 and subsequently yielding an estimated price of water at ¢12.2 per litre (or ¢12,194.5/ m^3) on the average.

4.3.2.3 Non-agricultural income of women approach

Petty trading, selling of fuel wood and off-farm wages are examples of household sources of non-agricultural income. Women in the sampled households on the average earn ¢1,018,319.0 annually as income from this source (GLOWA-Volta household survey, 2001) which constitutes 5.5% of total annual household income. This is equivalent to a daily

average of ¢8,575.1 per household[13]. Assuming household members work 8 hours daily means that, on the average, they earn ¢1,071.9 per hour. Put differently, an hour of water collection per day could potentially have earned them ¢1,071.9. That is, 3.42 hours allocated to daily water collection could generate ¢3,144.7 of non-agricultural income, which represents the daily opportunity cost of water collection. This figure indicates the amount of money lost through water fetching. Thus, the opportunity cost of consuming a unit of water (i.e., price of water) is derived by dividing the daily opportunity cost by the average daily water consumption by households, resulting in an estimated price of ¢12.3 per litre (or ¢12,307.3/m^3) of water.

4.3.3 Strengths and shortcomings of different approaches to value time

The focus has so far been on various approaches employed to value time allocated to water collection (opportunity cost) and subsequently deriving the price of water. However, these procedures described, although they may be intuitively appealing are not without drawbacks. Attention first should be drawn to the fact that only time costs of water collection and not the financial cost (which includes the actual fees paid per unit of water consumed) is considered in these approaches. This may result in underestimating the actual price of water (Choe and Varley, 1997), irrespective of the approach adopted.

The agricultural income and non-agricultural income of women approaches both utilised the GLOWA-Volta household survey information to value time spent collecting water. As the data from this survey is further used in subsequent analysis, information on opportunity costs for households can be matched with other household specific information for other variables to ensure consistency and the operation of variables at a given level. Kaimowitz and Angelsen (1998) note that it is unadvisable to mix micro-level and macro-level variables due to the level at which both operate in an economy and the combination of these variables in regression analyses may result in inappropriate coefficients that may lead to wrong policy recommendations.

A drawback in adopting the non-agricultural income of women approach is the implicit assumption of zero opportunity cost for agricultural income of women, which may not be realistic especially in rural settings because women as well own farms and generate incomes

[13] The average annual income of households was divided by the number of days in a year worked off-farm by women to generate the daily average non-agricultural income.

from farming activities. The exclusion of this cost ignores the opportunity for rural women to generate income through agricultural activities. What is needed to surmount the problem of misspecification is getting corresponding disaggregated information on agricultural incomes of women to combine with that of their non-agricultural income. Unfortunately, available data on agricultural income was not disaggregated by gender but rather for the whole household, suggesting that the agricultural income approach suffers from a similar problem. This is because the administered questionnaires did not sought for agricultural incomes of women separately.

The use of the national daily minimum wage as one of the approaches to calculate opportunity costs of time is likely to reduce variability in water prices, because this national wage was applied uniformly across all households for data extrapolation purposes. The possible effect is that opportunity cost of time would be uniform across households. Water price variability is essential in determining the extent to which it influences water demand. In addition, the daily minimum wage approach may possibly yield higher estimates because of employing a national or macro-level variable to extrapolate a community variable to a desired point in time. In essence, the national daily minimum wage was used to scale-up price data and this procedure may be acceptable because demand functions are homogenous of degree zero in prices and income. In view of the fact that this approach also ignores the non-agricultural income contribution of women to value time but only considers their agricultural incomes, this approach may as well not reflect or capture the true value of time.

The obvious question that arises is which of these approaches are preferable. It must be noted that both the agricultural income and non-agricultural income of women approach does not capture the true opportunity costs of time because they respectively ignore non-agricultural income or agricultural income. However, as far as women's time devoted to water collection is concerned, the agricultural income approach obviously overestimates the value by not differentiating between male and female income. Despite the fact that non-agricultural incomes of women constitute only 5.5% of total household annual income, the non-agricultural income of women approach sounds more realistic since women normally do the actual water hauling. It is their time that is the main focus. On the one hand, the national daily minimum wage and non-agricultural income of women approach outweigh the agricultural income approach on qualitative grounds because they capture, more or less, the time spent by water carriers. On the other hand, because the agricultural income and non-agricultural

income approach utilised reliable household survey information, which is at the micro level, they are preferred to the first, which depends on national data for projecting micro-level data.

A quantitative comparison of these approaches show a significant difference in the estimated price of water between the national daily minimum wage and the other two approaches. It also shows similarities in estimates between the agricultural income and non-agricultural income approaches both using field data for estimation. Table 4.22 summarises the estimated opportunity costs and price of water for each approach.

Table 4.22: Average water price estimation using different approaches

		Approaches		
Variable	**Units**	**National daily minimum wage**	**Agricultural income**	**Non-agricultural income of women**
Opportunity cost	¢/hour	722.5	892.4	1,071.9
Water price	¢/m^3	9,694.3	12,194.5	12,307.3

Source: Authors calculation from the GLOWA-Volta field data, 2001

Contrary to expectations, the estimated price of water employing the national daily minimum wage approach rather gave the lowest estimated water price of approximately ¢9,694 per cubic meter compared to the other two estimates. Upon second thought however, this should not be unexpected when compared to the two other approaches. The reasons being that, first, a micro level data (i.e., average basic hourly wage of ¢381 for women engaged in rural agriculture) utilised in the national daily minimum wage approach only aided in deriving a corresponding daily hourly wage for women in 2001. In other words, the estimated price of water using the national daily minimum wage approach also depended basically on actual micro level data. Second, this approach only utilised data on women in agriculture and therefore when compared with the agricultural income approach (which includes information on both men and women), the latter approach may reflect an overestimation, resulting in an estimated water price of approximately ¢12,195.

Comparing the difference in water price estimates between the national daily minimum wage approach and the non-agricultural income of women approach may be difficult in the sense that, although both focuses on women, the former approach exploit agricultural incomes whilst the latter make use of non-agricultural income. However, what can be said is that the national minimum wage approach may indicate an underestimation whilst the non-

agricultural income of women approach better reflects the true opportunity cost by using the survey data entirely for its estimations.

The closeness in water price estimates for agricultural income and non-agricultural income approaches is quite unexpected. Because the agricultural income approach includes information for men, it is expected to yield much higher estimates compared to the non-agricultural income approach. A likely explanation for this observation may be due to the inherent assumption of 300 days[14] of agricultural labour per year. If the actual number of persons days devoted to agricultural activities by households were known, the estimated price of water would have been much higher as it will serve as a numerator in computing the daily agricultural income which is then used to derive the hourly opportunity costs and subsequently the price of water. This is more likely to be the case when rest days (for example Sundays), days for communal labour, forbidden days of farming (depending on the community) and other social activities such as funerals keep households away from agricultural activities.

In generally, all the three approaches discussed above do not entirely reflect the true opportunity cost estimation. However, considering the actual time allocated by women for water collection and the magnitudes of the estimated price of water, it may seem more consistent, realistic and practical, as a first choice, to prefer the non-agricultural income of women approach in this study, followed by the national daily minimum wage approach.

4.4 Other costs

Apart from time costs, households incur other costs due to prevailing water insecurity situations, such as explicit costs, e.g., for storage and treatment. The sum of opportunity costs of time and explicit costs results in coping costs of water insecurity. The components of these costs are briefly outlines in this section.

4.4.1 Explicit costs

With respect to the price of water, explicit costs are additional costs, apart from the opportunity costs of time that households incur in securing a continuous supply of water at the household level. This comprises, for example, investments in water storage facilities and

[14] The assumption of 300 days of agricultural labour per year by rural households was derived by excluding weekends and statutory public holidays in Ghana.

water treatments costs. Investment in water storage facilities ensures continuous water availability at home whilst water treatment ensures that water perceived to be unsafe for consumption is rendered safe. Water treatment is either by boiling, addition of chemicals such as alum or by filtration or a combination of these. Explicit costs may require some financial outlay that stretches the household budget. These costs have to be included as part of the water price because such household strategies and activities makes this good available at home when ever needed (availability, reliability and accessibility) and finally transforms the original good into a different commodity (through water treatment) by adding value to the final good consumed.

4.4.1.2 Investments in water storage facilities and amortisation

About 95% of households[15] in the Volta basin store water and for that matter may consciously invest in water storage facilities. Five main storage facilities of varying sizes were identified, namely, cisterns (clay pots), gallons, barrels, tanks and buckets. As these facilities are used over time, the amortised values of these facilities were estimated. The amortised values indicate the amount of money that would have been paid by households on monthly basis for each storage facility over its economic life. The salvage value of the facility was not considered. A real interest rate of 13% was used for this calculation and this was based on end of quarter average inflation rate of 34% (second and third quarter of 2001) and a nominal interest rate of 47% for the same period[16]. The real interest rate is then calculated as the nominal interest rate minus the inflation rate. An assumption made was that the economic life of these storage facilities equals its expected usage life. To remove the effects of inflation, the real prices of the storage facilities were computed by using the consumer price index (CPI) with 1997 as the base year. The average monthly amortization of each facility is shown in Table 4.23.

For example, a household that stores water in barrels would be paying a monthly fee of about ¢52.00 over the next 15 years. On the average, the monthly amortisation for all storage facilities equals ¢51.18. The average cost of storing in each storage facility is also estimated

[15] Further information was not collected on households who indicated they do not intentionally store water. The reality however is that all rural households in Ghana more or less store water from various sources using storage facilities such as tanks, barrels, buckets, pots, plastic gallons and even cooking utensils.

[16] The survey period, 2001, span across these quarters so we decided to use the average for this period. For comparison, the annual average values for the year 2001 are 34.5% for inflation and 46.3% for nominal interest rate.

based on its monthly amortisation and the amount of each facility. This is indicated in Table 4.24.

Table 4.23: Average monthly amortization of water storage facilities

Storage facility	Average economic life (years)	Average monthly amortization (¢)	Standard deviation (¢)
Clay pots	12	19.81	48.47
Gallons	8	12.48	11.88
Barrels	15	51.60	103.73
Tanks	21	23.06	25.83
Buckets	13	15.23	21.41

Source: Authors calculation from field data, 2001

Table 4.24: Average monthly costs of water storage in storage facilities

Storage facility	Average monthly amortization (¢)	Average cost of storage (¢)	Standard deviation (¢)
Clay pots	19.81	81.86	232.66
Gallons	12.48	34.46	34.13
Barrels	51.60	125.19	265.76
Tanks	23.06	20.74	16.84
Buckets	15.23	33.24	32.39

Source: Authors calculation from field data, 2001

As expected, the storage cost of barrels is the highest because it happens to be the most expensive storage facility and the commonest for forest zone households. Taking account of all storage facilities used, the average cost of storing water in these vessels amounts to approximately ¢300.00 per month.

4.4.1.3 Water treatment costs

The decision to treat water may depend on household income, taste of water, household perceptions on water quality, and the number of infants in the household. Approximately 27% of households treat water perceived to be unhealthy for consumption. Out of this, more than 60% filter water from rivers in dry and rainy seasons. The cost of chemicals (such as chlorine for purifying water), filters and boiling constitute water treatment cost.[17] The sum of monthly amortisation cost of water storage facilities and the monthly treatment costs gives the explicit costs. The estimated average monthly expenditure on water treatment equals ¢1,749.53 (US$ 0.24)[18] whilst the average cost of water treatment per cubic metre of water

[17] The cost of water treatment could also be seen as operation and maintenance cost (O&M) to cope with water insecurity.
[18] Average exchange rate between the US Dollar ($) and the Ghanaian Cedi (¢) in 2001 was US $ 1=¢7,176

amounts to ¢19,641.84 (Table 4.25). From these results, the mean monthly explicit cost associated with water insecurity amounts to ¢159.44[19].

Table 4.25: Household water treatment costs (in ¢)

Variable	Mean	Standard deviation
Treatment costs/month	1,749.53	3476.91
Treatment costs/m^3	19,641.84	28,704.69

Source: Authors calculation from field data, 2001

4.4.1.4 Flat rates

The provision of improved water sources such as public taps, boreholes and communal wells comes at a cost. The providers of such improved water sources at least must recover the costs of operation and maintenance. Flat rates are therefore introduced in communities either on a monthly or yearly basis. Flat rates are mainly applied to boreholes whilst shallow communal wells are mostly free of charge. What pertains in some communities in the Volta basin is the payment of a fixed amount (sometimes depending on the household size) for repairs of the water source whenever it breaks down. This system of water pricing does not adequately determine household water demand behaviour as the quantity consumed does not depend on the price of water. That is, flat rates are only paid to utilise the boreholes and once they are paid, unlimited quantities can be consumed which makes it more likely to be overexploited, resulting in wasteful or uncontrolled consumption. In effect, this water pricing system can not be a good determinant of water demand in addition to the fact that flat rates may show little or no variability in price data, a situation that is certainly unpleasant in demand analyses.

4.4.2 Coping costs

According to Choe and Varley (1997), explicit and opportunity costs should feature in the estimation of water price for rural settings where water is collected from distance sources and household water storage and treatment a daily activity. Explicit and opportunity costs determine coping costs of water insecurity. This is expressed as:

Coping cost (¢/m^3) = Explicit costs (Investment in water storage facility
+ [Cost of chemicals + cost of filters + cost of boiling water])
+ Opportunity costs

[19] This value applies only to those who indicated they store water.

Coping costs could serve a good proxy for water price since it incorporates both opportunity costs and explicit costs in its calculations. Moreover, coping costs are more likely to reflect the reality of daily household water coping mechanisms in securing water.

In conclusion, this section looked at three approaches employed in estimating the price of water for rural households. These approaches considered only the opportunity costs of time lost to water fetching. The financial cost is excluded because the administration of flat rates on a monthly or yearly basis for boreholes and communal wells in some communities does not adequately allocate quantities of water consumed based on price. Moreover, using flat rates may not generate adequate variability in the water price data across households. The estimated price of water using the non-agricultural income of women approach seem to be more reasonable from the qualitative and quantitative points of view as discussed above. However, these water price estimates could serve as a proxy for the price paid by households for consuming a unit of water while bearing in mind the drawbacks inherent in these calculations because all three approaches fail to capture the true opportunity costs. Other cost components that could be incorporated into the price of water are explicit costs. Explicit costs incorporate investments in water storage facilities and the costs of water treatment whilst coping costs combines both opportunity costs and explicit costs.

4.5 Summary

Household water security issues are not limited to water availability, accessibility and usage. Water quality also plays an important role in determining the overall security of households, communities and nations. Unsafe or unimproved sources such as rivers and streams, rainwater and hand dug wells represent the most important water sources for rural households in the Ghanaian part of the Volta basin. They also express serious dissatisfaction with these water sources all year round, regarding the fear of contracting infections, colour of water and presence of particles in the water. This suggests inadequacy of water supply options at the community level. Water is therefore treated mainly by filtration to enhance drinking water security. In addition, households experience difficult water accessibility due to considerable distances travelled, especially in the dry season and the savannah zone, which reflects in substantial amount of time devoted to this task. Contrary to expectation, households in the forest zone allocate more time to water collection in the dry season.

More water is generally consumed in the rainy season than in the dry season. Poorer households generally consume more water than wealthier households. However, on per capita daily basis, the latter appear to consume more than the former. Taking Gleick's daily water consumption of 50 litres per capita as given, water consumption in the basin is low and thus likely to result in faecal-oral and water-washed diseases. To avert these potential health problems, it is important to understand the relationship between quantities of water consumption and its determinants such as distance and costs of coping with water insecurity. Considering the enormous amount of time involved in accessing water coupled with water quality perceptions, it suffices to say that households may be willing to pay or contribute towards the acquisition of improved water sources, *ceteris paribus*.

As the price of water is an important determinant of water demand, several approaches have been adopted to estimate this price. Based on qualitative and quantitative considerations of the data, the non-agricultural income of women approach is a reasonable choice employed to value women's time for estimating water price. This price proxy's the price paid by households for consuming a unit of water while.

5 THEORETICAL FRAMEWORK, MODELLING CONCEPTS AND METHODOLOGY

5.1 Introduction

Water demand by economic agents may be divided into residential (or domestic), industrial, commercial, public and agricultural water demands. Water demand has to be studied and analysed to inform policy makers with appropriate and reliable information regarding price, income or expenditure elasticities and that of demand shifters to enhance policy formulation in water demand management and planning. Achieving this important objective empirically begins with the development of a sound theoretical foundation to model consumption behaviour.

Models that do not conform to fundamental consumer behaviour may lead to misspecifications and can be detrimental in prescribing wrong policy conclusions. Although there is usually a dilemma between realism and theory (Sadoulet and Janvry, 1995), an appropriate framework can adequately capture relevant aspects of reality. Persson (2000) emphasises the importance of specifying underlying models because the inability to do this may not rule out the possibility of inconsistent utility maximisation behaviour.

The focus of this chapter is to develop appropriate theoretical frameworks based on economic theory of consumer behaviour to model the determinants of household (domestic) water demand and the factors that influence their choice for improved water sources and quantities consumed thereof. The theory underlying consumer demand behaviour is first outlined in section 5.2 by discussing household preferences, commodity separability and two-stage budgeting. Approaches adopted in modelling consumer demand systems and desirable properties of functional forms in empirical analysis are also discussed in this section as they are fundamental to understanding household optimisation problems. Section 5.3 develops the theoretical underpinnings and methodology for the household water demand model in the context of the Almost Ideal Demand System (AIDS) modelling framework. The uniqueness of the demand systems approach lies in its ability to exploit both the costs as well as indirect utility functions to derive a flexible and integrable demand function (Lewbel, 1991). This is then followed by a discussion of the theory and methodology of the Heckman two-stage model (discrete-continuous choice model) in section 5.4 to explain first, the key determinants

that weigh in a household's decision to use improved water sources (selection model) and second, the factors that determines the quantities of water consumed from improved water sources (outcome model). Random Utility Model (RUM) framework is the underlying theory employed to derive the conditional choice probabilities of the selection model. This is followed by the derivation of the outcome model.

5.2 Consumer demand modelling framework

The nature of household demand behaviour hinges on the concept of preferences or choices that lead to the existence of utility functions. Based on preference orderings of bundles of commodities that a household's budget will allow, utility is either maximised subject to budgetary constraints or expenditure is minimised given a fixed level of utility to yield consumer demand functions. This section gives expositions into the neoclassical consumer demand modelling concepts that underpin the development of the empirical household water demand model for this study. Assumptions underlying consumer preference formation are stated and linked to the existence of utility functions. Issues of separability and aggregation of commodities and household expenditure budgeting approaches are presented in section 5.2.2. This is followed by consumer demand modelling systems in section 5.2.3 where a distinction is made between complete and partial (incomplete) demand systems, and approaches followed in arriving at demand systems. Section 5.2.4 then concludes with a discussion on the desirable properties of functional forms.

5.2.1 Consumer preferences and utility function

The choices made by households or groups of households over the purchases of commodities to satisfy their wants serve as a starting point to the analysis of consumer demand behaviour. Six assumptions govern the behaviour of consumers. The assumptions state that consumer preferences are *reflexive, complete, consistent (or transitive), continuous, non-satiable and convex*. Commodities bundles, q^1 and q^2, are used to explain these axioms. The assumption of *reflexivity* implies that each bundle is at least as good as itself whilst the assumption of *completeness* renders the two bundles of commodities comparable because consumers can judge between these bundles. Either bundle q^1 is at least as good as q^2 or q^2 is at least as good as q^1. *Transitivity* or *consistency* axiom is the main assumption at the centre of the theory of choice. For example, if a consumer prefers 10 apples to 6 eggs and at the same time prefers 6 eggs to 8 oranges, then the consumer is expected to prefer 10 apples to 8 oranges,

given a correctly defined choice set and for a given time frame. This practically demonstrates the existence of consumer preferences.

The ability of consumers to judge, make comparisons (completeness) and to be consistent in their choices (transitivity) implies a preference ordering for commodities over a given choice set. Preference orderings are possible if there are continuities (and not discontinuities or kinks) in preferences. Preferences are represented by indifference curves that show preferred bundles at higher levels. The addition of the continuity assumption makes it possible to express consumer ordered preferences for commodities by a utility function $u(q)$. The preferred or best choice q^1 yields the highest value compared to the less preferred choice q^2. This is expressed mathematically as $u(q^1) \geq u(q^2)$.

Nonsatiation, the fifth assumption listed above, states that utility function $u(q)$ does not decrease in each of its arguments q_i, and all the arguments in the choice set is increasing in at least one of its arguments. It implies that consumers are not satisfied with less of a commodity but prefer more to less of it. This assumption then ensures that consumer preferences (represented by utility functions) are restricted to lie on the budget constraint and not inside it. As noted by Deaton and Muellbauer (1980), the above assumptions translate the consumers' choice problem to one of maximising utility (or preferences) due to a budget constraint that consumers face. The *convexity* axiom indicates that preferences are convex to the origin. For a two-commodity case, convexity simply implies that one of the two commodities would be purchased whilst strict convexity suggests that both commodities have to be purchased given the consumers budget. Strict convexity does not hold in practice because consumers are confronted with unlimited number of commodities and do not purchase a little of each. For demand functions to be continuous preferences must be convex, otherwise they are discontinuous. However, as long as the representing utility function is quasi-concave, it implies that preferences are convex.

The existence of commodity preferences and household budgetary constraints brings to the fore numerous choice problems. It is one of either maximising utility subject to budget constraints (primal approach) or minimising expenditure subject to a given level of utility (dual approach). Both approaches eventually lead to the derivation of demand functions. For the case of households in the Volta basin of Ghana, it is believed that, given the difficult

prevailing economic circumstances, households are more likely to make judicious use of available income by minimising household expenditures subject to a targeted level of utility. Deaton (1986) notes that when one aims at developing empirical models with quantity demanded being a function of commodity prices and total income, expenditure minimisation is the most convenient. The duality representation respecifies consumer preferences in terms of prices by defining a cost or an expenditure function, the preferred approach used in this study to estimate household water demand.

