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Water Demand and Financing in Rwanda: An Empirical Analysis

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To Charles, Lisa & Gaëlle

"Success is not measured by what you accomplish, but by the opposition you have encountered, and the courage with which you have maintained the struggle against overwhelming odds". *Orison Swett Marden*

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Acknowledgements

Before starting this long journey, I was caught between two stools, given that I was not sure if I should fly to Gothenburg to do the PhD, or stay in Rwanda, close to my family – especially since my children were very young at that time. Right after I had taken the decision and started the PhD, the tough times set in: and the situation became harder and harder. I eventually reached a point where I was not sure which way to go anymore. Fortunately, in the middle of it all, things took a better turn and my progress showed me that I had to persevere. With each step, it was not only my own efforts that forced me to keep looking forward, but also the encouragement and support from many different sides which contributed in one way or another to help me achieve my goal.

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Thesis summary

Although water is a renewable resource, the growing water scarcity and water stress relative to human demands is now evident in many parts of the world, particularly in developing countries (Postel 1993; Postel 2000). In these countries, clean water and sanitation services are still severely lacking and this results in a multitude of people suffering from preventable illnesses from which many die each year (Montgomery and Elimelech 2007). In fact, many millions of people in developing countries use an unreliable water supply of poor quality, given that the majority lack piped connections to their premises (Howard and Bartram 2005). The problem is that current policies exclude many from the supply network and the unconnected tend to be the poorest. In addition to the high costs per unit to purchase non-piped water, households without a connection to the piped network spend an undue amount of time walking to the nearest source of water such as a private or public tap, wells, or water vended from trucks (Van den Berg and Nauges 2012). Furthermore, even though households who are connected to the piped network are assumed to have access to an improved water supply system, the fact is that water quality is still a general problem for all, given that many existing systems only operate intermittently. This results in service interruptions, which in turn lead to water stagnancy and the growth of microorganisms (Lee and Schwab 2005). During such interruptions, it is understandable that households connected to the piped network also rely on water from alternative, non-tap sources.

The main cause of service discontinuities by utilities in developing countries is the lack of a water tariff scheme that enables the cost of supply to be recovered. Full-cost-recovery pricing for all water would exclude the poorest, however; for this reason, many utilities subsidise at least part of their water delivery through low tariffs. Nonetheless, these low tariffs usually lead to losses to the utility and are often poorly targeted. These implicit subsidies, which frequently operate through so-called Increasing Block Tariff schemes, have also been judged to be regressive and badly targeted in the sense that they are not good redistribution tools, they do not reach the poorest households, and they cannot reach households that are not connected to the piped network (UN 2007). Since the implicit subsidies reduce the revenue for utilities, they also mean that, without government subsidies, the utilities frequently lack the funds to maintain the piped networks – let alone expand them.

Thus, there are issues with managing supply, i.e. how to set tariffs so that utilities can afford to maintain and invest in infrastructure; but there are also the questions of how to manage demand, and how to allocate water among different, competing uses.

In fact, competition for limited water resources is increasing among a variety of stakeholders. Generally, agriculture, as a sector, consumed the most water (80% or more of total withdrawals in developing countries). Therefore, the issues revolve around the value generated by water in this sector, and whether such water could be put to better use elsewhere (Falkenmark 1990). In developing countries, the agricultural sector accounts for large fractions of employment and constitutes the primary source of livelihoods, but it is also characterised by low-value subsistence production. In addition, due to the low productivity registered in this sector, irrigation has been seen as a way to enable smallholders to adopt more diversified cropping patterns and to switch to high-value market-oriented production (Intizar and Munir 2004). Thus, given that irrigation accounts for around 70% of water withdrawals worldwide and over 80% in low-income developing countries, better water access is likely to result in improved outcomes for farmers (Meinzen et al. 2001). However, given that overall water availability is constrained, allocating even more water to agriculture is not necessarily the best choice. Both the water itself and the infrastructure needed to supply it has potential alternative uses, such as improved access to water for households, industrial uses or environmental uses, and the benefits generated in agriculture need to be compared with the benefits that the water could have generated elsewhere.

Given the current water scarcity and competition between uses and users, any successful policy for improved water management is likely to be context-dependent. In fact, water resource management takes place in a complex socio-economic context; thus, the successful implementation of water reform requires all stakeholders – and especially end-users – to participate as fully as possible in development

planning and management in the decision-making process (UNDP 2008). In fact, it has been observed that when local communities, which are better placed to manage their environment and resources, are given the responsibility of water resource management, it tends to be more effective (Oosterveer and Van Vliet 2010). However, how well this works will depend not only on the local community spirit, but also on whether or not there are clearly defined groups of water users managing the water.