5.2.2 Separability, aggregation and two-stage budgeting

Decision making processes by consumers is not as simple as outlined in the previous section. Being a more complex process to achieve the highest attainable levels of satisfaction, it may sound plausible to imagine that consumers may categorise or separate their preferences of commodities into different groups to aid in decision-making. Thus, items or commodities that interact closely to yield a particular type of utility can be grouped so that preferences within a group do not depend on the quantities of commodities in other groups. This implies that the marginal utility derived from consuming a good in group *i* (e.g., water for drinking and cooking) does not depend on the quantity of another good consumed in group *j* (e.g., clothing), suggesting that the cross-partial derivatives are equal to zero, expressed as $\partial MU_i / \partial q_j = 0$,

where MU_i denotes the marginal utility of the ith good and q_j denotes the quantity of good j. This underlies the concept of weak separability in utility, as indicated by Deaton and Muellbauer (1980) and Sadoulet and Janvry (1995). Households for example, could separate commodities into water, food, clothing, shelter, utilities and transportation groups with each providing a specific utility that the other groups can not provide. Invoking the assumptions underlying consumer preferences, it follows that sub-utility functions for each group may exist and these separate groups compete in providing an overall utility for the household. This is expressed as:

$$u(q_1, q_2, ..., q_J) = f\left[u_w(q_1, q_2), u_f(q_3, q_4), ..., u_K(q_n, ..., q_K)\right] \qquad (5.1)$$

where $u(.)$ denotes the overall household utility, $f(.)$ represents some increasing function, u_w, u_f and u_K are sub-utility functions for water group, food group and the Kth commodity

group and $q_1,...,q_K$ denotes the individual commodities in each subgroup. The possibility also exists that a subgroup could further be disaggregated into smaller subgroups or that a subgroup may have only one good.

Inherent in the concept of separability is the idea of commodity aggregation. Aggregation of commodities into groups enables households to simplify complex consumer decision making processes to manageable ones by grouping commodities that provide similar utility into one group. This helps in household budgeting. Household expenditure is first allocated to specific groups, such as food and non-food groups, and then to individual commodities in each group. This embodies the concept of two-stage budgeting and indicates that at the first stage households allocate total expenditure to the commodity groups and in the second stage, group expenditures are allocated to individual commodities. Because weak separability which is necessary and sufficient for the second stage of two-stage budgeting (Deaton and Muellbauer, 1980) supports the idea of utility maximisation or expenditure minimisation at each stage of the decision-making process, it is a very useful concept that can be used in modelling household water consumption. Homothetic functions, which are functions that can be expressed as a monotone transformation of a homogeneous function (suggesting that all homogeneous functions are also homothetic and not the other way around), could apply in two-stage budgeting. That is, households' utility function could be homothetic separable in the various groups, such as for the water group, and the composition of the budget is independent of total expenditure or of utility (ibid, 1980). The implication is that all expenditure elasticities are unity (linear Engel curves), which contradicts known household budget studies (ibid, 1980). Note that a homogeneous function of degree one in prices (such as the expenditure function) is sometimes called linear homogeneity. It must be mentioned that, depending on the nature of commodities considered, multistage budgeting could result where individual commodities in each group are further disaggregated into smaller groups and expenditures allocated to them.

The question then arises as to what individual goods constitute the water group. Empirical literature identifies two approaches regarding the role water plays in household preferences. The first is to consider water as a single good, implying a single good in the water group whilst the second approach disaggregates water into different end uses that yield different utilities (Hanemann, 1998), suggesting more than one good in the water group. End uses of

water include cooking and drinking, dish and cloths washing, and bathing, conveniently categorised as indoor uses. Outdoor uses may include the use of water for watering lawns and gardens and these are virtually nonexistent in rural Ghanaian households and therefore not considered in this study.

It is assumed that the utility derived by households in using water for drinking and cooking is different from utility derived in using water for other indoor purposes. This view is supported by the fact that households store water for drinking and cooking separately from water for other purposes. This suggests different preferences and the possible existence of different demand functions for these two commodities.

Household expenditures are first allocated to the water group and then to the individual commodities. Allocating expenditures to non-water goods[20] are not examined in this study, likewise the dynamics or the intertemporal water expenditure allocation decisions. By this consideration, it is therefore implicitly assumed that households' water utility function is separable intertemporally. This assumption paves the way for water expenditures or quantities in a given period to be expressed as a function of explanatory variables in that same period.

Water demand by households is considered a final demand in that it does not serve as an input into profit-oriented production activities for the sampled households in the basin. They derive utility from the consumption of water, among several goods. Denoting q_D and q_O as goods constituting the water group, the conditional sub-utility function for water, u_w can be expressed as:

$$u_w = u_w \left(q_D , q_O\right) \qquad (5.2)$$

where q_D denotes quantity of water demanded for drinking and cooking and q_O denotes water demanded for other indoor purposes such as dish washing. Based on the concept of two-stage budgeting (where expenditure is first allocated to the water group level and then

[20] Non-water goods may be viewed as a separate group that can further be disaggregated into food and non-food groups. With expenditure data available for these broad commodity groups, Engel curves (instead of a complete or partial consumer demand systems) can rather be estimated for each commodity when commodity prices are unavailable. In this way, commodities can be grouped as luxuries or necessities.

trickles down the two commodities) households are assumed to minimise expenditure subject to a fixed level of household utility. This problem can be formulated as:

Minimise $y_w = p_D q_D + p_O q_O$ subject to $u_w = u_w\left(q_D , q_O\right)$ (5.3)

where y_w denotes total expenditure on water, p_D and q_D denotes the price and quantity of water demanded for drinking and cooking, respectively whilst p_O and q_O denotes the respective price and quantity of water demanded for other purposes. Multistage budgeting is applicable in the case where, for example, households have to decide on how much expenditure to allocate to the purchase of micronutrient-rich foods such as vegetables, beef, fish, chicken, fruits, milk and eggs, after first allocating expenditure to the food group, second to the category of food (i.e., food crops or meat) and third to the type of micronutrient to purchase (see for instance Block, 2003). What pertains in our context is two-stage and not multistage budgeting.

It is instructive to mention that separability of preferences and two-stage or multi-stage budgeting imposes restrictions on consumer behaviour. The idea of separable groups limits the possibility of commodity substitution between different groups. This inadequacy is overcome to some extent when goods that are related to one another either as substitutes or complements are put into one group, which may likely be the case for the two suspected complementary goods under consideration in this study.

5.2.3 Consumer demand systems

Single or system of several demand equations could constitute a consumer demand system and could employ complete or incomplete (partial) system of demand equations in the modelling process, depending on the category of commodities considered and data availability. This section briefly discusses these issues together with the properties of consumer demand systems and approaches employed in deriving such systems.

5.2.3.1 Complete versus incomplete demand systems

The category of commodities under study and the stage of expenditure allocations to various commodities determine the choice of a complete or incomplete system of consumer demand equations. Highly aggregated commodities may feature at an earlier stage in household

budgeting whereas disaggregated commodities may require several stages (multi-stage) of expenditure allocation to individual goods. For example, households could broadly categorise commodities into food and non-food groups for purposes of expenditure allocation. This constitutes the fist stage. At the second stage, the food group could further be disaggregated into food crops and animal products. A third-stage of expenditure allocation is possible if the interest, for example, is to study the demand for grains, tubers, and vegetables in the food crop group. The notion of separability, two- and multi-stage budgeting allows the use of an incomplete demand system to study the demand for food crop products. The expenditure considered at this stage is that devoted to only food crops. However, when household expenditures are allocated to broad groups such as food, education, housing, health, energy at the first stage of household budgeting, then a complete demand system is plausible, assuming expenditure data are readily available.

5.2.3.2 Single versus demand system equations

Empirical studies on household demand for goods have adopted either single equations (single demand function) or system of demand equations that could be complete or incomplete (partial) system as discussed above. The use of single equations sometimes does not conform to microeconomic theory of consumer demand behaviour. For example, quantity projections may violate household budget constraints (Sadoulet and Janvry, 1995; Ryan and Wales, 1996) in single demand equations. This is because consumers in practice face several commodity choice situations that lead to complex decision-making procedures. Consequently, budgetary constraints are unavoidable, leading to rational consumer behavioural patterns. Frohberg and Winter (2001) mention the necessity for rational consumer demand behaviour to conform to fundamental properties of demand, which are *adding-up*, *homogeneity*, *symmetry* and *negativity* properties. These properties are briefly explained in the following section.

5.2.3.3 Properties of consumer demand systems

The property of adding-up stipulates that the total value of commodity demands (from both the Marshallian and Hicksian demand functions) should add up to total household expenditure. The property of homogeneity states that the Marshallian demands are homogeneous of degree zero in prices and total income (or expenditure) whilst the Hicksian demand is homogeneous of degree one in prices. Homogeneity further implies the absence of "money illusion" in that when prices and income increase by a fixed factor, quantities

purchased remain unaffected. Symmetry property indicates that the cross-price derivatives of Hicksian demands are symmetric. This property derives from Young's Theorem suggesting that the order in which a function is differentiated with respective to two of its arguments is irrelevant since it does not change the value of the derivative (Chiang, 1984). The negativity property suggests that the n-by-n substitution or Slutsky matrix formed by the elements of cross-price derivatives of Hicksian demands is negative semidefinite.

One other condition often violated in consumer demand and supply models, according to Frohberg and Winter (2001), is *curvature* or *concavity* property. Curvature conditions stipulates that, (1) the direct utility function of households should be quasi-concave in quantities (this implies convexity of preferences), (2) the indirect utility function should be quasi-convex in prices, (3) the reciprocal indirect utility function should be quasi-concave in prices, and (4) the expenditure function should be concave in prices (Ryan and Wales, 1996). These conditions then require that the Slutsky matrix associated with the corresponding demand system be symmetric negative semidefinite. These conditions are often violated in consumer demand systems so they have to be imposed. Imposing curvature conditions locally (that is at specific points in the sample) does not necessarily destroy the flexibility of the underlying functional form whilst global imposition often does.

5.2.3.4 Approaches to specify consumer demand systems

The possible non-adherence of single equation models to fundamental demand properties necessitates the application of a system of demand equations to empirically estimate demand for goods and services. Economic literature identifies three separate approaches followed to specify consumer demand models (Sadoulet and Janvry, 1995). First, a utility function is specified and then maximised subject to a budget constraint to derive Marshallian demand functions. The Linear Expenditure System (LES), Cobb Douglas, and the Constant Elasticity of Substitution (CES) demand systems are examples that use this approach. Second, a Marshallian demand function is specified directly and a set of parametric constraints are devised to ensure that the properties governing the demand function are guaranteed. Such demand functions are formulated without reference to a preference function, such as a direct, indirect utility or cost function. The double-log demand system uses this approach.

A third, the dual approach involves the minimisation of expenditure subject to a given utility level to yield an expenditure function (consumer demand theory) or cost function (in the case

of production theory). The expenditure function (with commodity prices and utility as arguments) that gives the minimum expenditure needed to achieve a fixed level of utility has the following properties: (1) *Monotonicity*: non-decreasing in prices and increasing in utility, (2) *Homogeneity*: homogeneous of degree one in prices (but demand functions are homogeneous of degree zero in prices and incomes), (3) *Curvature*: concave in prices (also implies convexity of preferences). This property suggests that increases in price result in at most proportional increases in expenditure[21], (4) *Continuity*: continuous in prices and must be first and second differentiable everywhere along the function and (5) *Shephard's lemma*: this states that if $h_i(p, u)$ is the expenditure minimising demand necessary to achieve utility level u at prices p, then $h_i(p, u) = \partial e(p,u)/\partial p_i$ for i = 1, ..., N where $\partial e(p,u)$ is the expenditure function and it is assumed that the derivative exists and $p_i > 0$.

An expenditure function is then specified and mathematically inverted to give the indirect utility function (which depends on prices and income) and by applying Roy's identity to the indirect utility function[22], the Marshallian demand function is derived and then specified in budget shares. The Almost Ideal Demand System (AIDS), member of the group of flexible functional forms[23], is obtained using this approach. The dual approach is applicable in situations where commodity prices are readily available whilst the primal approach favours situations where quantities of purchased commodities are available. The quantities of goods q that solve the utility maximising problem (primal) also solve the expenditure minimisation problem (dual) (Varian, 1992).

5.2.4 Desirable properties of functional forms

The choice of an appropriate functional form to estimate economic relationships is very important because the function must closely approximate the actual relationship between exogenous and endogenous variables. Functional forms could be selected ex ante or ex post.

[21] As noted by Elsner (2001), the violation of this property may result in positive compensated own price elasticities in empirical estimations.

[22] An alternative approach is to start with an expenditure function to obtain the Hicksian demand function by applying Shephard's Lemma (i.e., this requires partially differentiating the expenditure function with respect to price). However, because the Hicksian demand function is unobservable (as it depends on utility which is not observable), the expenditure function is then mathematically inverted to give the indirect utility function (which depends on prices and income) that is then substituted into the Hicksian demand function to obtain a Marshallian demand function (see Deaton and Muellbauer, 1980).

[23] Diewert (1974, p.113 as cited by Ryan and Wales, 1996) defines a functional form as flexible (second-order flexibility) if it is capable of attaining arbitrary quantities demanded, income derivatives, and own and cross price derivatives at a specified price-income situation.

Ex ante functional form is the algebraic functional form chosen before the actual empirical estimation is performed. The choice is based on a priori information not specific to the data set available. For ex post functional forms, a particular functional form is selected based on estimated results and sometimes predictive tests of several functional forms using actual data and the "best" chosen. What follows in the remaining of this section draws heavily on Lau (1986) where desirable properties of ex ante functional forms are discussed. Lau (1986) lists five important criteria or properties that need consideration when selecting an algebraic functional form ex ante to eventually build an econometric model. These are: (1) theoretical consistency, (2) domain of applicability, (3) flexibility of the functional form, (4) computational facility and (5) factual conformity.

5.2.4.1 Theoretical consistency

For a selected functional form to be theoretically consistent implies that it possesses all the theoretical properties of the economic relationship being studied for an appropriate choice of parameters. For example, a complete system of demand functions for consumers who are assumed to maximise utility subject to a budget constraint must adhere to *adding-up*, *homogeneity*, *symmetry,* and *negativity* properties of demand. Using symmetry and negativity as examples, demand functions should have a negative semi-definite Jacobian matrix and a symmetric Slutsky substitution matrix for an appropriate choice of parameters within the whole range of the variables of interest (globally) or for a close range (locally). Similarly, specified cost functions should possess these desirable properties.

5.2.4.2 Domain of applicability

The domain of applicability mainly refers to the range of values of the independent variables over which the functional form satisfies all the requirements of theoretical consistency. This range is usually the set of positive prices of both commodities and household incomes (for system of consumer demand functions) and the set of positive input prices (for cost functions). If the functional form is theoretically consistent over the whole range of the set of independent variables, it is said to be globally theoretically consistent or valid and if it applies over a short range, it considered being locally valid.

5.2.4.3 Flexibility

Flexibility refers to the ability of a functional form to approximate arbitrarily a theoretically consistent behaviour using appropriate parameters. With respect to consumer demand

systems, Lau (1986) defines a functional form as flexible "… if at any given set of nonnegative (positive) prices of commodities and income or total expenditure the parameters, α, of the complete system of consumer demand functions can be chosen so that the consumer demand and their own and cross-price and income elasticities are capable of assuming arbitrary values at the given set of prices of commodities and income subject only to the requirements of theoretical consistency." In other words, if an indirect utility functional form for instance, can provide any set of theoretically consistent values of the first and second derivatives (i.e., own and cross-price elasticities) and possibly the third derivative, such a function is said to be flexible. The more information in terms of parameters one can generate from higher order derivatives, the higher the degree of flexibility of that functional form.

Flexible functional forms allow quadratic and interaction terms in the explanatory variables and are linear in parameters (Lau, 1986), which is obviously a desirable property in empirical applications. Examples of flexible functional forms include the Rotterdam model by Theil (1965), the translog model by Christensen, Jorgenson, and Lau (1975), the generalised Leontief functional form by Diewert (1971) and the Almost Ideal Demand Systems (AIDS) model by Deaton and Muellbauer (1980). Moreover, the AIDS model has additional advantages in that it can be aggregated over individuals and easy to impose constraints or later test theoretical restrictions like adding-up, homogeneity of degree zero in prices and income and symmetry (Deaton and Muellbauer, 1980; Nevo, 1999). After the advent of the AIDS model, there have been several extensions to enrich it. Notable among them are the Generalised Almost Ideal Demand System (GAIDS) proposed by Bollino (1990), the Inverse AIDS (IAIDS) by Moschini and Vissa (1992), the Quadratic AIDS (QAIDS) by Banks *et al.* (1997) and the Semi-Flexible AIDS (SFAIDS) developed by Moschini (1998). The Linear Expenditure System (LES) by Stone (1954) that pioneered the complete demand system modelling approach, is inflexible in representing consumer behaviour, does not allow for complementarities between pairs of goods, does not allow negative income elasticities (inferior goods) and has linear Engel curves (Conniffe, 2001, 2002).

5.2.4.4 Computational facility

The computational facility of a functional form implies the following desirable properties:

- It should be *linear-in-parameters*. This implies that the unknown parameters should be easy to estimate from the data. The double logarithm functional form is an example of a linear in parameter functional form that has the constant-elasticity property,

suggesting that the parameters are independent of the units of measurement of the variables, certainly a desirable property.

- It should be *explicitly representable*, meaning that the function and its derivatives are represented in an explicit closed form, thus making it easy to estimate the values of different quantities of interest and their derivatives with respect to the exogenous variables. Homothetic utility functions are known to have this property and the specification of an indirect utility function right from the onset guarantees the property of explicit representability.
- There should be *uniformity* of the functional forms in the complete system of either the consumer demand functions or cost-minimising input demand functions. This suggests that the different functions in the given demand system, for example, should have the same algebraic functional form but with different parameters. This obviously excludes a system with only one function. This property thus makes computations easy.
- The functional form should be *parsimonious* so that the number of parameters should be the minimum necessary to achieve a desired level of flexibility. This is essential when considering the degrees of freedom in estimating functions with several parameters and fewer observations.

5.2.4.5 Factual conformity

It is required that the functional form chosen should *conform* to known empirical facts concerning the relationship being studied. Engel's Law, for example, is one of the known empirical facts about consumer demand behaviour and it indicates that the income elasticity of necessities, such as food, is less than unity. As homotheticity implies an income elasticity of unity for commodities, the implication of sticking to Engel's Law excludes the use of direct or indirect homothetic utility functions. Another implication of an accepted fact that not all Engel curves are linear in income suggests that the Gorman condition can be used as an approximation for analysing aggregate consumer demand.

It is evident that no algebraic functional form can simultaneously possess all these desirable properties. For example, strictly basing the ex ante choice of a functional form on empirical facts excludes the use of homothetic utility functions. However, according to Lau (1986), all known complete system of consumer demand functions for three or more commodities that

are theoretically consistent and are linear in parameters have unitary income elasticities for all the commodities. Therefore, selecting theoretically consistent functional forms imply foregoing the linear in parameters property. In effect, one has to forgo some of the desirable properties especially in the area of domain of applicability since it may be unpractical to compromise on theoretical consistency, flexibility and perhaps computational facility (Lau. 1986). He adds that, the surest way of having a theoretically consistent and flexible system of consumer demand functions is to specify a nonhomothetic indirect utility function and then use Roy's Identity to derive the system of demand functions.

The AIDS model seems to be a likely candidate to be employed in this study by virtue of its desirable properties. Moreover, its functional form makes it possible to achieve the set objectives of this study. However, one needs to be circumspect in that various functional forms end up with very different empirical results, meaning that the choice of functional form matters (Al-Qunaibet and Johnston, 1985 in Hanemann, 1998).

5.3 Household water demand within the Almost Ideal Demand System (AIDS) modelling framework

The demand for water in this study is modelled using the dual approach discussed earlier in section 5.2.3.4. Assuming the applicability of two-stage budgeting which implies weak separability of preferences, the households optimisation problem is specified as one of minimising expenditures on water subject to a targeted utility level.

Deaton and Muellbauer (1980) indicate that the assumption of weak separability and the existence of subutility functions imply the specification of subindirect utility functions and corresponding expenditure functions. The implication is that budget shares within each group are independent of the total group expenditure, and thus suggesting that luxuries and necessities can not be grouped together. Equation 5.4 specifies an indirect subutility function of the original AIDS model for the water group $u_w(.)$ as:

$$u_w(y_w, p) = \frac{\ln\left(\frac{y_w}{a(P)}\right)}{b(p)} \tag{5.4}$$

where y_w denotes total water expenditure and p denotes price of water. The ratio $y_w/a(P)$ denotes total water expenditure in real terms where $a(P)$ denotes a price index used to deflate current water expenditures and $b(p)$ denotes a function with price as its argument which is expressed as:

$$\ln b(p) = b_0 + \sum b_i \ln p_i \;\; ; \; \sum b_0 = 0 \; .$$

The price index $a(P)$ takes the form:

$$\ln \; a(P) \; = \; \alpha_0 + \sum_i \alpha_i \; \ln(p_i) + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \; \ln(p_i)\ln(p_j)$$

where b_i, α_0, α_i and γ_{ij} denote parameters to be estimated. Assuming that consumer preference in the long-run can be represented by Price-Independent Generalised Logarithmic (PIGLOG) specification[24], the expenditure function associated with equation (5.4) proposed by Deaton and Muellbauer (1980) is expressed as follows:

$$\ln \; c(u, P) \; = \; \ln a(P) + \ln b(p)$$

$$\ln \; c(u, P) \; = \; \alpha_0 + \sum_i \alpha_i \; \ln(p_i) + \frac{1}{2}\sum_i \sum_j \gamma^*_{ij} \; \ln(p_i)\ln(p_j) + \prod p_i^{b_i} u \qquad (5.5)$$

where *c* denotes the minimum expenditure or consumption required to attain a fixed level of utility at given prices, *P* denotes a vector of prices and p_i and p_j denote prices of the ith and j^{th} commodity respectively. The other parameters and variables are as defined above. The idea is to get close to the true unknown functional form of this expenditure function with a specific functional form that has enough parameters to be regarded as reasonable. For this expenditure function to be well behaved, the following restrictions on the parameters are imposed:

$$\sum_i \alpha_0 = 1, \quad \sum_i \alpha_i = \sum_i \gamma^*_{ij} = \sum_j \gamma^*_{ij} = 0 \qquad (5.6)$$

[24] These are flexible demand systems that express budget shares as linear functions of the logarithm of total expenditure.

Substituting equation (5.5) into the indirect utility function (5.4) and then applying Roy's identity yields the water budget shares which are functions of total expenditure and prices:

$$w_i(p, y_w) = \frac{\partial \ln a(P)}{\partial \ln p_i} + \frac{\partial \ln b(P)}{\partial \ln p_i} In\, y_w \qquad (5.7)$$

where $w_i(p, y_w)$ is the budget share on the ith water use, p_i is the price of the ith water use and y_w is the total expenditure on water. From equation 5.7, the AIDS model budget share equation is then empirically expressed as:

$$w_i \;=\; \alpha_i + \sum_j \gamma_{ij} \;\ln(p_j) + \beta_i \;\ln \frac{y_w}{P} + \;\mu_i \quad i \;=\; 1,\ldots,N \qquad (5.8)$$

where P is the Stone price index and μ_i is the random disturbances with a zero mean and constant variance. Note that good w_i is a necessity (luxury) if β_i is less than (greater than) zero. This Stone price index is expressed as:

$$\ln P \;=\; \alpha_0 + \sum_i \alpha_i \;\ln(p_i) + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \;\ln(p_i)\ln(p_j) \qquad (5.9)$$
$$i \;=\; 1, \ldots, N \quad j \;=\; 1, \ldots, N$$

Under symmetry conditions, the parameters γ_{ij} 's are defined as:

$$\gamma_{ij} \;=\; \frac{1}{2}\left(\gamma_{ij}^* + \gamma_{ji}^*\right) = \;\gamma_{ji} \quad j \;=\; 1, \ldots, N \qquad (5.10)$$

Equations (5.8), (5.9) and (5.10) constitute the AIDS model. As noted by Moschini (1998), the AIDS model easily satisfies the adding-up (or Engel aggregation) property. However, to investigate whether adding-up, homogeneity and symmetry properties hold, the following constraints are imposed on the parameters of the AIDS model of equation 5.8:

$$\sum_i \alpha_i = 1, \;\sum_i \beta_i = 0, \;\sum_i \gamma_{ij} = 0, \;\sum_j \gamma_{ij} = 0, \quad \gamma_{ij} = \gamma_{ij} \qquad (5.11)$$

The first three constraints in (5.11) are *adding up* constraints for all *j* whilst the forth and fifth are the *homogeneity* and *symmetry* constraints. However, the *Slutsky* and *curvature* properties are difficult to impose in practice so they are checked after estimating the model. Two problems that plague the AIDS model (5.8) are that the price index given in (5.9) is non-linear in parameters, thus raising estimation difficulties and second, the theory of the household does not provide any empirically plausible values for the intercept. The next section reviews the choice of an appropriate price index to linearise the parameters.

5.3.1 Choice of price index to linearise the AIDS model

Price indices reflect the cost of living or expenditure outlays of consumers between two given periods. They measure the pure price component of the cost of living and are not affected by changes in quantities consumed. Excluding the Stone (Translog) price index, several price indices are potential candidates for use in the AIDS model. These include the Fisher, Paasche, Laspeyres, and Divisia (or Törnqvist) price indices. To explicitly account for or reflect the importance of different goods consumed by households, most of these indices, if not all, employ the use of "weights". Larger weights are attached to commodities that are more often purchased and therefore important to households' commodity basket.

The Laspeyres and Paasche price indices employ weighted means of price relatives and also compare expenditures at two points in time. Given that $\sum p_{i0}q_{i0}$ and $\sum p_{it}q_{it}$ denotes the total household expenditures on the ith commodity for the base (0) and current period (t) respectively, and p_i and q_i denotes price and quantity of commodity i respectively, the Laspeyres price index P^L expressed in its aggregative form is given as:

$$P_{0t}^L = \frac{\sum p_t q_0}{\sum p_0 q_0} \tag{5.12}$$

This index uses base year quantities of commodity purchased q_0 to place "weights" on prices whilst the Paasche price index P^P, expressed as:

$$P_{0t}^P = \frac{\sum p_t q_t}{\sum p_0 q_t} \tag{5.13}$$

uses the current year quantities q_t to “weight” prices. The important difference to note is that the Laspeyres price index uses base year quantities in the numerator and denominator whilst the Paasche price index does likewise by using current year quantities. Both indices avoid the ambiguity associated with the cost of living (or Value) index (von de Lippe, 2002). The ambiguity arises because the Value index, V_{ot} index, expressed as:

$$V_{ot} = \frac{\sum p_{it} q_{it}}{\sum p_{i0} q_{i0}} = \frac{\sum p_t q_t}{\sum p_0 q_0} = \frac{p_t q_t}{p_0 q_0} \tag{5.14}$$

does not measure pure price effect because both price and quantity change at the same time. For purposes of estimating the cost of living index, Von de Lippe (2002) notes that whilst the Laspeyres price index is commonly expressed as the weighted arithmetic mean of price relatives, where the weights are relative expenditure in the base year, the Paasche price index is commonly expressed as a weighted harmonic mean of price relatives, where the weights are expenditure shares in the current period t. The two indices in price relatives are given as:

$$P_{0t}^{L} = \sum \frac{p_t}{p_0} \left(\frac{p_0 q_0}{\sum p_0 q_0} \right) \tag{5.15}$$

$$\left(P_{0t}^{P} \right)^{-1} = \sum \frac{p_{i0}}{p_{it}} \left(\frac{p_{it} q_{it}}{\sum p_{it} q_{it}} \right) \tag{5.16}$$

Equation (5.13) is mathematically equivalent to (5.15) whilst that of (5.14) is equivalent to (5.16). The only difference lies in their interpretation and its applicability: the Laspeyres price index infer rising prices directly from rising costs of fixed budgets whilst conceptualising price movements in the Paasche price index calculation is indirect (Von de Lippe, 2002). Another index, the Fisher “ideal” index, P_{0t}^{F} is a combination of Laspeyres and Paasche indices, expressed as $P_{0t}^{F} = \sqrt{P_{0t}^{L} P_{0t}^{P}}$. This is of less importance insofar as “linearising” the AIDS model is concerned.

Feenstra and Reindorf (1999) define the Divisia price index as an expenditure-weighted integral of price changes between an initial and a final point. Assuming p_0 and p_1 are commodity prices for period 0 (base period) and period 1 (current period), the Divisia price index P^D is then expressed as:

$$\log P^D = \int_0^1 w_t \, \dot{p}_t \, dt \qquad (5.17)$$

where w_t denotes a vector of budget shares of commodities in period t and $\dot{p}_t$ denotes a vector of log price changes ($(\partial p_{it}/\partial t)/p_{it}$) with p_{it} representing the price of the ith commodity in period t. Usually, $\dot{p}_t$ takes the form $\log(p_1/p_0)$ in practice and uses a geometric mean in weighting prices. The Divisia price index is dependent on the path chosen (for example, choosing a log-linear functional form) for commodity prices when the underlying utility function is nonhomothetic. Feenstra and Reindorf (1999) indicate that when the path chosen is a straight line for the log of price and income, the estimated price index gives a good approximation for $\log(P^D)$ in almost any demand model.

These indices take different form when applied to linearise the AIDS model. The applied forms used to linearise the AIDS model are expressed as follows:

$$\ln P_t^L = \sum_i w_{i0} \ln p_{it} \qquad \text{Laspeyres price index}$$

$$\ln P_t^P = \sum_i w_{it} \ln(p_{it}/p_{i0}) \qquad \text{Paasche price index}$$

$$\ln P_t^D = \frac{1}{2}\sum_i (w_{it} + w_{i0}) \ln(p_{it}/p_{i0}) \qquad \text{Divisia price index}$$

where w_{i0} in the Laspeyres price index denotes the geometric mean of budget shares in period 0 (base period), w_{it} in the Paasche price index denotes the harmonic mean of budget shares in period *t*. The Divisia price index denoted by P_t^D is a linear combination of the Laspeyres and Paasche price indices and also uses geometric means as weights for price. In

practice, price of the ith commodity in period t (times series) is replaced with price of the ith commodity that pertains in a given cross section or location. The Stone price index P^S is expressed as:

$$\ln P^S = \sum_i w_i \ln(p_i) \qquad i = 1, \dots, N \tag{5.18}$$

where w_i is the arithmetic mean budget share of the commodities involved is widely used to "linearise" the AIDS model (Asche and Wessells, 1997). Yet, this index has been criticised because it is bound to introduce units of measurement error (Alston, Foster, and Green, 1994; Moschini, 1995, and Asche and Wessells, 1997). It does not satisfy the fundamental properties of index numbers because the index takes on different values (i.e., lack of invariance) when the unit of measurement of prices changes. In other words, the Stone index depends on the units in which prices are measured.

Moschini (1995) and Chern *et al*. (2002) suggests the scaling of prices by their sample mean to correct for the units of measurement error problem associated with the Stone price index. However, Buse and Chan (2000) demonstrate that mean-price scaling of the Stone index does not solve the invariance problem and adds that the Paasche index is as unsatisfactory as the Stone index. An important finding by Buse and Chan (2000) is that the other proposed invariant indices all generate biased and inconsistent estimators. Buse and Chan (2000) further add that when prices are highly positively collinear, the Laspeyres price index does better whilst the Divisia price index is more appropriate under mixed or zero collinearity.

Deaton and Muellbauer (1980) indicate that the exact form of the price index is irrelevant in terms of the results obtained. But Monte Carlo studies by Henningsen (2003) on how to estimate the AIDS model conclude that LAIDS estimation using the Divisia or Laspeyres price index gives acceptable estimates of elasticities and the mean-scaling of prices does not bias the results.

Based on the above observations, this study employs the Laspeyres price index, P^L to linearise the AIDS model. It is empirically expressed as:

$$\text{In}\, P^{L} \;=\; \sum_{i} \overline{w}_{i}\ \text{In}(p_{i}) \tag{5.19}$$

where $\overline{w}_i$ denotes the geometric mean of budget shares for the ith good. The Laspeyres price index is preferred to other indices because it is the only index that measures the pure price component (von de Lippe, 2002). Substituting (5.19) into the AIDS model (5.8) yields in the Linearised Almost Ideal Demand System (LAIDS):

$$w_{i} \;=\; \alpha_{i}^{*} + \sum_{j} \gamma_{ij}\ In(p_{j}) + \beta_{i}\left(In\, y_{w} - \sum_{j} \overline{w}_{j} In(p_{j}) \right) + \ \mu_{i}^{*} \tag{5.20}$$

where $\alpha_{i}^{*} = \alpha_{i} - \beta_{i}\left(\alpha_{0} - \sum_{j} \overline{w}_{j}\ In(\overline{p}_{j}) \right)$ and $\overline{p}_j$ denotes the mean price of the jth commodity. Other variables maintain their usual meaning.

5.3.2 Inclusion of demographic variables in the LAIDS model

The LAIDS model has income and price as the only determinants of demand. This specification assumes that households behave similarly or have identical preferences and that socio-economic and demographic characteristics do not affect demand behaviour. Would it not be appealing, for example, to say that preferences of young couples may differ from that of elderly couples with several dependents? In like manner, differences in household size, levels of education, age composition, among others could determine household preferences. Moreover, it has been shown that socio-economic and demographic factors impact on the expenditure allocation of different goods. This necessitates the inclusion of these variables, which from the policy standpoint are important determinants of household water demand.

The issue that arises is whether to treat some or all the socio-economic and demographic variables as exogenous because of possible endogeneity that results in biased estimates. This possibility is ruled out in this study in that such socio-economic and demographic factors are less endogenous in the short run compared to household water consumption. As noted by Deaton and Muellbauer (1980), such biases in practice may not be very important due to the similar reasons advanced above.

Two broad approaches are often employed to incorporate policy relevant socio-economic and demographic variables into consumer demand analyses. They are introduced indirectly or explicitly into the analysis (Elsner, 2001). The indirect approach estimates separate demand systems on different sub-samples of households with similar socio-economic and demographic characteristics. The parameters of the sub-samples are compared and interpretations advanced regarding the impact of these variables on the dependent variables.

The explicit approach, as the name suggest, introduces these variables explicitly into the direct or indirect utility functions, the cost function or the demand system. Economic modelling of consumer demand systems over the last four decades has focused on this approach, dating from Barten (1964) who proposed a technique called Demographic Scaling based on the concept of equivalence scales[25] (Deaton and Muellbauer, 1980). Other approaches in this category include Gorman specification by Gorman (1976), Demographic Translation by Pollak and Wales (1978), modified Prais-Houthakker procedure attributed to Muellbauer (1980), Reverse Gorman proposed by Pollak and Wales (1981) and Price Scaling by Ray (1983). Each of these procedures modifies the original function (i.e., the direct or indirect utility function, cost function or demand function) by assuming that some parameters of the demand system, such as commodity prices depends on the socio-economic and demographic variables. This requires the specification of a functional form relating the parameters to the socio-economic and demographic variables, suggesting that these variables influence household utility or cost functions through prices. For example, the geographic location of households in communities (often proxied with dummy variables) or household size could influence the expenditure or demand for water. Nevertheless, the modified system of demand equations still remains consistent with consumer demand theory.

To account for effects of socio-economic and demographic variables on household water consumption, this study emulates Chern *et al* (2002) by applying linear demographic translation because it preserves the linearity of the LAIDS model whereas demographic scaling does not (Elsner, 2001). It is represented as:

[25] These are economic index numbers used to deflate the real income or welfare levels across households for purposes of comparison by taking into account demographic characteristics such as size and composition. The equivalence scales is based on the assumption that the only differences in tastes between households is only due to observable characteristics.

$$D_h(\pi) = \sum_{r=1}^{N} \phi_{h\mathrm{r}} H_r \tag{5.21}$$

where D_h denotes the translating parameters, H denotes a vector of socio-economic and demographic variables such as household size, sex, age and level of education and ϕ denotes their respective parameters. Other exogenous variables such as physical and water source characteristics (e.g., geographic location of community, distance to water source, water quality), and climate variables (e.g., seasons, temperature and rainfall) can be included in the model using dummy variables. With communities scattered across the basin, the inclusion of dummies may be important in capturing community or geographic heterogeneity prevalent in the data. Substituting equation (5.21) into (5.20) gives the translated LAIDS model to be estimated in this study.

$$w_i = \alpha_i^{**} + D_h + \sum_j \gamma_{ij} \, In(p_j) + \beta_i \left(In\, y_w - \sum_j \overline{w}_j In(p_j) \right) + \mu_i^{**} \tag{5.22}$$

where $\alpha_i^{**} = \alpha_i^{*} - D_h$ whilst the other variables and parameters have their usual meaning. The LAIDS model is estimated subject to adding-up, homogeneity and symmetry constraints. Adding-up property requires that not only the constant terms be constrained to 1, i.e., $\sum_i \alpha_i^{**} = 1$, but also the coefficients of the socio-economic and demographic variables, i.e., $\sum_r \phi_{h\mathrm{r}} = 0$, with r = *1,…, N*, where *N* denotes the number of socio-economic and demographic variables.

5.3.3 Price and expenditure elasticities

The derivative of equation (5.8) with respect to the logarithm of price, p_j gives the Marshallian (uncompensated) own price $(i = j)$ and cross price $(i \neq j)$ elasticities e_{ij}.

$$e_{ij} = -\delta_{ij} + \left(\frac{1}{w_i}\right)\left(\frac{\partial w_i}{\partial\, In\, p_j}\right) = -\delta_{ij} + \left(\frac{\gamma_{ij}}{\overline{w}_i}\right) - \beta_i \qquad \text{Own-price}$$

(5.23)

$$e_{ij} = -\delta_{ij} + \left(\frac{\gamma_{ij}}{\overline{w}_i}\right) - \left(\frac{\beta_i}{\overline{w}_i}\right)\overline{w}_j \quad , \quad \forall i, j = 1,\ldots,n \qquad \text{Cross-price}$$

where the Kronecker delta, δ_{ij}, equals 1 if $i = j$ and equals 0 if $i \neq j$. The derivative of the share equation (5.8) with respect to total logarithm of expenditure results in the expenditure elasticity η_i:

$$\eta_i = 1 + \left(\frac{1}{w_i}\right)\left(\frac{\partial w_i}{\partial In\, y_w}\right) = 1 + \left(\frac{\beta_i}{w_i}\right) \tag{5.24}$$

The Hicksian (compensated) price elasticities, s_{ij} which measure only price effects are derived as in equation (5.25) below. Other variables have their usual meaning:

$$s_{ij} = -\delta_{ij} + \left(\frac{\gamma_{ij}}{\overline{w}_j}\right) + \overline{w}_j \quad = e_{ij} + \eta_i\, w_j \qquad \forall i, j = 1,...,n \tag{5.25}$$

The most often reported elasticity is the uncompensated price elasticities because the Hicksian elasticity is based on an unrealistic assumption that consumers are compensated with income when price increases. The reality is that consumers instead reorganise the kinds and quantities of goods purchased at a given income and uncompensated elasticities measure exactly that. Nevertheless, the Hicksian elasticities are the most unambiguous.

5.3.4 Household water demand model for the Volta basin

This section is devoted to the empirical water demand model specification within the framework of the LAIDS model. The method for model estimation is presented and the hypotheses to be tested stated.

5.3.4.1 Empirical model specification

The theoretical framework developed earlier to estimate household water demand served as a starting point to build a model for empirical investigation. Among the group of flexible functional forms, the AIDS model was chosen based on its notable advantages such as the possibility of comparing budget allocations amongst consumer goods as the sum of the budget shares (dependent variables) equals unity. This could be in a complete or incomplete consumer demand system

Weak separability and two-stage budgeting are assumed for the water group, suggesting a water demand subsystem and not a complete demand system. Household water consumption comes from several sources such as boreholes, hand dug wells, river/stream/ponds, rainwater, water from neighbours, vendor purchased, bottled/sachet water and public tap/compound water. Total water consumption by each household is a summation of quantities consumed from these sources.

Water used for drinking and cooking and water used for other indoor purposes (such as dish washing, household cleaning, bathing etc.) are two aggregated goods of interest. Two goods imply the specification of two equations for the water demand subsystem. The first specifies the budget shares for water used for drinking and cooking and the second specifies that for water used for all other indoor purposes. Total budget on water equals the sum of the two budget shares. In this way, adding-up property holds because the sum of the budget shares adds up to one. From equation (5.22), the household water demand system of equations is econometrically specified as:

$$w_{1,h} = \alpha_1 + \phi_{1,h} D_{1,h} + \gamma_{11} \ln p_{1,h} + \gamma_{12} \ln p_{2,h} + \beta_1 \ln\left(Y_h / P^L\right) + \varepsilon_{1,h} \quad (5.26a)$$

$$w_{2,h} = \alpha_2 + \phi_{2,h} D_{2,h} + \gamma_{21} \ln p_{1,h} + \gamma_{22} \ln p_{2,h} + \beta_2 \ln\left(Y_h / P^L\right) + \varepsilon_{2,h} \quad (5.26b)$$

where

$w_{1,h}$ = budget share for water used for drinking and cooking by household *h*

$w_{2,h}$ = budget share for water used for other indoor purposes by household *h*

$D_{i,h}$ = vector of socio-economic and demographic variables for the ith equation

$\phi_{i,h}$ = coefficient of the socio-economic variables for the ith equation

$\ln p_{i,h}$ = the logarithm of water price for the ith use by household *h*

$\ln Y_h$ = the logarithm of total water expenditure by household *h*

α_i = a constant for the ith water use

γ_{ij} = own- or cross-price elasticity of water

β_i = expenditure coefficient of the ith water use

P^L = Laspeyres price index

$\varepsilon_{i,h}$ = random or stochastic disturbance with zero mean and constant variance for the ith water use by household *h*.

Demographic translation was selected as the approach to explicitly incorporate the effects of socio-economic and demographic variables including water source characteristics on water demand. Socio-economic factors (i.e., gender, education, household size, occupation and assets), characteristics of the supply/source in terms of opportunity costs, availability (quantity), quality and reliability of supply and household attitudes towards government policy and water service providers (Webster, 1999) are known to impact on water demand.
As the household survey pools data from 20 communities in 7 administrative regions, 6 regional dummies are introduced to capture the effects of location of each community on water consumption. With respect to water for drinking and cooking (good 1), the demographic translating parameters may be specified as:

$$\begin{aligned} D_{1,h} = \; & \phi_{h1}FEMALE + \phi_{h2}HS + \phi_{h3}ED + \phi_{h4}STORE + \phi_{h5}WC + \\ & + \phi_{h6}MTIME + \phi_{h7}MTHS + \phi_{h8}TREAT + \phi_{h9}DUMAR + \phi_{h10}DUMBA \\ & + \phi_{h11}DUMER + \phi_{h12}DUMNR + \phi_{h13}DUMUE + \phi_{h14}DUMVR \end{aligned} \tag{5.27}$$

where $D_{1,h}$ denotes the translating parameters of household h affecting good 1, FEMALE denotes the gender (1=female, 0=otherwise) of the household head, HS denotes net household size (excluding those who spend more than 6 months away from home), ED denotes the level of education of household head (1=education, 0=otherwise), STORE denotes the total water storage capacity (measured in litres) of water storage vessels, WC denotes the number of water carriers per households, MTIME denotes average time devoted to water collection, MTHS denotes an interaction term between HS and MTIME, TREAT denotes whether households treat water (1=yes, 0=otherwise), DUMAR, DUMBA, DUMER, DUMNR, DUMUE and DUMVR denotes dummy variables for the Ashanti, Brong Ahafo, Eastern, Northern, Upper East and the Volta regions respectively (1=yes, 0=otherwise). One of the communities in the Upper East region with the highest number of households is excluded from the model and reference made to it when comparing effects of location on water consumption.

Explicitly incorporating equation (5.27) into equation (5.26a) yields the econometric model to be estimated:

$$\begin{aligned} w_{1,h} \;=\; & \alpha_1 + \gamma_{11} \ln p_{1,h} + \gamma_{12} \ln p_{2,h} + \beta_1 \ln(EXP) \\ & + \phi_{h1} FEMALE + \phi_{h2} HS + \phi_{h3} ED + \phi_{h4} STORE + \phi_{h5} WC + \phi_{h6} MTIME \\ & + \phi_{h7} MTHS + \phi_{h8} TREAT + \phi_{h9} DUMAR + \phi_{h10} DUMBA + \phi_{h11} DUMER \\ & + \phi_{h12} DUMNR + \phi_{h13} DUMUE + \phi_{h14} DUMVR + \varepsilon_{1,h} \end{aligned} \qquad (5.28)$$

where EXP denotes the real total household expenditure on water. The error term denoted by $\varepsilon_{1,h}$ captures model misspecification or other important variables that may explain household water demand but are excluded from the set of explanatory variables. They are assumed to be independent with each having a multivariate normal distribution with $E(\varepsilon_h) = 0$ and $E(\varepsilon_h \varepsilon'_h) = \Omega$, where Ω is constant over time (i.e., homoscedastic). The other parameters and variables have their usual meaning.

5.3.4.2 Method of estimation

The Laspeyres price index P^L is employed as an appropriate index to linearise the AIDS model before estimation. In terms of good 1, the index is expressed as $P_h^L = \sum_{i=1}^{2} \overline{w}_i \ln p_{i,h}$, where $\overline{w}_i$ denotes the geometric mean budget share of good *i*. The price index is thus a geometrically weighted average of prices. These are first estimated separately outside the model for all households and then substituted into equation (5.26).

The application of the LAIDS model to household water consumption does not suffer from the usual econometric problem of censored dependent variable when zero consumption of some goods is present in the data set. All households in this study have positive water consumption for the two goods. Consequently, the Heckman two-stage approach is not required. However, because the dependent variables in this model are budget shares that must satisfy the budget constraint, their error terms are correlated although they seem unrelated. The application of Ordinary Least Squares (OLS) may not give efficient estimates but Seemingly Unrelated Regression (SUR) model developed by Zellner (1962) provides efficient estimates that first estimate the variance-covariance matrix among the residuals by OLS and in the second stage uses this matrix in Generalised Least Squares (GLS) estimation.

Due to the singular matrix generated because of adding-up property, the SUR procedure deletes one of the expenditure share equations in the water demand system. The budget share

equation for water used for drinking and cooking is maintained and parameters of the deleted budget share equation (i.e., water used for other purposes) is recovered by virtue of the adding up, homogeneity and symmetry restrictions imposed on the model. Specifically, the Iterative Seemingly Unrelated Regression (ITSUR), which is equivalent to full Information Maximum Likelihood (FIML) estimation can be applied as it generates estimates that are invariant to the equation excluded.

A unique problem arises when Iterative Seemingly Unrelated Regression (ITSUR) procedure is applied to only two equations in a demand system. After dropping one of the two equations, ITSUR procedure fails to estimate the coefficients for the maintained equation. An alternative approach that imposes constraints on the parameters of the model to satisfy consumer demand theory is needed. Constrained Linear Regression (CLR), which is a single equation method, estimates the model equation by equation by Ordinary Least Squares (OLS) procedure with constraints imposed. For the water demand system to conform to economic theory of consumer behaviour, homogeneity and adding-up constraints are imposed on the model during estimation. It must be noted that with only two goods, symmetry restriction does not imply any additional restrictions if homogeneity and adding-up are imposed. Elsner (2001) and Chen *et al*. (2002) mention the need to also impose restrictions on the translating parameters in order to have consistent demand system. This is not imposed in the above study. From equation (5.26), adding-up constraints requires that:

$$\alpha_1 + \alpha_2 = 1, \beta_1 + \beta_2 = 0, \gamma_{11} + \gamma_{21} = 0, \gamma_{12} + \gamma_{22} = 0, \sum_{i} \phi_{ir} = 0$$

and that of homogeneity (imposed globally on good 1) requires that:

$$\gamma_{11} + \gamma_{12} = 0, \gamma_{21} + \gamma_{22} = 0,$$

For the regularity conditions to hold, the coefficients α_i and β_i in the system must be greater than or equal to zero (Ryan and Wales, 1996). Curvature constraint is verified after estimation by examining the signs of the own-price and expenditure elasticity estimates.

Relevant ex post statistical tests are performed. The Lagrange Multiplier (LM) test for heteroscedasticity is performed. Possible model misspecification arises when an endogenous variable is specified as an exogenous variable, resulting in simultaneous equation bias in

conditional demand models. To check if expenditure (EXP) departs from exogeneity, the Durbin-Wu-Hausman test is employed (Greene, 2000), where a rejection of the null hypothesis of absence of endogeneity at a specified significant level requires model estimation through instrumental variables. In addition, homotheticity, which implies that the water budget shares are independent of total household expenditure, is tested by setting the parameter β_1 equal to zero. A homothetic model has unitary expenditure elasticity and has linear Engel curves.

5.3.4.3 Hypotheses

The study makes the following hypotheses regarding the independent effects of explanatory variables on water demand for drinking and cooking. It is hypothesised that female headed-households would allocate more to drinking water because of the likelihood of them knowing the importance of using adequate water for drinking and cooking, *ceteris paribus*.

It is expected that households with more members would require more water for several activities, ceteris paribus. The possibility exits that due to economics of scale increase in household size may lead to a less than proportional increase in water consumption. However, Arbues *et al* (2000) report that beyond a certain threshold, economics of scale disappears and water consumption increases with household size. In such a case, water consumption may not necessarily go up with increase in household size but may rather increase at a decreasing rate. On the other hand, large household size could imply the availability of more water carriers and hence increase in consumption, *ceteris paribus*.

Some level of education of the household head (assumed to be the decision maker regarding water management at home) may reflect the knowledge of rationally economising on household water use for drinking and cooking. Moreover, this commodity is relatively expensive hence a negative relationship is expected between education and budget allocations to water for drinking and cooking. It is possible that knowledge of water-linked diseases such as skin irritation and eye diseases would also create the awareness to use adequate quantities for hygienic and sanitation purposes thus resulting in more water consumption. Therefore, the effect of educational level of the household head could be indeterminate. Nevertheless, a negative effect is expected.

The essence of having several storage vessels is to enhance household water security and therefore increase water availability. As water storage capacity increases, budget allocations to water for drinking and cooking is expected to decrease, *ceteris paribus* because water for such purposes are often stored in relatively smaller and separate vessels from that of water designated for other indoor purposes. The number of available water carriers, who are mainly women, is hypothesised to increase budget allocations to this good.

As more time is devoted to water collection, budget allocation to water for drinking and cooking is expected to reduce, ceteris paribus. The interaction between water collection time and household size is also hypothesised to reduce the share of this good in the household water budget. The treatment of water for drinking and cooking is expected to reduce budget allocations to this good because it increases the cost of acquiring that good. It is expected that irrespective of the regional location of all the communities in the basin, households would increase the budget share of drinking water because of its importance in achieving drinking water security. Hence a positive sign is expected for all the regional dummies.

Generally, the higher the price of a good, the less of it will be demanded leading to a reduction in budget share of that particular good. Own price elasticities for both goods are expected to be negative. Elasticities are estimated at their sample means. Variable descriptions, units of measurement and the expected effects on the dependent variable (water budget shares) are summarised in Table 5.1. With water considered as a normal good, i.e., consumption levels increase with higher income levels, it is hypothesised that the higher the household income (or expenditure), *ceteris paribus*, the more water is consumed.

Table 5.1: Description of variables, measurement units and expected effects on drinking water budget share (demand) model

Variables	Description	Measurement units	Expected effect on dependent variable
w_1	Budget share of water used for drinking and cooking	NA	*Dependent variable*
w_2	Budget share of water used for other household purposes	NA	*Dependent variable*
FEMALE	Gender of household head	Dummy	+
HS	Household size	Number	+
ED	Level of years of education of household head	Dummy	-
STORE	Water storage capacity	Litres	-
WC	Number of water carriers	Number	+
MTIME	Average time devoted to water collection	Hours	-
MTHS	Interaction between MTIME and HS	Hours	-
TREAT	Whether households treat water	Dummy	-
p_1	Price of water used for drinking and cooking	¢/litre	-
p_2	Price of water used for other indoor purposes	¢/litre	-
EXP	Household real expenditure on water	Cedi (¢)	+
DUM(XX)	Regional dummy variables	Dummies	+

Note: + denotes a positive effect on the dependent variable, - denotes a negative effect on the dependent variable, and NA denotes "no unit of measurement (dimensionless)".

5.4 Modelling framework for choice of improved water source

An estimation approach that adequately handles the joint problem of factors that determines the choice of an improved water source and quantities consumed from this source is the Heckman two-stage approach (1978). The first stage, which is a discrete choice problem, investigates the likelihood that households would use improved water sources whilst the second stage determines quantities of improved water consumed. This section develops the theoretical framework that underpins these household decision-making processes.

5.4.1 Discrete choice component (selection model)

Households have to decide on the water sources to use amongst other alternatives. In making these economic decisions they are faced with discrete alternatives rather than a continuous choice set of water sources. Modelling such decisions involves econometric analysis using discrete choice model developed by McFadden (1974).

Households are assumed to be rational in making economic choices that maximise their utility subject to budgetary and other constraints. Assume a household h faces a choice set J

of water sources, has utility function $U_h(.)$ and chooses alternative $j \in J_h$. Then according to the standard revealed preference argument, it implies that $U_h(j) \geq U_h(k)$ where all $k \in J_h$. It follows that the probability of a household chosen at *random* from the population with a utility function that makes j the utility maximizing alternative is given as:

$$P(j) = P\left[h: U_h(j) \geq U_h(k), \text{ for all } k \in J_h\right] \qquad (5.29)$$

Equation (5.29) is referred to as a Random Utility Model (RUM) that explains observed choices by households (Manski, 2001). Note that equation (5.29) does not have the ability to forecast consumer behaviour in new settings, when faced with different set of alternatives or when alternatives are no longer available, for example, when major water bodies permanently dry up. What the RUM can do is only describe observed behaviour by indicating that the choice made is what maximises household utility.

At this stage, the qualitative attributes of each alternative water source and household characteristics come into play. It is then assumed that each water source chosen is characterised by certain water source attributes whilst the household exhibits certain characteristics. Thus, the utility derived by household h in choosing alternative j is a function of a vector of water source attributes and a vector of household characteristics. It is expressed as:

$$U_{hj} = U_{hj}(x_j, \boldsymbol{c}_h) \qquad (5.30)$$

where x_j denotes water source attributes such as the price of improved water and water quality, and $\boldsymbol{c}_h$ denotes vectors of household characteristics. Equation (5.30) can be used to predict household's choice behaviour. The researcher does not know the exact form of the household utility function and optimisation problems encountered due to imperfections. Only a partial knowledge of the cross-sectional distribution of the missing attribute data on source and household characteristics is known. In that case, household utility function in equation (5.30) can be separated into deterministic and stochastic terms.

$$U(x_j, \boldsymbol{c}_h) = \widetilde{V}(x_j, \boldsymbol{c}_h) + \varepsilon_j \qquad (5.31)$$

where U denotes the unobservable conditional indirect utility function, $\widetilde{V}$ denotes the deterministic indirect utility which the researcher can observe and ε_j is the disturbance term that expresses the contribution of unobserved attributes to utility. It is assumed independent and identically type I extreme-value distributed.

Dow (1999) cited by Persson (2000) asserts that household utility conditional on choice j, can be specified as an additive linear function. Asthana (1997) adds that as far as water source attributes do not significantly influence household characteristics and vice versa allows the specification of additive utility functions. Thus, according to McFadden (1981) cited by Manski (2001), the household conditional indirect utility has the linear-in-parameter separable form.

$$U(c_h, x_j) = \alpha c_h + \beta x_j + \varepsilon_j \quad (5.32)$$

with α and β denoting the respective household and source attributes parameter vectors to be estimated. In choosing alternative j over alternative k the RUM suggests that the choice probability conditional on alternative j is given by:

$$P(j \mid c,x) = P\left[\alpha c_h + \beta_j x_j + \varepsilon_j \geq \alpha c_h + \beta_k x_k + \varepsilon_k, \ for\ all\ k \in J_h\right] \quad (5.33)$$

The dichotomous-choice model (selection model) to be estimated is specified as:

$$d_j = \beta_0 + \alpha c_h + \beta_j x_j + \varepsilon_j \quad (5.34)$$

where d_j denotes the selection of improved water source j by household h and $\varepsilon_j \sim N(0,1)$. The error term ε_j summarises the effects of unobserved determinants or characteristics on the likelihood of households opting for improved water. The variable d_j is defined as:

$$d_j = \begin{cases} 1 & if\ source\ j\ is\ chosen \\ 0 & otherwise \end{cases}$$

The choice (yes or no) of using an improved water source implies the use of limited dependent variable model. The estimation of the selection model represents the first stage of the Heckman two-stage estimation procedure where the decision for choice j is a function of water source attributes such as its price, distance to that source, perceived water quality, unobserved determinants of choice (also called alternative specific characteristics of water source) such as tastes or smell of water. Household size and age composition, gender, educational level of the household head and level of income are some household characteristics affecting such decisions.

5.4.2 Continuous choice component (outcome model)

After the decision to use improved water sources (selection), the next issue is to determine the factors that explain quantities of water demanded from this source (outcome). The selection and outcome decisions are assumed to be jointly or simultaneously taken and not sequentially.

Estimating the outcome decisions by selecting only households who use improved water may introduce sample selection bias that arises from the fact that quantities of improved water consumed are only observed when households decide to use improved water. It excludes households not using these available sources. This is equivalent to data censoring which may result in model misspecification, and thus tantamount to problems of omitted variables (Maddala, 1983) and giving rise to correlated errors. What is therefore missed is the impact of using an improved water source on the quantities of water consumed and this bias must be corrected for.

Heckman (1978) suggested a two-stage estimation procedure that corrects for the potential bias. It is estimated in one step but in two stages. The first stage, which is the selection model (5.34), estimates a dichotomous-choice probit regression to calculate the inverse Mills ratio (λ) (also called the hazard rate or function) for each household. This ratio is computed as follows:

$$\lambda_h = \frac{\phi_h(c, x)}{\Phi_h(c, x)} \tag{5.35}$$

where ϕ_h denotes the standard normal probability density function (pdf) and Φ_h denotes the standard normal cumulative density function (cdf). The inverse Mill's ratio, which is a measure of the odds of selection in the first stage, is retrieved for each household and used as an instrument in the second stage regression. The second stage uses households who responded yes to using improved water sources as observations in an Ordinary Least Squares (OLS) regression. The amount of improved water consumed is formulated as:

$$q_{imp} = \alpha_i + \sum_{k} \phi_{ik} \pi_k + \gamma_i p_i + \beta_i y_w + \psi_i \lambda_i + \varepsilon_i \tag{5.36}$$

where q_{imp} denotes the quantity of improved water consumed and ψ_i denotes the inverse Mills ratio coefficient whilst the other variables maintain their usual meaning. It is assumed that the residuals from the selection and outcome models are normally distributed with zero mean and variance of one:

$$\begin{aligned} &\varepsilon_j \sim N(0,1) \\ &\varepsilon_i \sim N(0,1) \\ &corr(\varepsilon_j, \varepsilon_i) = \rho \end{aligned} \tag{5.37}$$

The error terms will be correlated if the sample selection procedure in the first stage creates a bias. Hence, if the correlation of the error term, $\rho = 0$, it implies Heckman estimation procedure adds no additional information and the regressions could as well be run separately by OLS. If $\rho = 1$, it suggests the use of a Tobit model and if ρ lies between 0 and 1, it implies the presence of a selection bias, justifying the use of Heckman two-stage procedure. In other words, the two decisions are taken simultaneously. Given the above assumptions about their errors, the conditional expectation $E(.)$ of the outcome equation may be combined with the selection equation as:

$$\begin{aligned} E(q_{imp,i} \mid X_i, d_i = 1) &= X_i \beta + E(\varepsilon_i \mid d_i \geq 0) \\ &= X_i \beta + \sigma \rho M (Z_i \gamma) \end{aligned} \tag{5.38}$$

where $M(Z_i\gamma)$ denotes the inverse Mill's ratio, X and Z denotes the explanatory variables for the outcome and selection equations respectively and β and γ denote their respective coefficients.

5.4.3 Identification of parameters

The issue of identifying the selection and outcome equations is as important as the results produced by this model. Teo (2002) notes that "although rarely stated, the consequences of specifying identical sets of predictors for events that are governed by non-identical processes is simply omitted variable bias". This is the exact problem the Heckman model attempts to overcome. The exclusion restriction on identification requires that there should be at least one explanatory, instrumental variable in the selection equation that only affects the choice of using improved water source and not the quantities of water consumed from that source (Maddala, 1983). The cost of model misspecification or not explicitly identifying the parameters of the model is the inability of the model to converge or incorrect parameter estimates. It is however important to mention that Heckman two-step model is estimated when one believes that the quantities or the subsequent outcome depends upon prior choices made in the first stage of selection.

5.4.4 Discrete-continuous choice model for improved water

5.4.4.1 Empirical model specification and estimation method

The framework developed handles the discrete and continuous decision processes simultaneously by accounting for sample selection bias if any. The Heckman two-stage (Heckit) model procedure captures this impact[26]. The first-stage employs a binary probit model that estimates the probability that a given household consumes improved water whilst the second stage models the key determinants that explain the quantities of improved water consumed from this source.

Not all the 20 surveyed communities had access to improved and unimproved water sources. Therefore to explain the factors that influence households' decision to use improved water sources, only communities with access to both water sources were included in this analysis.

[26] It has to be pointed out that the Tobit model, which is applied to correct for bias in censored data can not be used in the case of water consumption considered in this study. This is because the issue of censorship does not apply in our context as there is no possibility of zero water consumption for households who use improved water.

There should be at least one improved and one unimproved water source available in a community to qualify for inclusion in the analysis. Water sources considered as improved include boreholes and public/stand pipes whilst unimproved sources include rivers, streams, ponds, hand dug wells and rainwater[27]. Fifteen of the twenty communities fulfilled this criterion for inclusion into this analysis. Recalling from equation (5.34), the binary probit model is empirically formulated as:

$$\begin{aligned} IMP_h = {} & \beta_0 + \alpha_1 LINCOME + \alpha_2 LPRICE + \alpha_3 LHS + \alpha_4 FEMALE + \alpha_5 ED \\ & + \alpha_6 LAGE + \alpha_7 LCHADT + \alpha_8 LSTORE + \alpha_9 LDISTBH + \alpha_{10} TREAT \\ & + \alpha_{11} SATISBH + \alpha_{12} DUMAR + \alpha_{13} DUMNR + \alpha_{14} DUMUE + \alpha_{15} DUMVR + \varepsilon_h \end{aligned} \quad (5.39)$$

where IMP_h denotes the choice for an improved water source by household h (1=yes, 0=otherwise), LINCOME denotes logarithm of total household income, LPRICE denotes the logarithm of price of improved water, LHS denotes the logarithm of net household size (excluding those who spend more than 6 months away from home), FEMALE denotes the gender of the household head (1=female, 0=male), ED denotes the level of education of household head (1=education, 0=otherwise), LAGE denotes the logarithm of age of the household head, LCHADT denotes the logarithm of children to adults ratio in the household, LSTORE denotes the logarithm of total water storage capacity (measured in litres) of water storage vessels, LDISTBH denotes the logarithm of average distance to an improved water source (borehole), TREAT denotes whether households treat water (1=yes, 0=otherwise), SATISBH denotes households perception of improved water quality (1=good, 0=otherwise), DUMAR, DUMNR, DUMUE and DUMVR denotes dummy variables for the Ashanti, Northern, Upper East and the Volta regions respectively (1=yes, 0=otherwise) and ε_h denotes the error term assumed to be normally distributed.

Equation (5.39) is estimated by Maximum likelihood method. The inverse Mills ratio (λ) is calculated for each household and used in the second stage of the estimation process to correct for the bias. The second stage applies OLS regression to determine the quantities of improved water consumed by those who actually use water from these sources. Equation

[27] WHO/UNICEF (2000) considers water from household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection as “improved“ water sources whilst unprotected wells, unprotected springs, vended water, bottled water (because of limited supply or quantity and not its quality) and tanker truck provision of water as “unimproved“ water sources. This classification is not strictly followed in this study especially regarding rainwater.

(5.40) includes an inverse Mill's ratio, (now denoted as MILLS) as an instrumental variable and is specified as:

$$\begin{aligned} LQTY_{imp,h} = {} & \beta_0 + \phi_1 LINCOME + \phi_2 LHS + \phi_3 LPRICE + \phi_4 FEMALE \\ & + \phi_5 ED + \phi_6 LAGE + \phi_7 LCHADT + \phi_8 LSTORE + \phi_9 LDISTBH \\ & + \phi_{10} LWC + \phi_{11} MILLS + \phi_{12} DUMAR + \phi_{13} DUMNR \\ & + \phi_{14} DUMUE + \phi_{15} DUMVR + \mu_h \end{aligned} \quad (5.40)$$

where $LQTY_{imp,h}$ denotes the logarithm of quantity of improved water consumed by the hth household, LWC denotes the logarithm of the number of available water carriers per household, MILLS denotes the inverse Mills ratio for household h, ϕ_{11} denotes the coefficient of the inverse Mills ratio which tests for the significance of the correlation between the errors of equations (5.39) and (5.40) and μ_h denotes the error term of the outcome equation, also assumed to be normally distributed. The other variables maintain their usual meaning. For purposes of parameter identification, it is important that equations (5.39) and (5.40) have different sets of explanatory variables (Maddala, 1983). Generally, Heckman two-stage approach uses Full Information Maximum Likelihood (FIML) as the estimation method.

If the coefficient ϕ_{11} in equation (5.40) is not statistically different from zero, it implies that the Heckman two-stage procedure adds no additional information because the purported sample selection bias is not a problem and the models could have been estimated separately. The sign of the coefficient ϕ_{11} depends on both the correlation between the errors (ε_h) and (μ_h) of the two equations and the correlation between the inverse Mills ratio and the explanatory variables in the outcome equation (5.40). It is more likely that the errors will be positively correlated because households who consume improved water are also more likely to have the propensity to opt for such sources.

5.4.4.2 Hypotheses for selection and outcome models

Higher household income is expected to result in the choice of improved water sources as well as increasing the quantity demanded from these sources because of more purchasing power to demand the good, *ceteris paribus*. Although the effect of age could be indeterminate in that older household heads may be more aware of health benefits of using improved water

thereby opting for improved sources, they may be traditionally oriented and likely to stick to unimproved sources probably due to tastes. This study expects older household heads to be more knowledgeable regarding the importance of choosing and demanding more improved water for health reasons. Hence a positive relationship is expected in both cases.

It is hypothesised that female-headed households are much more likely to use and increase consumption of improved water sources to minimise risks involved in using less quality water in the presence of better quality water, ceteris paribus. The expectation is that they would care more about health of their families.

Given household income and assuming that the price of improved water is more expensive than unimproved sources, households are less likely to use improved water sources the larger the household size because they have to pay more to secure enough water to satisfy household needs. This is more likely to be the case when other water sources are available free of charge. However, once the decision is taken to use this source, quantity consumed is expected to increase with household size.

The higher the price of improved water vis-à-vis unimproved sources, the more unlikely households will opt for it and therefore consume less of it, *ceteris paribus*. It is assumed that knowledge of health benefits associated with usage of quality water increases with years of education (either formal or informal). Hence, education is expected to translate into choosing and consuming adequate quantities of improved water, *ceteris paribus*. If improved water sources are far removed from the household whilst other unimproved sources are very close, they are less likely to use this source and thereby consuming less of it, all things being equal. The higher the water storage capacities, the more likely households would use and consume more water from improved sources. A similar positive effect is expected for the number of available water carriers.

The higher the children to adult ratio of household, the more likely improved water sources would be chosen and increased quantities consumed. The expectation is that household heads care about the health of their children and would want to consume quality water for better health. If households are to treat improved water, the less likely it would be used because of additional financial burden. Satisfaction with the quality of improved water would result in its usage, *ceteris paribus*. Finally, it is expected that due to unsatisfactory water security

conditions, households located in the entire basin would choose and consume adequate quantities of improved water when available, keeping everything else constant. Variable descriptions, units of measurements and the hypothesised effects of the determinants of choice and quantities consumed are presented in Table 5.2.

Table 5.2: Description of variables, measurement units and expected effects for the discrete-continuous choice model

Variables	Description	Measurement units	Expected effect on dependent variable	
			Selection model	Outcome model
IMP_h	Decision to use improved water source (1=yes, 0=no)	Dummy	*Dependent variable*	NA
$QTY_{imp,h}$	Demand for improved water	Litres/year	NA	*Dependent variable*
INCOME	Total household income	(¢)	+	+
PRICE	Price of improved water (borehole)	(¢/litre)	-	-
AGE	Age of household head	Years	+	+
FEMALE	Sex of household head (1=female, 0=male)	Dummy	+	+
HS	Household size	Number	-	+
ED	Number of years of schooling of household head	Dummy	+	+
DISTBH	Distance of improved water source from home	Metres	-	-
STORE	Household water storage capacity	Litre	+	+
WC	Number of water carriers per household	Number	NA	+
TREAT	Whether household treats water	Dummy	-	NA
SATISBH	Satisfied with quality of borehole water	Dummy	+	NA
CHADT	Child to adult ratio	-	+	+
MILLS	Inverse Mills ratio	-	NA	+
DUMAR	Ashanti region	Dummy	+	+
DUMNR	Northern region	Dummy	+	+
DUMUE	Upper East region	Dummy	+	+
DUMVR	Volta region	Dummy	+	+

Note: + denote a positive effect on the dependent variable
- denote a negative effect on the dependent variable
NA denotes "not applicable"

6 DISCUSSION OF RESULTS AND POLICY IMPLICATIONS

6.1 Introduction

This chapter presents estimation results of the analysis based on the empirical models developed in chapter 5. The choice for an appropriate water price variable to employ in the modelling exercise is justified. The Heckman two-stage estimation procedure is employed to model the likelihood of households using improved water and the quantities consumed from these sources. The translated and linearised AIDS model is used to estimate the coefficients of total water demand model by means of constrained linear regression using Ordinary Least Squares (OLS) estimation procedure. These estimates represent the second-stage of household budgeting where water expenditures are allocated between the two goods under consideration (i.e., water for drinking and cooking and water for other indoor purposes). Price and expenditure elasticities are then derived from the model. Policy implications derived from these results are discussed. STATA (version 8.2) is the econometric package used to generate the coefficients of the models presented.

6.2 Choice of water price variable

In Section 4.3, three approaches employed to derive opportunity costs of time allocated by women to water collection were discussed. These are the national daily minimum wage approach, the non-agricultural incomes of women approach and the agricultural income approach. Time was valued and subsequently used to estimate the price of water. The inherent merits and demerits associated with each approach were discussed and later ranked on qualitative and quantitative grounds in a decreasing order as follows: non-agricultural income of women approach, national daily minimum wage approach and the agricultural income approach (see section 4.3.3). However, due to problems of missing data in the price data for the preferred approach (i.e., non-agricultural income of women), it was dropped and replaced with the second best approach, i.e., the national daily minimum wage approach. Table 6.1 presents the number of observations before and after replacements of missing data for the estimated water price variables.

The water price variables using the other two approaches were also used in estimating the water demand models to compare their performance with the preferred choice. Based on their statistical properties such as expected signs of coefficients, significance of variables and root

mean square errors, they turned out to be unsatisfactory compared to the daily minimum wage approach. Furthermore, estimating their Marshallian and Hicksian own-price and cross-price elasticities yielded positive own-price elasticities, which is an undesirable situation that suggest the nonconformity to curvature condition in consumer demand behaviour. These statistical criteria further support the choice for the daily minimum wage approach.

Table 6.1: Number of observations before and after data processing

	Before data processing			After data processing		
Approach	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.
National daily minimum wage						
Water price (drinking and cooking)	501	489.00	30.37	501	489.00	30.37
Water price (other purposes)	475	9.69	8.19	501	9.48	8.05
Non-agricultural incomes of women						
Water price (drinking and cooking) [a]	501	223.36	1280.55	501	917.72	1543.68
Water price (other purposes)	121	14.49	33.90	450	19.17	24.68
Agricultural income						
Water price (drinking and cooking) [a]	501	664.83	4585.09	501	844.15	4604.37
Water price (other purposes)	375	21.74	163.62	501	20.79	142.63

[a] Having the same number of observations for the "before" and "after" data processing, the "after" observations had zero water price values replaced with their respective community mean values.

6.3 Choice and demand for improved water

Rural communities in Ghana still depend on traditional water sources such as rivers, streams, hand dug-wells and rainwater. Most of these sources are unsafe due to pollution and therefore serve as main sources of water-born and water-related diseases prevalent in rural communities (Gyau-Boakye and Dapaah-Siakwan, 1999). It is documented that about 70% of diseases in Ghana are linked to insufficient rural water supply and sanitation coverage (IFFM, 2002). In addition, this current study finds that approximately 8% of annual household income is spent on health and other related problems. It is therefore necessary to have a better understanding of factors that influence households' choice for improved water sources among available alternatives and the quantities consumed from these sources in order to circumvent potential health problems. This section deals with the empirical investigation of the determinants of this two-stage decision-making process in communities with access to improved and unimproved water sources.

Such decisions are conveniently modelled using the Heckman two-step procedure. The first stage, a dichotomous choice model, is estimated by means of binary Probit whilst the second stage is accomplished by Ordinary Least Square (OLS) procedure to examine the

determinants of quantities of improved water consumption. Sources of water considered as improved water are public taps and boreholes, whereas unimproved sources include rainwater, rivers, streams, ponds and hand-dug wells. Fifteen (75%) of the 20 communities surveyed have access to both water sources hence the analysis is performed using these group of households.

6.3.1 Probit estimation results (first stage)

Estimates of the Probit model presented in Table 6.2 examines the factors that determine the changes in probability of households using water from improved sources conditional on unit changes in the explanatory variables. The model minimises or corrects for heteroscedasticity by using the robust option in STATA to reduce the variance in the standard errors. The convectional Wald test statistic follows a χ^2 distribution with 15 degrees of freedom and significant at 1%. It rejects the null hypothesis that all coefficients except the intercept are zero. The model has no multi-collinearity problems (correlation and multi-collinearity statistics of variables used is found in Appendix 6 Table A6.1). Based on the statistical significance of the McFadden R^2 (measure of the goodness of fit) at 1%, explanatory variables explain 34% of the variation in the probability that households would decide on using improved water sources. From this point onwards, only significant variables in the model are commented on.

Contrary to *a priori* expectations, increases in household incomes (LINCOME) significantly decrease the probability of using improved water, *ceteris paribus*. This finding is counterintuitive but could be speculated that higher income households may have acquired tastes (based on some beliefs) for traditional water sources thereby decreasing their likelihood of using these sources (although they may have the financial means to treat water).

The larger the household size (LHHS), the more likely improved water sources would be used, *ceteris paribus*. This is likewise unexpected because of the possibility of increased household water expenditures associated with the use such sources as families get larger. However, this positive relationship could be attributed to the availability of human resource (water carriers) to undertake this daily activity. Price of improved water (LPRICE) conforms to the hypothesised *a priori* sign and is significant at 1% level, implying that increases in the price of improved water (high opportunity cost) decreases the probability of its usage. As expected, treating water from unimproved sources (TREAT) has the tendency of decreasing

the likelihood of households using improved water sources, *ceteris paribus*. If households decide to channel resources (time and money) into treating unimproved water to render it more safe, then the less likely they would use water from improved sources (which also comes at a financial cost), *ceteris paribus*. Having good perception about the quality of improved water (SATISBH) increases the probability of its usage. The regional location of households in the entire region (DUM) as against being located in the Upper West region (DUMUW) decreases the likelihood of choosing quality water. The negative effect of location on choice of quality water, though unexpected, may be indirectly linked to other determinants, such as distance and price, in discouraging quality water usage. Such an observation for the entire basin may as well be the result of hidden factors, such as institutional constraints and the siting of improved water delivery points that discourages the use of quality water.

Table 6.2: Probit estimates (first-stage) of the Heckman model (equation 5.39)

Dependent variable = IMP

Explanatory variables	Coefficients	Robust standard error	z	P>z
LINCOME	-0.2857	0.1383	-2.06	0.03**
LHHS	0.5882	0.2273	2.59	0.01***
LPRICE	-0.6945	0.1766	-3.93	0.00***
FEMALE	-0.4974	0.3539	-1.41	0.16
EDUC	0.3280	0.3219	1.02	0.30
LAGE	0.2301	0.4816	0.48	0.63
LCHADT	-0.1367	0.1561	-0.88	0.38
LSTORE	0.1388	0.1508	0.92	0.35
LDISTBH	-0.1986	0.1866	-1.06	0.28
TREAT	-0.9513	0.4028	-2.36	0.01**
SATISBH	1.4678	0.6965	2.11	0.03**
DUMAR	-0.3767	0.4262	-0.88	0.37
DUMNR	-0.5394	0.6503	-0.83	0.40
DUMUE	-0.1313	0.3410	-0.38	0.70
DUMVR	-1.0197	0.5616	-1.82	0.06*
Constant	3.2020	3.6717	0.87	0.38
No. of observation	181	McFadden's R^2	0.34	
Wald chi^2 (15)	51.85	Log likelihood	-62.71	
Prob. > chi^2	0.00	IMP (predicted)	0.78	

Note: z denotes z-statistics; *** significant at 1%, ** significant at 5%, * significant at 10%

Other important determinants of choice, such as distance to the improved water source (LDISTBH) (significant at 28%), child to adult ratio (LCHADT) (significant at 38%), educational level of household head (EDUC) (significant at 30%) and being a female-headed household (FEMALE) (significant at 16%) have their a priori expected signs (except FEMALE and LCHADT) but seem not to significantly influence the probability of making this decision.

6.3.2 Effects of policy relevant variables on improved water choice

As noted by Long and Freese (2001), estimates from the Probit model do not provide direct useful information on the relationship being studied hence deriving meaningful interpretations from these models should be based on predicted probabilities and functions of these probabilities. The Probit model on the average predicts 78% of the probability that households would choose improved water sources. Three important policy relevant variables are manipulated to investigate their impact on predicted probabilities. Statistical significance and conformity of the variables to *a priori* direction of effect are the criteria considered for inclusion is this kind of analysis. They include level of education of the household head (EDUC), distance to improved water source (LDISTBH) and price of improved water (LPRICE). These variables are varied between low and high values and predicted probabilities computed. A relevant question of what constitutes high or low water price, for instance, is a subjective one that depends on the researcher's perception. To approach this issue objectively by defining what "low" and "high" values are, the economic distance approach, one of the approaches by which poverty lines of countries are drawn to classify households or families as poor or otherwise (Förster, 1994), is adopted so that cut-off points (which represents values of variables regarded as "low" and "high") could be used (see section 4.1.4 for more on this approach).

The choice of an appropriate economic distance then becomes another issue. To aid in this choice, various distances from the median value of each variable are explored to verify how sensitive predicted probabilities are to the choice of an economic distance. Distances of 40%, 60% and 80% below (low value) and above (high value) the median are computed for the price of water (LPRICE) and distance to improved water source (LDISTBH). As level of education of household head is a dummy variable, it assumes a value of 0 for no education and 1 otherwise. Scenarios are then created to examine their impact on predicted probabilities. All other variables are held at their mean values. Table 6.3 presents the effects of changes in these policy variables on predicted probabilities. Predicted probabilities show a consistent trend for each policy scenario with little or no variation in predicted probabilities irrespective of the economic distance chosen. This implies that the choice of economic distance may not matter. Depending on the scenario, predicted probabilities either increase or decrease with economic distance. The ensuing discussions are based on the 80% economic distance since it represents adverse (for example, high water price) and conducive (for example, low water price) conditions of the explanatory variables.

Table 6.3: Effect of some policy relevant variables on predicted probability of using improved water

Policy Scenario	Distance (%) below or above median value		
	80	60	40
No education, low water price, long distance	0.977	0.938	0.901
No education, low water price, short distance	0.992	0.965	0.927
No education, high water price, long distance	0.689	0.725	0.763
No education, high water price, short distance	0.743	0.785	0.832
With education, high water price, long distance	0.784	0.807	0.844
With education, high water price, short distance	0.892	0.881	0.884
With education, low water price, long distance	0.911	0.942	0.969
With education, low water price, short distance	0.934	0.961	0.983
An "average" household		0.874	

Source: Own computations

The predicted probability of an average[28] household choosing improved water sources is 0.87. Important findings that emerge from the scenarios considered are as follows::

- Given the price of improved water and level of education, shorter distances to improved water sources results in higher predicted probabilities of using those sources, *ceteris paribus*;
- Given the educational level of household heads and distance, low price of improved water increases the likelihood of using quality water, *ceteris paribus*;
- Given the price of improved water and distance to improved water sources, the level of educational of household heads seem to have conflicting effects on predicted probabilities of using improved water, *ceteris paribus*;

6.3.3 Marginal effects on probability of using improved water

Marginal probabilities are computed to examine the effects of changes in the predicted probability of using improved water sources as a result of changes in decision variables. It is instructive to note that the marginal change depends on the levels of all variables in the model (Long and Freese, 2001). Table 6.4 presents the marginal effects for households who are average on all characteristics (Refer to Table A6.2A to C in Appendix 6 for three other computed marginal effects). Only significant variables that conform to hypothesized direction of effect are commented on.

On the average, a 1% increase in the price of improved water (LPRICE) decreases the marginal probability of households using improved water by approximately 0.14 whilst a 1%

[28] The word "average" refers to the case where households are average on all characteristics.

increase in household size (LHHS) increases the marginal probability by 0.12, *ceteris paribus*. Treating water from unimproved sources (TREAT) as against not doing so leads to a significant decline in marginal probability by almost 0.3 whilst a change in households perception of the quality of borehole water (SATISBH) from bad to good increases the marginal probability by 0.5. Water quality perceptions by households' represent the highest marginal effect in probability, suggesting the importance of subjective water quality ratings (perhaps influenced by tastes, traditions and education) in shaping perceptions.

Table 6.4: Marginal effects (at mean values) on predicted probability of using improved water sources

Explanatory variable	Marginal effects	Standard error	z	P>z
LINCOME	-0.059	0.027	-2.13	0.03**
LHHS	0.121	0.052	2.30	0.02**
LPRICE	-0.143	0.032	-4.38	0.00***
FEMALE[a]	-0.123	0.100	-1.22	0.22
EDUC[a]	0.068	0.069	0.98	0.32
LAGE	0.047	0.102	0.46	0.64
LCHADT	-0.028	0.031	-0.89	0.37
LSTORE	0.028	0.031	0.92	0.35
LDISTBH[a]	-0.041	0.037	-1.10	0.27
TREAT[a]	-0.275	0.144	-1.91	0.05**
SATISBH[a]	0.493	0.257	1.91	0.05**
DUMAR[a]	-0.083	0.099	-0.84	0.40
DUMNR[a]	-0.142	0.204	-0.70	0.48
DUMUE[a]	-0.028	0.075	-0.37	0.70
DUMVR[a]	-0.300	0.200	-1.50	0.13
IMP (predicted)	0.87			

Note: z denotes z-statistics; *** significant at 1%, ** significant at 5%, * significant at 10%
([a]) dy/dx is for discrete change of dummy variable from 0 to 1

Table 6.5 shows computed marginal probabilities for the situation where uneducated household heads pay high prices for improved water located long distances away from home. This represents a difficult water accessibility scenario associated with high opportunity cost. Household size, income, water price, water treatment and quality perceptions are again significant. A notable difference is that predicted probability of choosing improved water sources is decreased from 0.87 (for average households) to 0.68 for the difficult water accessibility scenario. Moreover, the estimated marginal effects are higher for this scenario than the "average" case. For example, a 1% increase in the price of improved water decreases the probability of its usage by 0.24 as against 0.14 (average case), representing a 71% change in marginal effect. A regional dummy (DUMVR) becomes significant at 5% level, implying that being in the Volta region as against the Upper West region (DUMUW) reduces the marginal probability of opting for improved water sources by 0.39. This negative relationship

is expected as the tendency to use improved sources of water is more likely to decline under conditions of high water prices and difficult accessibility. Note that this effect is observed for the other regional dummies although not statistically significant.

Table 6.5: Marginal effects of household heads with no education, pay high water prices for distant water sources on predicted probabilities of using improved water sources

Explanatory Variable	Marginal effects	Standard error	z	P>z
LINCOME	-0.101	0.047	-2.16	0.03**
LHHS	0.209	0.084	2.48	0.01***
LPRICE	-0.247	0.060	-4.06	0.00***
FEMALE[a]	-0.187	0.134	-1.39	0.16
EDUC[a]	0.106	0.104	1.02	0.31
LAGE	0.081	0.173	0.47	0.64
LCHADT	-0.048	0.055	-0.89	0.37
LSTORE	0.049	0.053	0.92	0.35
LDISTBH[a]	-0.070	0.068	-1.03	0.30
TREAT[a]	-0.363	0.148	-2.45	0.01***
SATISBH[a]	0.526	0.177	2.96	0.00***
DUMAR[a]	-0.136	0.162	-0.84	0.40
DUMNR[a]	-0.206	0.258	-0.80	0.42
DUMUE[a]	-0.047	0.125	-0.38	0.70
DUMVR[a]	-0.388	0.200	-1.90	0.05**
IMP (Predicted)	0.68			

Note: z denotes z-statistics; *** significant at 1%, ** significant at 5%, * significant at 10%
([a]) dy/dx is for discrete change of dummy variable from 0 to 1.

The predicted probabilities scenarios and marginal effects of explanatory variables at least point to the importance of water price, distance to improved water sources, household water quality perceptions, and water treatment in influencing the use of good quality water. These findings give emphasis to the importance of ensuring affordability of and easy accessibility to safe water to overcome water insecurity.

6.3.4 Ordinary Least Squares estimates (second-stage)

The second stage of the Heckman model investigates the key factors that influence quantities of improved water demanded by households who actually consume water from these sources. Selectivity bias in the second stage is verified through the inclusion of the inverse Mills ratio calculated for each household from the first-stage probit model. The second-stage empirical results are presented in Table 6.6. The explanatory variables jointly (F-test) influence the demand for improved water by explaining 30% of the variation in the quantity of improved water consumption (see Table A6.3 in Appendix 6 presents the collinearity diagnostics of

these variables). Heteroscedasticity is tested using the Breusch-Pagan test and the null hypothesis of homoscedasticity is not rejected even at 10% level.

Table 6.6: OLS estimates (second-stage) of the Heckman model (equation 5.40)

Dependent variable: LQTY

Explanatory Variable	Coefficients	Standard error	t	P>t
LINCOME	0.016	0.069	0.23	0.81
LHHS	0.395	0.139	2.83	0.00***
LPRICE	-0.361	0.093	-3.85	0.00***
FEMALE[a]	0.546	0.187	2.92	0.00***
EDUC[a]	0.080	0.151	0.53	0.59
LAGE	-0.217	0.230	-0.96	0.34
LCHADT	-0.016	0.084	-0.19	0.84
LSTORE	0.094	0.069	1.35	0.18
LDISTBH[a]	0.126	0.075	1.67	0.09*
LWCARRY	0.038	0.101	0.38	0.71
MILLS	-0.442	0.256	-1.72	0.08*
DUMAR[a]	0.077	0.206	0.37	0.70
DUMNR[a]	-0.216	0.315	-0.69	0.49
DUMUE[a]	-0.287	0.196	-1.47	0.14
DUMVR[a]	-0.034	0.273	-0.13	0.89
Constant	5.405	1.46	3.69	0.00***
Number of observation	181	R^2	0.36	
F (15, 165)	6.22	Adj. R^2	0.30	
Prob > F	0.00			

Note: t denote t-statistics; *** significant at 1%, ** significant at 5%, * significant at 10%
([a]) denotes dummy variable

Household size (LHHS), price of improved water (LPRICE), and the gender of the household head (FEMALE) are significant at 1% and conform to hypothesised *a priori* expectations. The larger the household size, the higher the consumption of improved water where a 10% increase in household size leads to approximately 4% rise in improved water demand. The demand for improved water is price inelastic where the effect of a 10% increase in price is to decrease quantity demanded by 3.6%. In other words, the higher the opportunity costs of water collection (which is reflected in the price of water), the less of it households would consume. The importance of water price regarding quantities consumed re-emerges, thus emphasising the need to ensure that quality water is made affordable to rural households.

Being a female household head increases the demand for quality water by 0.5%, suggesting that female-headed household, though unlikely to choose improved water sources (Probit model), know the importance of consuming or utilizing adequate quantities of quality water. Women in rural Ghana are mainly responsible for household chores especially cooking hence

the expectation is that they would know the importance of using sufficient quality water, *ceteris paribus*.

Unexpectedly, long distances to improved water sources (LDISTBH) significantly increase the quantities of water demand at 10% level, with a 10% increase in distance resulting in a 1.3% increase in quantity demanded. Upon first though, such an observation seems counterintuitive. However, a careful examination of this two-stage decision process gives insights into household water demand behaviour. We note at the first-stage that long distances discourage their use (significant at 28%) which is expected. Second, once this decision has been made by households, quantities consumed thereof increase with distance. This phenomenon can only be logically explained by assuming that households would consume more water even as distance increases only up to a certain limit or threshold distance deemed tolerable, beyond which quantities consumed would be expected to decrease with further increase in distance. This observation suggests that households have not yet reached that critical distance for the expected negative relationship to be observed. The determination of this critical distance is an empirical question that further research.

Credence may be given to the above argument as it has been observed elsewhere in some sub-Saharan African countries (but not in Ghana) by Rosen and Vincent (1999) who report that water consumption increased with distance until a threshold distance beyond which the expected negative relationship is observed. Caincross and Kinnear (1992) observe a similar phenomenon in Khartoum, Sudan, where water consumption was remarkably constant for households collecting water a few minutes from home and those collecting from a distance of 1 kilometre. By recognising that quality water is a very important good for these households (because they have chosen to use quality water), it is quite understandable that these households would travel extra kilometres to source water without compromising on quantities consumed. This result could be viewed as an indication of households, probably in a few communities, demonstrating a form of resilience by defying distance up to a certain maximum point to make water available at home.

Another unexpected observation is that demand for improved water decreases for households located in the Ashanti (DUMAR), Northern (DUMNR), Upper East (DUMUE), and Volta regions (DUMVR) as against being located in the Upper West region (DUMUW) of the Volta basin of Ghana. This negative effect perhaps reflects the high opportunity costs of

water collection prevalent in these communities which subsequently may serve as a disincentive to using quality water. The significance of the inverse Mills ratio (MILLS) at 10% indicates selectivity bias as a problem and has been corrected for. The implication is that modelling improved water demand by selecting only households who respond yes to consuming improved water introduced a sample selection bias. In other words, estimating the second-stage decision regarding quantities consumed without considering zero responses would have generated biased estimates. The negative direction of effect is unexpected because it is thought that choosing an improved water source implies it is preferred and should result in increasing the quantities consumed.

Household income (LINCOME) has the expected positive relationship with improved water demand but with a weak effect ($p>0.81$). This result may suggest the importance of household income as a decision variable that influences the probability of using improved water but unimportant in determining quantities consumed thereof. Household water storage capacities (LSTORE) and educational status of household heads (EDUC) conform to hypothesised *a priori* expectations but with insignificant effects on quantities demand. Other decision variables like age of the household head (LAGE), the ratio of children to adults (LCHADT), and the number of available water carriers in the household (LWCARRY) seem not to impact on the choice and quantities of improved water consumption.

To summarise, long distances to these sources discourage their usage but not likely to decrease quantities demanded once it has been chosen until a certain threshold distance is reached where water consumption declines with increasing distance. The price of improved water (opportunity cost of water collection) is an important decision variable that determines choice and quantity of water demanded.

6.3.5 Policy implications and conclusions (two-stage model)

Households generally acknowledge the importance of consuming quality water as evidenced by a probability of 0.87 for households who are “average” on all characteristics in using improved water sources. The statistically significant effect of household size on the likelihood of households using quality water implies that population growth in rural communities is likely to be accompanied by increases in the demand for quality water, with the potential effect of improvement in the health of households. Despite the continual reliance on traditional water sources for their daily requirements, households nevertheless have very

good perceptions about the quality of improved water. The insight gleaned is that, all things being equal, quality water consumption would increase when its supplies are available, easily accessible and affordable.

A decline in the probability of using quality water by 0.14 that results from a 1% increase in the price of improved water has a greater impact in reducing the consumption of quality water, *ceteris paribus*. As price is a major determinant of demand, the negative impact of water price on the consumption of quality water by rural households may result in the shift to and dependence on unsafe traditional water sources even when quality water is available. This situation may further expose households to water-related health risks which may have consequences on agricultural productivity.

The various policy scenarios considered in section 6.3.2 also shed light on the importance of water price and distance as determinants of choice. Taken the educational level of household heads and distance to improved water sources as given, low price of improved water increases the likelihood of its usage, *ceteris paribus*. The implication is that, to encourage the consumption of safe water in adequate quantities by rural households, its price affordable or the opportunity cost of acquiring this commodity should be drastically reduced. Taken the price of improved water and level of education of the household head as given, it was observed that short distances to improved water sources significantly increases predicted probabilities of using those sources, *ceteris paribus*.

Although distance to improved water sources did not significantly influence the use of improved water (Probit model), it however represented an important driving force in determining the quantities consumed (second-stage model). The evidence from the second-stage estimates that quantity of improved water consumption increases with distance brings to the fore some implications. First, rural households have shown a form of resilience by defying distance travelled up to a threshold distance. As it is expected that households would behave rationally beyond this unidentified threshold distance, water consumption would decline with further increases in distance commuted. The determination of this threshold distance requires further research. Second, distance plays a crucial role in determining the quantities of quality water consumption but not a major factor in influencing the use of quality water. Hence, locating improved water supply points very close to homes (and should be within this threshold distance) would therefore encourage its usage and quantities

consumed may increase substantially thereby enhancing drinking water security. Empirical evidence from sub-Saharan Africa suggest that per capita water consumption increase substantially above the 20 litres per capita per day (l/c/d) threshold recommended by the World Health Organisation (WHO) only when water sources are located either inside the house or compound to make time allocated to water collection or distance travelled practically nil (Rosen and Vincent, 1999).

In general, high opportunity costs associated with water collection hinder the choice for quality water. Households have demonstrated their sensitivity to price changes as shown in this analysis. Price of water is often employed in water demand management strategies as a non-structural economic incentive to regulate demand (Dube and van der Zaag, 2003). Due to low water consumption levels mainly from unsafe sources, Volta basin households need to be educated and encouraged to use more quantities of safe water. However, if the provision of improved water supply in rural communities is based solely on price (demand drive approach) where households and communities can have access to improved water only if they demonstrate their ability to pay (not just the willingness to pay) a greater percentage of the full cost associated with delivery, it then implies that several rural communities in the basin would be prevented from accessing safe and adequate water necessary for a healthy growth and productive lives. The supply side of water demand management, although expensive, may still be more important at this stage in Ghana's rural water development efforts. It therefore has to be vigorously pursued to complement the demand side strategies now gaining popularity. In this way, the Community Water and Sanitation Authority's (CWSA) current vision of achieving 85% rural water coverage by the year 2009 may not be a mirage.

6.4 Household water demand model

It is a common practice to substitute total expenditure for income in empirical research and one of the reasons is the belief that total expenditure figures better reflect the permanent income of the household. In addition, income figures are often subject to errors of measurement and thus rendering inconsistent coefficient estimates (Tansel, 1986). Total water expenditure (i.e., sum of expenditures on water for drinking and cooking and water for other household indoor purposes) is used as a measure of income in the water demand system. With only two goods in the water demand system, a single equation econometric method, such as constrained linear regression, is appropriate for estimating the model (see Section 5.3.4.2 for a discussion of this estimation method). The Linearised Almost Ideal

Demand System (LAIDS) model is thus constrained by imposing homogeneity and adding-up constraints on the two equations in the system to generate parameter estimates. Imposing symmetry constraint is unnecessary since this is automatically fulfilled for the case of two goods. Curvature conditions are not imposed *a priori* but rather verified using the sign of the estimated own-price elasticities.

6.4.1 Parameter estimates determining water demand

The empirical results for the LAIDS model for the two goods, water for drinking and cooking (SDRINK)[29] and water used for other indoor purposes (SOTHERS) is presented in Table 6.7. The dependent variables SDRINK and SOTHERS are in budget shares (refer to Table A6.4 in Appendix 6 for model summary statistics). Statistically significant variables are briefly discussed and emphasis placed on the derived income and price elasticity estimates because of the relevance of their implications for policies on domestic water demand.

The explanatory variables jointly and significantly explain (F-test) the variation in the demand for the two goods. Multi-collinearity among the variables is not a problem due to low Variance Inflation Factor (VIF) values (below 10). There is model stability as a result of a low condition number less than 10. Correlations among explanatory variables are likewise low (see Table A6.5 in Appendix 6). Possible endogeneity of the total household water expenditure variable (LEXP) in the model is tested using the Durbin-Wu-Hausman test and results indicate the absence of endogeneity of this variable, implying that constrained linear regression by Ordinary Least Squares (OLS) estimation gives consistent coefficient estimates (see Table A6.6 in Appendix 6 for the test results).

6.4.1.1 Socio-economic and demographic factors

The results indicate that being a female-headed household (FEMALE) decreases the demand or budget allocation to drinking water (SDRINK) whilst it increases the share of water for indoor purposes (SOTHERS). Although contrary to *a priori* expectations, this result may suggest that female household heads economise on the use of drinking water for two likely reasons: substantial amount of household water budget allocated to this good (it represents 95% of household budget on water) and high water treatment cost.

[29] For brevity, demand for water meant for drinking and cooking would now simply be referred to as "drinking water".

Table 6.7: Parameter estimates determining drinking water demand using the LAIDS model (Equation 5.28)

Meaning of variable	Explanatory variables	Coefficients	
		SDRINK	SOTHERS
Gender of household head (1=female, 0=otherwise)	FEMALE	-0.0071* (-1.85)	0.0071* (1.85)
Household size	HHS	0.0013*** (2.42)	-0.0013*** (-2.42)
Level of education of household head (1=education, 0=otherwise)	EDUC	-0.0027 (-0.84)	0.0027 (0.84)
Water storage capacity (litres)	STORE	-0.0000*** (-2.53)	0.0000*** (2.53)
Number of water carriers	WCARRY	0.0011 (1.27)	-0.0011 (-1.27)
Average time devoted to water collection (hours)	MTIME	-0.0073 (-1.31)	0.0073 (1.31)
Interaction between MTIME and HHS (hours)	MTHS	-0.0023*** (-4.23)	0.0023*** (4.23
Household treats water (1=treat, 0=otherwise)	TREAT	-0.0086** (-2.34)	0.0086** (2.34)
Price of water (drinking and cooking) (¢/litre)	LPDRINK	0.0183*** (5.82)	-0.0183*** (-5.82)
Price of water (other indoor purposes) (¢/litre)	LPOTHERS	-0.0183*** (-5.82)	0.0183*** (5.82)
Household real expenditure on water (¢)	LEXP	0.0085*** (4.88)	-0.0085*** (-4.88)
Dummy variable for communities in the Ashanti region (1=yes, 0=otherwise)	DUMAR	0.0190*** (2.46)	-0.0190*** (-2.46)
Dummy variable for communities in the Brong-Ahafo region (1=yes, 0=otherwise)	DUMBA	0.0155** (1.95)	-0.0155** (-1.95)
Dummy variable for communities in the Eastern region (1=yes, 0=otherwise)	DUMER	0.0159* (1.65)	-0.0159* (-1.65)
Dummy variable for communities in the Northern region (1=yes, 0=otherwise)	DUMNR	0.0143** (1.93)	-0.0143** (-1.93)
Dummy variable for communities in the Upper East region (1=yes, 0=otherwise)	DUMUE	0.0198*** (2.74)	-0.0198** (-2.74)
Dummy variable for communities in the Volta region (1=yes, 0=otherwise)	DUMVR	0.0236*** (2.77)	-0.0236*** (-2.77)
	Constant	0.7962*** (33.64)	0.2037*** (8.61)
Number of observations		498	498
F (16, 481)		30.71	30.71
Prob. > F		0.00	0.00

Note: t statistics in parenthesis; *** significant at 1%, ** significant at 5%, * significant at 10%.

Household size (HHS) is a significant determinant of drinking water demand where an increase in household size increases the drinking water budget allocation whilst it decreases budget allocation to water for other indoor purposes. This suggests that more drinking water is consumed with an additional household member and this would be the case until a threshold point where consumption may decline with an additional household member. The underlying idea behind this phenomenon is economies of scale in household water use.

The observation that an increase in household water storage capacity (STORE) reduces drinking water budget allocation conforms to *a priori* expectations. Households, to a larger extent, distinguish between storage vessels and the type of water for storage. Because drinking water in particular is often stored in smaller vessels and separately from water for other purposes, it is expected that households will allocate less of the water budget to this good. It also implies that budget allocations to water for other purposes increase as storage capacities increase.

Although not statistically significant, the more time is devoted to water collection (MTIME) the less the budget allocated to drinking water. However, an interaction term incorporated in the model to capture the relationship between time devoted to water collection and household size (MTHS) becomes significant (although with a weaker impact on drinking water budget shares). The statistical significance of the coefficient on the interaction term (MTHS) at the 1% level indicates that the effect of time on quantity of drinking water demanded or its budget allocation varies with household size: that is, more time is spent on meeting water requirements of larger households. The negative relationship indicates reduced budget allocations to drinking water with an increase in the interaction between time and household size.

Treating water (TREAT) leads to a reduction in household drinking water budget allocation whilst it increases budget allocations to the other good, *ceteris paribus*. As it is a rational behaviour to treat drinking compared to water for bathing and dish washing, this result is actually expected. The intuition is that rendering drinking water safe through its treatment increases the cost of acquiring this good and would decrease its demand or budget allocation. In other words, the more expensive it is to treat water, the more likely the quality of drinking water will be compromised, thereby exposing households and families to various health risks. This underscores the importance of rural water delivery as enshrined in Ghana's vision 2020 document.

6.4.1.2 Location of community in the basin

Regional dummies are introduced to investigate the effect of community location in the Ghanaian Volta basin on drinking water budget allocations. Using the Upper West region

(DUMUW) as the base[30] for comparison, the results suggest that households located in all the regions compared to being in the Upper West Region significantly increases the drinking water budget allocations. All the coefficients of the regional dummies are significant, conveying the message that households in the basin attach much importance to drinking water in meeting part of their daily water needs. This could imply that achieving drinking water security is of prime concern to Volta basin households and not limited to a few communities in each region. Even though budget allocations to water for other purposes (SOTHERS) declines in these regions, this could rather be interpreted to mean that households place drinking water high on their water security agenda than water for other purposes.

6.4.1.3 Price and expenditure on water

Increases in the price of drinking water (LPDRINK) and for other purposes (LPOTHERS) are expected to decrease their respect water budget share allocations whilst increasing total water expenditures (LEXP) or income should increase budget allocations to both goods, *ceteris paribus*. The positive effect of price on drinking water budget share suggests that an increase in the price of drinking water (increasing opportunity costs) does not reduce its drinking water budget share. The results also indicate that an increase the price of water for other purpose (LPOTHERS) decreases the drinking water budget share, suggesting in advance complementarity between the two goods in achieving household water security. Increases in drinking water budget shares associated with expenditure increases indicate that a good is a normal good. Because these parameter estimates in themselves are not easily interpretable, they are often ignored and attention focused on the calculated elasticities (Balcombe and Davis, 1996). This is because the effects of water price and expenditures on budget shares are an integral part of the estimated elasticities hence emphasis is rather placed on these elasticities, which is the subject for discussion in the next section.

6.4.2 LAIDS price and expenditure elasticity estimates

This section presents the conditional price and expenditure elasticity estimates. They are conditional elasticities because they are derived from the second-stage of households' expenditure allocations to water. Marshallian elasticities (i.e., uncompensated price

[30] This region is chosen as reference point for comparison because it has only one community representing that region (likewise the Eastern region). Moreover, the community representing this region has the highest number of improved water sources (i.e., boreholes) among the communities surveyed.

elasticities) and Hicksian elasticities (i.e., compensated price elasticities) are calculated from the coefficients of the drinking water demand equation (SDRINK)[31] to investigate the degree of responsiveness of households to changes in the price of water. Uncompensated price elasticities measure substitution and income effects resulting from a change in price whilst compensated elasticities measure only the substitution effect, which is a change in consumption in response to a price change, keeping real income (or utility) constant.

The value of the expenditure elasticity (η_i) classifies commodities as normal goods ($\eta_i > 0$) or inferior goods ($\eta_i < 0$). When the expenditure elasticity of the commodity is greater than one ($\eta_i > 1$) it is considered a luxury good and a necessity when this value lies between zero and one ($0 < \eta_i < 1$). Own-price elasticities are expected to be negative whilst cross price elasticities could be negative or positive depending on the relationship that exists between the commodities under consideration. Negative (positive) cross price elasticities indicate that goods are complements (substitutes). Two pairs of commodities are complementary to each other when an increase in price of one commodity leads to a decrease in the consumption of the other commodity because they tend to be consumed together. They serve as substitutes when a price increase in one commodity results in an increase in the consumption of the other commodity because of replacement or substitution for the other commodity.

6.4.2.1 Expenditure elasticities

Expenditure and price elasticities presented in Table 6.8 are computed at mean budget shares (for elasticity formulas, refer to section 5.3.3). Due to the explicit inclusion of socioeconomic characteristics in the LAIDS model, it is assumed that the estimated expenditure and price coefficients capture only price and expenditure related effects and not socioeconomic related effects (Elsner, 2001).

Table 6.8: Estimated price and expenditure elasticities

Quantity demanded	Marshallian price elasticities		Hicksian price elasticities		Engel expenditure elasticities
	SDRINK	SOTHERS	SDRINK	SOTHERS	
SDRINK	**-0.989**	-0.019	**-0.031**	0.029	1.008
SOTHERS	-0.209	**-0.617**	0.573	**-0.577**	0.826

Source: Estimated from coefficients of the LAIDS model
Note: Own-price elasticities are in bold.

[31] When these elasticities are calculated using the coefficients of the other water demand equation (SOTHERS) would give the same results.

The demands for water for drinking (SDRINK) and for other indoor purposes (SOTHERS) are normal goods, suggesting that increases in household income results in increased consumption of both goods. The expenditure elasticities generally suggest that water is a necessity. Water for other indoor purposes is expenditure inelastic where a 10% increase in household income increases its expenditure by 8.3%. With respect to drinking water, a 10% increase in income results in a 10% increase in its demand, implying unitary elasticity. The high expenditure elasticity of drinking water also suggests that more of it is consumed than the other good when income increases. This is not an unexpected observation, the reason being that this good constitutes 95% of households' budget allocations to water hence with rising income levels households could afford to spend more on this good by way of water treatment. This again points to the relative importance attached to water for drinking and cooking in household water security.

Expenditure elasticity values are generally high, especially for drinking water, giving the idea that its demand by rural households is very sensitive to changes in household per capita expenditures. This high responsiveness is not entirely unexpected because of high levels of poverty prevalent in these communities. The closeness to unity of the elasticity of drinking water may suggest that this good in particular may be perceived as a luxury good in the minds of these rural households living in water-scarce environments, which is mainly due to inadequate water access.

6.4.2.2 Uncompensated (Marshallian) price elasticities

Uncompensated own-price elasticities are negative as expected but with relatively larger values. Water for other purposes (SOTHERS) is own-price inelastic (-0.62) suggesting that a 10% increase in its price would reduce its consumption by 6.2%. Drinking water (SDRINK) is almost unitary price elastic, where its consumption declines by 9.8% with a 10% increase in own-price. The high elasticity values suggest high responsiveness of demand to water price. High opportunity costs associated with water collection may account for the high own-price elasticity values. In addition, the near luxury nature of drinking water suggests it is a relatively more expensive good hence households are more sensitive to changes in its price and this may be partly attributed to the costs of treating drinking water. Nevertheless, the World Bank Water Demand Research Team (1993) and Zekri and Dinar (2003) note that own-price elasticities falling in the estimated range in this study (Table 6.8) is reasonable for developing countries.

Comparing the degree of responsiveness of these goods to own-price changes give the impression that water consumed on indoor purposes (SOTHERS) is more of an essential good in the sense that more is consumed than water for drinking and cooking (SDRINK) because households are less sensitive to the price of the former (-0.62) than that of the latter (-0.98), although both goods are necessities. This assertion is substantiated by the fact that households consume more water for other purposes than for drinking and cooking (see Figure 4.3).

The cross-price elasticities are also inelastic with values much lower than own-price elasticities indicating weaker responsiveness of one good to changes in the price of the other good. Consumption of both goods is virtually unresponsive to changes in the price of the other. For example, the cross price elasticity of drinking water to changes in the price of water for other purposes is approximately -0.02. Cross-price elasticities also shed some light on the relationship that exists between the two goods. The observed negative cross-price elasticities indicate complementarity between these goods, where an increase in the price of drinking water, for instance, leads to a decrease in the quantity of water demanded for other indoor purposes.

It is quite understandable to say that drinking water and other indoor uses of water such as bathing, hygiene and cloth washing are related. In the sense of achieving complete household water security needs, it can be argued that drinking water and water used for other activities are always jointly consumed[32]. For example, it may be difficult to imagine that households would consume water on drinking and cooking and not simultaneously do likewise on bathing, dishing and cloth washing at home when the aim is to attain the highest possible levels of utility from water consumption. Based on the observed complementarity existing between these closely related goods, it is thus concluded that when drinking water consumption declines by 9.8% as a result of a 10% increase in own-price, households would accordingly decrease water consumption for other purposes by approximately 0.2%, *ceteris paribus* (Table 6.8).

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[32] The possibility of substituting water meant for other purposes with drinking water (but not likely to be the reverse) in some instances can not be ruled out.

6.4.2.3 Compensated (Hicksian) price elasticities

The estimated compensated own-price elasticities measure the strength of the substitution (price) effects in affecting consumption of the two goods. It is informative to mention that negative compensated own-price elasticities indicate that the necessary condition of concavity (or curvature) of the cost function used to derive the AIDS model is fulfilled (Tiffin and Aguiar, 1995; Balcombe and Davis, 1996). As shown in Table 6.8, compensated own-price elasticities are negative, indicating the fulfillment of concavity condition at the point of evaluation (mean values). With income compensation to keep household utility constant, own-price elasticity for drinking water (-0.03) and water for other purposes (-0.58) are also price inelastic. These elasticity values are smaller in absolute terms compared to uncompensated own-price elasticities due to the principle of income compensation.

The low value of compensated own-price elasticities indicates that households become less responsive to own-price changes, suggesting the possibility of higher water demand as real incomes increase under the condition of income compensation. That is, households show much real income effects with changes in the price of the two goods. For purposes of comparison, a 10% increase in the price of drinking water leads to a reduction in its consumption by 9.8% (without compensation) and only by 0.3% (with compensation). This difference in responsiveness is quite significant, bringing to the fore the strength of the substitution or price effect when households are compensated with income to maintain initial utility levels.

An interesting pattern emerges when compensated cross-price elasticities are examined to determine the relationship that exists between the two goods: the two goods are positively related, indicating substitutability between them. The insight derived from this unexpected observation is that accounting for pure price effects categorises the two goods as substitutes where, for instance, an increase in the price of drinking water leads to an increase in the demand for water meant for indoor purposes. If income compensation classifies these goods as substitutes, then a further interpretation may be that affluent households are more likely to consider both goods as substitutes whilst for poorer households, they play complementary roles. Nevertheless, the nearness to zero of both compensated and uncompensated cross-price elasticities of drinking water consumption with respect to price of water for other purposes could suggest that in the minds of households, these two goods are unrelated. This may not

necessarily be true regarding the elasticity of water demand for other purposes with respect to the price of drinking water.

6.4.2.4 Uncompensated price elasticities by income (expenditure) group

How does household income affect water consumption behaviour? In answering this question, the study re-estimated the uncompensated own-price and expenditure elasticities disaggregated into expenditure quintiles. Table 6.9 presents these results for only two expenditure groups, i.e., the first (lowest) and fifth (highest) expenditure quintiles.

Table 6.9: Marshallian own-price and Engel expenditure elasticities by income quintile

	Uncompensated own-price elasticities			**Expenditure elasticities**		
	Income group			Income group		
	Lowest	Highest	Mean	Lowest	Highest	Mean
SDRINK	-0.98	-0.98	-0.98	1.02	1.00	1.00
SOTHERS	-0.39	-0.65	-0.62	0.72	0.90	0.83

Source: Estimated by author from the LAIDS model estimates

It would be expected that wealthier and poorer households would exhibit different water consumption behaviour contingent, where wealthier (poorer) households would be less (more) responsive to own-price changes, implying the consumption of more (less) water compared to poorer (wealthier) households. The elasticity estimates, as shown in Table 6.9, suggest different demand behaviour contingent on the type of good and income level. For the case of drinking water (SDRINK), the poorest and the wealthiest households have similar high responsiveness to own-price (elasticities of -0.98). Expenditure elasticities are also high and similar for both income groups, indicating the near-luxury nature of this good irrespective of households' income group. Note that the averages of own-price and expenditure elasticities are similar to those in Table 6.8.

This is not the case with water for other indoor purposes (SOTHERS), where own-price and expenditure elasticities are observed to increase in absolute terms with rising incomes. This may suggest that this good is more of a necessity (essential) to poorer households than wealthier ones probably due to large household sizes. The estimates also suggest that wealthier (poorer) households are more (less) sensitive to changes in price of this good, which contravenes *a priori* beliefs. A cogent explanation for such an observation may be due to the fact that because poorer households have larger families and consume more water than

wealthier ones (see section 4.2.1), water for indoor purposes plays a crucial role for poorer households and hence are expected to be less responsive to changes in the own-price (opportunity costs) of this good.

It is also observed that in general own-price and expenditure elasticities differ by type of good. Own-price and expenditure elasticities for both income groups are lower for water for indoor purposes compared to that of drinking water, implying less price and income responsiveness to this good. This is again explained by considering water for indoor purposes more essential than drinking water. This claim is substantiated by the fact that less than 5% of the water budget is allocated to water for other purposes.

In general, it can be concluded that the poor and wealthy alike are equally sensitive to changes in income and price of drinking water, and less sensitive to changes in the price of water for indoor purposes compared to drinking water. These groups of households also differ in income and own-price elasticities with respect to water used for indoor purposes. What these observations point to is a display of different water demand behaviour by rural households in the Ghanaian Volta basin based on type of good and its price, household size, and income levels.

6.4.3 Policy implications and conclusions (LAIDS model)

Empirical results generally reveal that households experience difficult water accessibility by allocating substantial amount of time to water collection and treatment of drinking water. Such difficulties in water insecurity worsen the larger the household size, implying high opportunity cost of time for such households. A high opportunity cost of time associated with water collection activities suggests loss of potential wage income that could otherwise have contributed to household welfare. Second, a decline in drinking water budget allocation as revealed by the LAIDS model implies that household drinking water security would be adversely affected in that water treatment may be ignored to reduce costs. Thus, the quality of drinking water may be compromised due to high water treatment costs, thereby putting the health of households and families in jeopardy. The consumption of unsafe (or untreated water) would directly or indirectly impact on the health and agricultural productivity of households by reducing the number of days worked on-farm due to ill health.

High own-price Marshallian elasticity values of both goods, especially that of drinking water implies that high water prices (i.e., high opportunity costs associated with the consumption of this good) have the tendency of reducing household drinking water consumption in particular. Empirical evidence from this study already finds that Volta basin households on the average consume 28.5 l/c/d, an amount that is below Gleick's recommended amount of 50 l/c/d deemed adequate for healthy and productive lifestyles. It therefore implies that high water prices would further reduce quantities consumed thereby putting the health of households and communities at risk.

An examination of the Hicksian elasticities gives insights into consumer behaviour regarding water consumption and its implications for water pricing vis-à-vis households' ability to pay. Although not a principle undertaken in practice, compensating households with income to maintain targeted levels of utility in water consumption reveals higher levels of water consumption associated with higher income levels. What this suggests is that higher income households are more likely to consume more water than poorer ones, *ceteris paribus*. Taking this as given, then it would be appropriate if the pricing of (improved) water delivered to rural communities follows a policy of differential pricing based on income strata instead of administering fixed or flat rates per unit of water demanded when the purpose is to ensure water accessibility by all. Note that flat rates may culminate in the under- or overexploitation of this resource. Hence, the implementation of such a pricing policy would be more efficient (in terms of encouraging its use) and also make water affordable to all to ensure drinking water security. One of the challenges to overcome in order to implement this pricing policy would be to identify poor and wealthy households in these communities. However, developing appropriate mechanisms would eventually result in a workable solution in the implementation of this pricing policy.

7 SUMMARY AND CONCLUSIONS OF THE STUDY

Water insecurity has the potential to stifle developmental efforts in Ghana by threatening economic sectors dependent on water, such as irrigated agriculture, hydroelectric power generation, industry and even tourism. In this sense, averting national and household water insecurity will involve huge expenditure outlay on the part of government and households respectively. At the household level, water insecurity is of much concern because of periodic and seasonal water scarcities experienced in the entire basin. Water security is multifaceted, dynamic in nature and cuts across issues on availability, accessibility, usage and quality and their dynamics over time and space determines the overall water security. It is one of the issues addressed by the GLOWA-Volta project and has been the focus of this study. Based on this study's empirical findings, this chapter provides a summary of major research findings and contributions to the body of knowledge in the field of rural household water security in general and the Ghanaian Volta basin in particular. Recommendations to inform policy are proposed and limitations encountered in this study highlighted. Future empirical research necessary to further bridge the knowledge gap regarding rural household water security are finally suggestions.

7.1 Summary of major findings

The study comes up with the following findings.

1. By disaggregating water into two heterogeneous goods, i.e., water for drinking and cooking (first good) and water for other indoor purposes (second good), the study finds complementary roles between the two goods in ensuring complete household water security. This means that irrespective of the usage purpose, water generally serves as an important resource that fulfils daily water needs for rural households.
2. With income compensation to maintain targeted utility, water for drinking and cooking and water for indoor purposes become substitutes. This suggests that the two goods are likely to serve as substitutes for affluent households whilst they may play complementary roles for poorer households.
3. Water for drinking and cooking and water for indoor purposes are normal goods and necessities. Without income compensation, households are more sensitive to changes in own-price of the two goods than with income compensation. Cross-price elasticities in both cases are less responsive to price. These imply that high water prices (high opportunity cost due to difficult water accessibility) has the potential of reducing

desired quantities of daily water consumption for various household needs. Moreover, rural households in the Ghanaian Volta basin display different water demand behaviour contingent on household size, income levels, type of good and its price.

4. Economic characteristics (such as water price and income), household characteristics (such as household size) and regional location of communities in the basin are important determinants of the share of household water budget allocated to water for drinking and cooking.
5. In general, socio-economic and household characteristics such income, water price, household size, water quality perceptions and the decision to treat water are significant in explaining the decision to use improved water sources. However, factors like the educational level of household head, number of available water carrier and household water storage capacities seem to be unimportant in explaining water demand by rural household in the Ghanaian Volta basin.
6. Water accessibility is inadequate in rural households as expressed in substantial amount of time spent (that implies high opportunity costs) in collecting water, especially for savannah zone households compared to households in the forest zone. However, in the dry season, forest zone households devote more time to this activity. About 3 hours is devoted daily to water collection, an activity mainly carried out by girls and women. Depending on the approach used to value time, average daily opportunity cost of water collection ranges from ¢1,831 to ¢3,145 (for year 2001).
7. Majority of rural households depend on unimproved (traditional) water sources and express serious dissatisfaction with these sources. They generally perceive improved water as safe for consumption and demonstrate a high likelihood to opt for these sources among other alternatives. Nevertheless, they often supplement their water needs with unsafe sources, suggesting important health implications. With roughly 8% of annual household income spent on health and other related problems, it is likely that rural households would be willing to pay for improved water accessibility. However, price of improved water, an important water demand management tool used to regulate demand, is likely to reduce the already low consumption levels in the basin.
8. Implicit and explicit costs of coping with water insecurity are high. As a means of coping, households use multiple water sources for different purposes without much distinction between source and usage type. Whilst the cistern (clay pot) is the commonest water storage facility for Savannah zone households, the use of barrels

dominate in the Forest zone. An average amount of 28.5 l/c/d is consumed by Volta basin households, which is much lower than Gleick's estimate of 50 l/c/d as adequate for healthy living. Poorer households generally consume more water than households in the high income bracket.

9. About 77% of rural households earn their livelihood through agricultural activities (dominated by crop production-95%) whilst the remaining 23% comes from non-agricultural sources. Average annual income earned from agricultural and non-agricultural sources by Savannah zone households exceeds that of Forest zone households. With respect to non-agricultural income, women in the Forest zone contribute twice more towards household income than women in the Savannah zone.

7.2 Contributions to empirical research in Ghana

This section summarises the contributions to the body of knowledge that fills the empirical gap in water demand studies in rural Ghana in terms of methodological approach and theoretical underpinnings.

1. Deviating from the approach commonly followed, where water is often modelled as a homogeneous commodity (a single good) this study has demonstrated the possibility of modelling rural water demand in Ghana by considering it as a heterogeneous good by disaggregating water into one for drinking and cooking and that for indoor purposes. Moreover, the modelling process applied a theoretical framework consistent with rational consumer behaviour.
2. This study is amongst the first, if not the pioneer in the use of a system of demand equations by applying a theoretically consistent demand model, the Linearised Almost Ideal Demand System (LAIDS) model that conforms to fundamental consumer behaviour to empirically model rural water demand in Ghana. Such flexible models rule out the possibility of inconsistent utility maximisation behaviour and avoid model misspecifications that lead to wrong policy conclusions.
3. This study combines aspects of water quality and quantity in explaining rural household water demand behaviour, an approach necessary for better understanding into their decision-making processes.
4. Under conditions where water has no price (i.e., when water is sourced from unsafe sources such as rivers, streams and unprotected hang dug wells), the challenge would be to price water. This study attempted placing value on rural water by estimating

daily and hourly opportunity costs associated with the task of water collection using three different approaches, namely, the national daily minimum wage approach, agricultural income approach and the non-agricultural income of women approach. These approaches could serve as guidelines in valuing rural water where the estimated water price gives an indication of their willingness to pay to access safe water. It also suggests the cost incurred by rural households in securing water.

7.3 Policy recommendations

Informing policy makers regarding improving the accessibility and provision of quality water for rural households is needed. The following recommendations are advanced in the light of Ghana's vision 2020 which aims at achieving 80% rural water coverage by the end of 2020 and the recent Community Water and Sanitation Agency's (CWSA) set target of 85% coverage by 2009 (CWSA, 2003).

1. To ensure that rural households live healthy and productive lives, it is governments' fiscal responsibility to ensure that safe water is made readily accessible by locating them very close, preferably within a maximum of 200 metres radius from homes. This has the potential of increasing adequate water consumption to reduce public health risks and generally increase rural household water security.
2. A short term measure of providing quality water is for government to substantially support the construction of more underground water sources (e.g., boreholes and protected wells) not only in the Savannah zones but more especially in deprived communities in the forest zone of Ghana where more hours are devoted to dry season water collection from all available sources. Long term plans of overcoming infrastructural constraints necessary for rural water coverage should be underway, if not already in place to meet set targets.
3. Pricing of safe water in rural communities should follow a policy of differential pricing based on income levels of households, rather than the administering of flat rates that has the potential of misusing or overexploiting water (for those who can afford it) as well as discouraging especially the poor from its usage due to unaffordability. Though it must be acknowledged that identifying households according to income levels may be a major challenge, differential pricing has the potential of ensuring that most households, if not all, have the ability to pay to access affordable water.

4. Basing the provision of improved water supply solely on demand driven approach may not be an optimal solution to ensure nationwide rural water coverage. Some communities still lack access to safe water (a basic human right) because of their inability to pay a stipulated minimum amount necessary to express their ability to pay, and operate and maintain the water source. Government still needs to play a dominant role by financially supporting rural water delivery whilst the contributions from communities complement governments' effort in the medium term.
5. More non-agricultural income generation opportunities need to be created in rural Ghana to alleviate poverty and thereby improve households' ability to pay for the provision of improved water.
6. For members of the World Water Council (WWC) which was established in 1996, it is recommended that governments' fiscal responsibility must be backed by the political will to ensure water accessibility for all, especially in rural Ghana.

7.4 Limitations of the study

1. Reliability of data is crucial for any empirical analyses. The unavailability of observed data on quantities of water consumed for various purposes and actual time devoted to water collection by households implied relying on households' recall ability to give this information. This may not necessarily correspond to actual quantities used and hence constitutes a major limitation to this study.
2. Estimating the price of rural water was based on assumptions regarding the number of daily trips women and children make in water collection and the number of days worked annually in agriculture. These assumptions may be unrealistic and likely to bias the estimated water price used in the modelling process. This as well represents a drawback to this study.
3. The unavailability of actual (financial) price of water prevented the use of water price, a major determinant of water demand among other policy relevant variables for policy simulations in this study.

7.5 Suggestions for future research

This study is unable to answer some relevant questions and overcoming some methodological limitations encountered during the study. Following are suggestions to enrich the results of future research urban and rural water demand studies, not only in Ghana but also in other developing countries.

1. To effectively come up with much reliable estimates of water demand and time allocated to access water from importance sources, it is recommended that future studies employ actual (observed) quantities of water consumed on various household activities per source and time devoted to water collection.
2. Research is needed to establish the basic daily minimum water requirement for various household activities both in rural communities and in urban areas. This would be helpful in water pricing where a certain basic minimum considered essential for public health reasons could be supplied freely, after which consumptions beyond this basic minimum would be charged. The findings of such studies could be first implemented in communities that have public piped systems for pricing to be effective.
3. Because the production and delivery of improved water to rural households' is costly, future studies could investigate and find solutions to these two related questions: What is the willingness to pay (WTP) for improved water supply (water price) and their WTP for the infrastructure needed to make improved water accessible (operation and maintenance). As noted by Winpenny (1994), if households and communities do not have a sense of entitlement to government services (especially water services), do not feel "free water" is their birthright, and do not have to make payments to non-local governments, households will be more willing to pay for improved water supply.
4. For purposes of taking advantage of the strengths of flexible consumer demand models and provided relevant data is available, water could further be disaggregated into several indoor uses so that symmetry and other constraints required for rational consumer behaviour could be imposed on the system of water demand equations.
5. Further investigations are needed to establish whether interventions in improved rural water supply in known communities have improved or worsen the welfare of households and communities. This is needed to give policy-makers the required feed back to improve on policy formulation and implementation strategies where necessary.

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APPENDICES

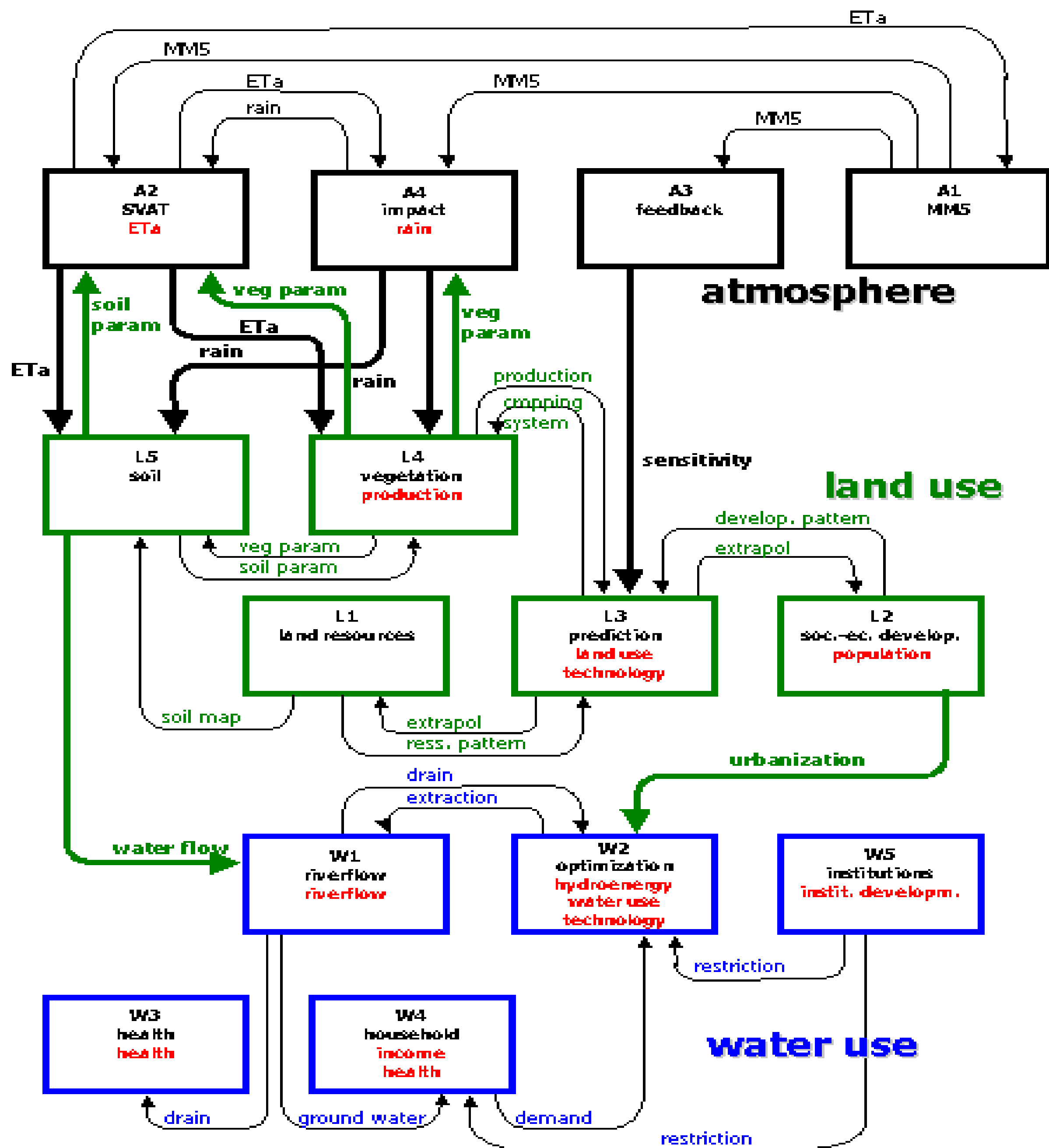
APPENDIX 1

Table A1.1: Socio-economic, water and sanitation indicators for the six riparian countries in the Volta basin, 2000.

Indicators	Units	Ghana	Burkina Faso	Côte d'Ivoire	Togo	Benin	Mali
Land area	('000) km^2	239	274	322	57	113	1,240
Total population (1990)	('000)	15,128	9,061	11,635	3,512	4,660	8,843
Total population (2000)	('000)	20,213	11,937	14,786	4,629	6,097	11,234
Urban	('000)	7,753	2,204	6,854	1,540	2,577	3,375
Rural	('000)	12,460	9,733	7,932	3,089	3,520	7,859
Population growth rate	%/yr	2.7	2.7	1.8	2.6	2.7	2.4
Average life expectancy	Yr	60	44.4	50.8	48.8	53.4	53.3
Rainfall	mm/yr	2,000	350	1,300	1,300	890	1,400
Renewable water resources	km^3/yr	53	28	74	12	26	62
Total water withdrawals	km^3/yr	0.30	0.15	0.71	0.09	0.11	1.36
Total water withdrawals	m^3/cap/yr	35	20	68	40	26	159
Water use							
Domestic	%	35	28	22	62	28	2
Industrial	%	13	5	11	13	14	1
Agricultural	%	52	67	67	25	58	97
Water coverage							
Urban (1990)	%	83	74	89	82	-	65
Urban (2000)	%	87	84	90	85	74	74
Rural (1990)	%	43	50	49	38	-	52
Rural (2000)	%	49	-	65	38	55	61
Sanitation coverage							
Urban (1990)	%	59	88	78	71	46	95
Urban (2000)	%	62	88	-	69	46	93
Rural (1990)	%	61	14	30	24	6	62
Rural (2000)	%	64	16	-	17	6	58

Source: Adapted from the country profiles of the World Health Organisation (WHO) Water supply and sanitation sector assessment 2000, part 2.

Figure A1.1: The structure of the GLOWA-Volta research project



APPENDIX 4

Table A4.1 Age distribution of sample households

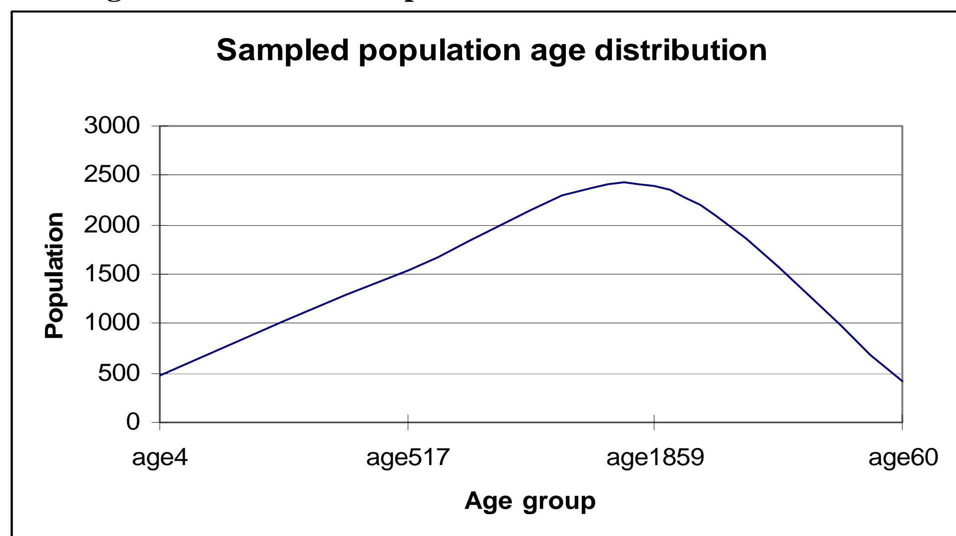


Table A4.2 Socio-economic characteristics by agro-ecology

Variables	Forest	Savannah
No. of respondents	196	305
Average age of household head (years)	50.6	50.7
Household size (persons)	7.2	9.3
Male-headed households (%)	73.8	83.9
No formal education (%)	29.6	64.9
Households without electricity (%)	85.1	73.0
Average annual income (¢)	5,795,971	8,598,900
Average annual expenditures (¢)	740,409	617,469

Table A4.3 Socio-economic characteristics at community level

Community /village	No formal education (%)	Male headed households (%)	Average age (years)	Household size	Average income	Average expenditure
Abrakaso	40	56	49.32	8.04	6,369,807	580348
Akutuasi	23	88	57.96	7.65	6,745,500	786574
Ejura	29	83	47.56	9.39	8,184,348	1218397
Kyebi	17	83	45.95	7.29	7,861,377	558351
Ayerede	33	67	50.62	6.04	1,510,000	591670
Kwagyeikrom/Bredi	58	54	53.87	7.95	8,519,563	592829
Koduakrom	46	63	43.41	5.25	10,200,000	440242
Miawoani	56	76	42.68	6.64	9,134,684	386060
Nsuta	35	65	57.88	6.03	1761067	1000513
Gbangbanpon	73	96	45.23	10.15	11,400,000	564140
Bagabaga	75	96	55.91	11.12	5,269,306	924534
Kaladan Barracks	29	83	52.25	7.29	3,104,137	718610
Kusawgu	79	96	57.83	13.66	6,042,113	820811
Dusabligo	85	85	47.59	8.85	7,191,606	472751
Gowrie	70	89	50.29	9.88	5,104,289	499779
Kologo Tangabisi	81	78	42.74	7.55	6,452,069	354890
Biu	54	85	47.88	10.38	18,200,000	915181
Korobognuo	78	100	62.40	11.96	7,713,544	620473.7
Nkonya Wurupong	29	71	54.87	7.41	3,237,607	562382
Kpando Torkor	29	83	46.56	6.5	2,363,916	782279

Figure A4.1 Composition of sampled households by ethnic groups

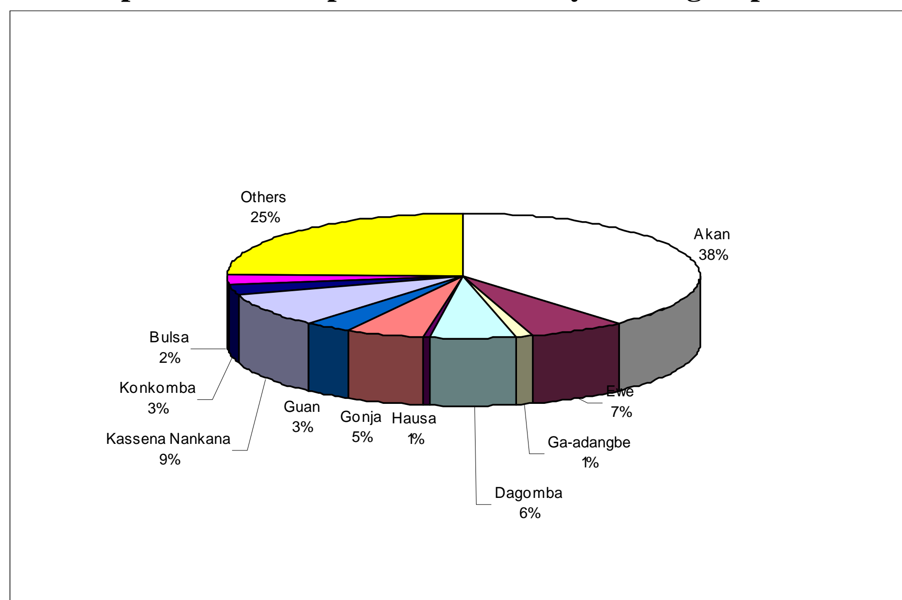


Table A4.4 Mean annual household income (excluding imputed food and animal products) by sector (in ¢ millions)

Source of income	Observations	Mean	Standard deviation	Min.	Max.
Agricultural	471	6.1	11.7	0.00095	110.0
Crops	458	5.9	11.8	0.00095	109.0
Livestock	249	0.5	1.0	0.00300	7.8
Non-agricultural	410	2.9	7.4	0.00200	112.0
Non-agricultural (women)	262	1.1	1.9	0.00400	19.0
Total income	497	8.2	13.1	0.01570	116.0

Source: GLOWA field survey, 2001

Table A4.5 Mean annual household income by agro-ecology (in ¢ millions)

Source of income	Observations	Mean	Standard deviation	Min.	Max.
Forest zone					
Non-agricultural	155	3.8	10.3	0.002	112.0
Non-agricultural (women)	98	1.7	2.6	0.020	19.0
Agricultural	183	3.8	6.4	0.014	64.0
Crops	179	3.6	6.1	0.014	58.8
Livestock	73	0.6	1.3	0.012	6.0
Total income	193	6.6	11.4	0.016	116.0
Savannah zone					
Non-agricultural	255	2.5	4.8	0.011	48.0
Non-agricultural (women)	164	0.8	1.5	0.004	11.6
Agricultural	288	7.6	13.9	0.001	110.0
Crops	279	7.5	14.1	0.001	109.0
Livestock	176	0.5	0.9	0.003	7.8
Total income	304	9.3	14.0	0.050	110.0

Source: GLOWA field survey, 2001

Table A4.6 Average time spent daily per household collecting water from rivers, by ecology zone and season

Ecological zone	Season	Number of observations	Average time
Forest	Rainy	99	0.91
	Dry	99	1.59
Savannah	Rainy	142	2.01
	Dry	146	3.06

Source: Derived from the GLOWA Volta field survey, 2001

APPENDIX 6

Table A6.1: Variable diagnostics used in first stage Heckman model

A. Spearman's rank correlation coefficients (Probit model)

(Observation = 181)

	LINCOME	LHHSIZE	LPRICE	FEMALE	EDUC	LAGE	LCHADT	LSTORE
LINCOME	1.000							
LHHSIZE	0.187	1.000						
LPRICE	-0.062	-0.146	1.000					
FEMALE	-0.155	-0.131	0.043	1.000				
EDUC	-0.215	-0.253	0.025	0.003	1.000			
LAGE	-0.015	0.218	-0.031	0.092	-0.267	1.000		
LCHADT	-0.082	-0.090	-0.081	0.036	0.074	-0.113	1.000	
LSTORE	0.038	0.155	0.080	-0.007	0.142	0.030	-0.027	1.000
LDIST	0.080	-0.013	0.530	0.052	-0.160	0.014	0.064	-0.058
TREAT	0.050	0.044	0.169	0.029	0.007	-0.080	-0.014	0.081
SATISBH	0.199	0.027	0.074	-0.110	-0.164	-0.022	-0.064	-0.156
DUMAR	-0.038	-0.143	0.175	0.055	0.326	0.037	0.005	0.103
DUMNR	-0.034	0.043	-0.049	-0.105	-0.151	0.067	0.054	0.073
DUMUE	0.207	0.136	-0.159	0.016	-0.272	-0.122	-0.092	-0.205
DUMVR	-0.293	-0.154	-0.129	0.123	0.248	-0.063	0.094	0.163

	LDIST	TREAT	SATISBH	DUMAR	DUMNR	DUMUE	DUMVR
LDIST	1.000						
TREAT	0.199	1.000					
SATISBH	0.055	0.061	1.000				
DUMAR	-0.110	-0.087	0.124	1.000			
DUMNR	-0.118	0.365	0.040	-0.178	1.000		
DUMUE	0.067	-0.119	-0.039	-0.475	-0.155	1.000	
DUMVR	-0.186	-0.023	-0.254	-0.267	-0.087	-0.233	1.000

B Collinearity diagnostics of variables used in the Probit model

Variable	VIF	Squared VIF	Tolerance	Eigenvalue		Cond. Index1	Cond index2	R-squared
IMPROV	1.45	1.21	0.6884	2.2603	1	1.0000	1.000	0.3116
LINCOME	1.27	1.12	0.7904	2.0925	2	1.0393	2.6498	0.2096
LHHSIZE	1.31	1.15	0.7619	1.6081	3	1.1856	2.7641	0.2381
LPRICE	1.87	1.37	0.5340	1.5352	4	1.2134	2.8354	0.4660
FEMALE	1.13	1.06	0.8823	1.3039	5	1.3166	3.1901	0.1177
EDUC	1.55	1.25	0.6446	1.1551	6	1.3989	3.3531	0.3554
LAGE	1.25	1.12	0.8027	0.9749	7	1.5227	3.6534	0.1973
LCHADT	1.10	1.05	0.9126	0.8932	8	1.5908	4.2238	0.0874
LSTORE	1.21	1.10	0.8239	0.8003	9	1.6805	5.3411	0.1761
LDIST	1.79	1.34	0.5580	0.7652	10	1.7187	7.6986	0.4420
TREAT	1.38	1.18	0.7229	0.6550	11	1.8577	8.6634	0.2771
SATISBH	1.20	1.10	0.8335	0.5502	12	2.0268	13.382	0.1665
DUMAR	2.43	1.56	0.4123	0.4581	13	2.2214	15.696	0.5877
DUMNR	1.56	1.25	0.6408	0.4229	14	2.3118	20.742	0.3592
DUMUE	2.06	1.43	0.4857	0.3294	15	2.6196	28.645	0.5143
DUMVR	2.01	1.42	0.4983	0.1955	16	3.4001	47.934	0.5017
					17		89.151	
Mean VIF	1.54			Condition Number		3.400	89.151	
				Determinant of correlation matrix		0.042		

Cond Index1 from deviation SSCP (no intercept)
Cond Index2 from scaled raw SSCP (w/ intercept)

Table A6.2: Marginal effects on the probability of households using improved water sources

A. No education of household heads, low improved water price, and long distance to water source

Explanatory variables	Marginal effects	Standard error	z	P>z	x
LINCOME	-0.015	0.013	-1.12	0.264	15.657
LHHSIZE	0.031	0.034	0.94	0.346	2.071
LPRICE	-0.037	0.028	-1.32	0.187	-1.328
FEMALE*	-0.037	0.045	-0.84	0.399	0.160
EDUC*	0.013	0.018	0.68	0.495	0
LAGE	0.012	0.032	0.39	0.700	3.893
LCHADT	-0.007	0.009	-0.81	0.420	-0.215
LSTORE	0.007	0.010	0.73	0.465	4.100
LDIST	-0.011	0.017	-0.62	0.533	6.445
TREAT*	-0.105	0.099	-1.06	0.289	0.116
SATIS*	0.262	0.252	1.04	0.2980	0.972
DUMAR*	-0.023	0.041	-0.55	0.581	0.353
DUMNR*	-0.046	0.091	-0.51	0.608	0.055
DUMUE*	-0.007	0.022	-0.35	0.729	0.292
DUMVR*	-0.118	0.146	-0.81	0.416	0.116
IMPROVE (Predicted)	0.977				

(*) dy/dx is for discrete change of dummy variable from 0 to 1

B. No education of household heads, low improved water price, and short distance to water source

Explanatory variables	Marginal effects	Standard error	z	P>z	x
LINCOME	-0.006	0.006	-0.92	0.357	15.657
LHHSIZE	0.012	0.016	0.74	0.461	2.071
LPRICE	-0.014	0.015	-0.92	0.357	-1.328
FEMALE*	-0.016	0.020	-0.76	0.445	0.160
EDUC*	0.005	0.007	0.60	0.548	0
LAGE	0.004	0.013	0.36	0.716	3.893
LCHADT	-0.002	0.004	-0.67	0.503	-0.215
LSTORE	0.003	0.004	0.64	0.524	4.100
LDIST	-0.004	0.005	-0.85	0.394	4.248
TREAT*	-0.049	0.065	-0.76	0.448	0.116
SATIS*	0.149	0.178	0.84	0.403	0.972
DUMAR*	-0.009	0.014	-0.62	0.535	0.353
DUMNR*	-0.020	0.036	-0.56	0.578	0.055
DUMUE*	-0.002	0.008	-0.34	0.732	0.292
DUMVR*	-0.056	0.067	-0.84	0.399	0.116
IMPROVE (predicted)	0.992				

(*) dy/dx is for discrete change of dummy variable from 0 to 1

C. High education of household heads, low improved water price, and long distance to water sources

Explanatory variables	Marginal effects	Standard error	z	P>z	x
LINCOME	-0.007	0.008	-0.91	0.360	15.65
LHHSIZE	0.015	0.016	0.92	0.357	2.071
LPRICE	-0.018	0.015	-1.17	0.240	-1.328
FEMALE*	-0.019	0.029	-0.69	0.492	0160
EDUC*	0.013	0.018	0.68	0.495	1
LAGE	0.006	0.015	0.39	0.695	3.893
LCHADT	-0.004	0.005	-0.76	0.445	-0215
LSTORE	0.004	0.005	0.72	0.469	4.100
LDIST	-0.005	0.008	-0.58	0.559	6.445
TREAT*	-0.060	0.058	-1.04	0.300	0116
SATIS*	0.174	0.182	0.96	0.339	0.972
DUMAR*	-0.011	0.020	-0.56	0.575	0.353
DUMNR*	-0.025	0.055	-0.45	0.652	0.055
DUMUE*	-0.003	0.011	-0.34	0.731	0.292
DUMVR*	-0.069	0.094	-0.74	0.459	0.116
IMPROVE (predicted)	0.990				

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Table A6.3: Collinearity diagnostics of variables used in the second-stage Heckman model

(Observations = 181)

	LINCOME	LHHSIZE	LPRICE	FEMALE	EDUC	LAGE	LCHADT	LWCARRY
LINCOME	1.000							
LHHSIZE	0.187	1.000						
LPRICE	-0.062	-0.146	1.000					
FEMALE	-0.155	-0.131	0.043	1.000				
EDUC	-0.215	-0.253	0.025	0.003	1.000			
LAGE	-0.015	0.218	-0.031	0.092	-0.267	1.000		
LCHADT	-0.082	-0.090	-0.081	0.036	0.074	-0.113	1.000	
LWCARRY	0.062	0.083	0.080	0.046	0.041	0.055	0.128	1.000
LSTORE	0.038	0.155	0.080	-0.007	0.142	0.030	-0.027	0.129
LDIST	0.080	-0.013	0.530	0.052	-0.160	0.014	0.064	0.067
DUMAR	-0.038	-0.143	0.175	0.055	0.326	0.037	0.005	0.201
DUMNR	-0.034	0.043	-0.049	-0.105	-0.151	0.067	0.054	-0.015
DUMUE	0.207	0.136	-0.159	0.016	-0.272	-0.123	-0.092	-0.172
DUMVR	-0.294	-0.154	-0.129	0.123	0.248	-0.063	0.094	0.023
MILLS	0.006	-0.384	0.703	0.224	-0.028	-0.155	0.058	0.110

	LSTORE	LDIST	DUMAR	DUMNR	DUMUE	DUMVR	MILLS
LSTORE	1.000						
LDIST	-0.058	1.000					
DUMAR	0.103	-0.110	1.000				
DUMNR	0.073	-0.118	-0.178	1.000			
DUMUE	-0.205	0.067	-0.475	-0.155	1.000		
DUMVR	0.163	-0.186	-0.267	-0.087	-0.233	1.000	
MILLS	-0.016	0.525	-0.035	0.049	-0.163	0.074	1.000

Table A6.4: Descriptive statistics variables used water demand model

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
SDRINK	499	0.95	0.05	0.632	0.998
SOTHERS	499	0.05	0.05	0.001	0.367
LPDRINK	501	6.18	0.25	0.984	6.287
LPOTHERS	501	1.92	0.842	-1.318	4.028
LEXP	498	8.22	0.93	5.088	13.353
AGE	500	50.80	15.08	16	105
FEMALE	500	0.20	0.40	0	1
HHSIZE	500	8.48	4.41	1	23
EDUC	501	0.48	0.50	0	1
STORAGE	501	124.46	372.96	0	7200
WCARRY	495	2.82	1.79	1	19
MTIME	501	0.67	0.60	0	3.5
MTHS	500	5.55	6.34	0	55.25
DUMAR	501	0.19	0.39	0	1
DUMBA	501	0.19	0.39	0	1
DUMER	501	0.05	0.22	0	1
DUMNR	501	0.19	0.39	0	1
DUMUE	501	0.21	0.41	0	1
DUMVR	501	0.09	0.29	0	1

Table A6.5: Variables diagnostics for LAIDS water demand model

A Collinearity diagnostics

Variables	VIF	Squared VIF	Tolerance	Eigenval		Cond Index1	Cond Index2	R-squared
SDRINK	2.13	1.46	0.4701	4.2018	1	1.0000	1.0000	0.5299
AGE	1.23	1.11	0.8127	2.0237	2	1.4409	2.7971	0.1873
FEMALE	1.13	1.06	0.8875	1.5723	3	1.6347	2.9623	0.1125
HHSIZE	2.55	1.60	0.3929	1.4040	4	1.7299	3.0850	0.6071
EDUC	1.38	1.17	0.7253	1.2715	5	1.8179	3.1534	0.2747
STORAGE	1.18	1.09	0.8443	1.1050	6	1.9500	3.2007	0.1557
WCARRY	1.20	1.10	0.8340	1.0496	7	2.0008	3.5356	0.1660
MTIME	7.34	2.71	0.1363	1.0205	8	2.0292	3.8047	0.8637
MTHS	5.31	2.31	0.1882	0.9054	9	2.1542	4.0460	0.8118
LPDRINK	8.40	2.90	0.1191	0.8189	10	2.2652	5.4918	0.8809
LPOTHERS	4.02	2.01	0.2487	0.7641	11	2.3449	6.2683	0.7513
LEXP	1.31	1.14	0.7644	0.5551	12	2.7512	7.4396	0.2356
DUMAR	4.54	2.13	0.2202	0.4936	13	2.9177	12.5987	0.7798
DUMBA	4.72	2.17	0.2118	0.3491	14	3.4692	14.7450	0.7882
DUMER	2.15	1.47	0.4645	0.2120	15	4.4524	15.9263	0.5355
DUMNR	3.88	1.97	0.2576	0.1197	16	5.9242	18.1620	0.7424
DUMUE	4.30	2.07	0.2324	0.0772	17	7.3757	39.3606	0.7676
DUMVR	3.00	1.73	0.3335	0.0564	18	8.6286	116.944	0.6665
					19		5057.223	
Mean VIF	3.32			Condition Number		8.6286	5057.223	
				Determinant of correlation matrix		0.0002		

Cond Index1 from deviation SSCP (no intercept)
Cond Index2 from scaled raw SSCP (w/ intercept)

B Spearman's rank correlation coefficients for variables used in LAIDS model

(Observations = 498)

	AGE	FEMALE	HHSIZE	EDUC	STORE	WCARRY	TIME	MTHS
AGE	1.000							
FEMALE	0.016	1.000						
HHSIZE	0.164	-0.121	1.000					
EDUC	-0.286	-0.108	-0.201	1.000				
STORE	0.087	-0.043	0.144	-0.029	1.000			
WCARRY	0.086	-0.005	0.269	0.006	0.103	1.000		
TIME	-0.047	0.080	-0.065	-0.032	-0.108	0.110	1.000	
MTHS	0.054	-0.015	0.445	-0.123	-0.054	0.253	0.734	1.000
LPDRINK1	-0.042	0.075	-0.005	-0.057	-0.107	0.075	0.899	0.725
LPOTHERS1	-0.044	0.081	-0.019	-0.041	-0.035	0.070	0.791	0.638
RXP1	0.047	-0.042	-0.145	-0.047	0.234	-0.006	-0.045	-0.110
DUMAR	-0.011	0.041	-0.037	0.234	-0.055	0.146	0.039	0.024
DUMBA	-0.101	0.171	-0.220	0.037	-0.065	-0.043	0.349	0.100
DUMER	0.110	0.085	-0.129	0.077	-0.022	0.026	-0.010	-0.080
DUMNR	0.064	-0.157	0.228	-0.135	0.189	0.006	-0.093	0.072
DUMUE	-0.111	-0.052	0.074	-0.223	-0.072	-0.096	-0.220	-0.127
DUMVR	-0.006	0.026	-0.114	0.165	0.008	0.005	-0.092	-0.115

	LPDRINK1	LPOTHERS 1	RXP1	DUMAR	DUMBA	DUMER	DUMNR	DUMUE
LPDRINK1	1.000							
LPOTHERS1	0.847	1.000						
RXP1	-0.039	-0.024	1.000					
DUMAR	-0.045	-0.032	-0.157	1.000				
DUMBA	0.423	0.417	-0.098	-0.243	1.000			
DUMER	-0.017	-0.022	-0.025	-0.116	-0.115	1.000		
DUMNR	-0.060	0.014	0.157	-0.243	-0.241	-0.115	1.000	
DUMUE	-0.200	-0.236	0.090	-0.257	-0.255	-0.122	-0.255	1.000
DUMVR	-0.167	-0.204	-0.041	-0.159	-0.158	-0.075	-0.158	-0.167

	DUMVR
DUMVR	1.000

Table A6.6: Durbin-Wu-Hausman test (augmented regression test) for endogeneity of total household expenditure on water

Dependent variable = rxp1

Explanatory variables	Coefficient	Standard error	t	P>t
AGE	0.003	0.002	1.26	0.208
FEMALE	0.030	0.100	0.30	0.761
HHSIZE	-0.064	0.013	-4.78	0.000
EDUC	0.068	0.089	0.77	0.443
STORAGE	0.000	0.000	5.36	0.000
WCARRY	0.044	0.022	1.94	0.054
MTIME	0.092	0.144	0.64	0.524
MTHS	-0.006	0.014	-0.49	0.626
LPDRINK	-0.020	0.081	-0.25	0.799
LPOTHERS	0.020	0.081	0.25	0.799
DUMAR	-0.905	0.197	-4.58	0.000
DUMBA	-0.888	0.203	-4.37	0.000
DUMNR	-0.204	0.188	-1.09	0.277
DUMUE	-0.278	0.191	-1.46	0.146
DUMVR	-0.802	0.220	-3.65	0.000
DUMER	-0.866	0.246	-3.51	0.000
Constant	8.991	0.480	18.70	0.000
Number of observation	498			
F(15, 482)	7.52	Prob > F	0.00	

Augmented regression

Dependent variable = SDRINK

Explanatory variables	Coefficient	Standard error	t	P>t
AGE	-0.000	0.0001	-1.71	0.088
FEMALE	-0.005	0.0038	-1.56	0.120
HHSIZE	0.000	0.0008	0.41	0.684
EDUC	-0.003	0.0033	-1.08	0.282
STORAGE	-1.05e-06	7.53e-06	-0.14	0.889
WCARRY	0.001	0.0009	2.05	0.041
MTIME	-0.007	0.0056	-1.36	0.176
MTHS	-0.002	0.0005	-4.43	0.000
LPDRINK	0.017	0.0031	5.58	0.000
LPOTHERS	-0.017	0.0031	-5.58	0.000
RXP1	-0.006	0.0109	-0.62	0.539
DUMAR	0.003	0.0075	0.42	0.676
DUMBA	-0.003	0.0076	-0.43	0.671
DUMNR	0.004	0.0061	0.73	0.465
DUMUE	0.010	0.0059	1.84	0.066
DUMVR	0.008	0.0077	1.12	0.261
rxp1_res	**0.015**	**0.0110**	**1.40**	**0.162**
Constant	0.950	0.0954	9.96	0.000
Number of observation	498	H_0 (rxp1_res)	0	
F(16, 481)	30.69	F(1, 481)	1.96	
Prob > F	0.00	Prob > F	0.16	

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