The present study aims to contribute to the analysis of water scarcity and management in developing countries, with Rwanda as a case study.

The thesis consists of five papers related to each other.

The first paper, entitled "Water demand by unconnected households in urban districts of Rwanda", analyses the demand by households in urban districts of Rwanda who lack piped connections to their premises and who rely on existing non-tap sources. It is shown that non-tap water not only occasions extra costs compared with tap water, but also exposes users to the higher risk of water-borne diseases. In the analysis, we consider that the household's decision to purchase water from a chosen source might depend on the price of that source as well as on the attributes of the other existing sources – whether chosen or not. Furthermore, we considered the fact that the time spent by households collecting water has an opportunity cost since that time could be used to generate income if the household was connected to tap water. Thus, the household's full income (i.e. the full value of the household's time) and the full cost of different water sources (i.e. the cost including the value of the time used to fetch the water) were important points in the analysis. The findings suggest that income elasticities are higher when the household's full income is considered rather than only its monetary income, and the full cost associated with alternative water sources is an important determinant of the choice of source. Furthermore, although unconnected households combine different sources of water, the majority uses only one source – the public tap. Extending the existing tap connection should be advantageous to these unconnected households. However, if one considers the current lower income registered by that group, an appropriate solution in the short run could be to improve the non-tap distribution systems in a way that the majority could still afford.

The second paper, "Individual status quo modelling for a rural water service in Rwanda: Application of a choice experiment", addresses the supply of water for domestic and irrigation purposes in rural areas of Rwanda. For domestic purposes, many rural households collect water from unsafe sources; this often exposes them to worms, dysentery, cholera, etc. However, referring to the existing individual levels of some attributes of existing non-tap sources, such as the unit price of water, the distance to the nearest water point, and the frequency of contracting a water-borne disease, there is evidence of a wide variation in baseline status. The same situation applies to the uneven distribution of irrigation water through different parts of the country, and can be observed through the amount of irrigation water available during the dry season, the frequency of irrigation events, the price paid by farmers for such water, and the degree of famers' current involvement in irrigation water management. In respect of both types of supply, i.e. domestic and irrigation, we considered that these heterogeneous baseline conditions might lead to variations in individuals' preference for an improved service. The results from our experiment show that using existing information on individuals helped to improve the model fit, and led to higher estimates of the overall willingness to pay for improved services. However, it also allowed us to identify who actually wanted changes in the supply service and why. From a policy perspective, therefore, not accounting for the individual's existing situation could be misleading: one might end up either with projects that are implemented but do not respond to real individual needs, or with policies that generate an overall improvement, but which worsen conditions for those with a favourable status quo.

The third paper, titled "Social cohesion in Rwanda: Results from a public good experiment", records our study of how differences in prosocial behaviour can affect the provision of local public amenities, such as water, in Rwanda. Given Rwanda's turbulent history, culminating in the 1994 genocide and the remaining tensions, the quality and extent of cooperation among members of local communities in practice could potentially have implications for the success of Rwanda's public service. With a traditional public good experiment, the results showed clear variation in the level of contribution to the public good when it came to respondents from different backgrounds. The research evidence may have implications for Rwanda's current decentralisation policies. In fact, the success of these policies will mainly depend on whether and to what extent local communities feel a sense of responsibility for maintaining the public amenities that have been decentralised to them. However, people might not act for the well-being of the group, given their personal histories. In such a case, the government should consider promoting their decentralisation policies along with initiatives to improve social cohesion among the various groups in Rwanda.

The fourth paper, namely "The value of access to water: Livestock farming in the Nyagatare District, Rwanda" (resubmitted to *Regional Environmental Change*), deals with the effect of access to an improved water supply on the revenue generated in livestock farming. Such effect is determined by assessing the current priorities in water policies in Rwanda, specifically in the Nyagatare District. We found that reducing the walking distance for cattle to the nearest water point – i.e. one of the channels through which productivity might improve – did not in fact ensure an overall positive impact. Thus, if one considers that existing funds are targeted more towards improving water infrastructure for livestock, it is worth examining the extent to which improved access to water actually contributes positively to the livestock industry. The existing situation shows that many households in the district still lack access to safe water, and rely on non-tap water. This scarcity in domestic water use is mainly caused by the existing, generally poor state of water supply infrastructure in the entire country, and by the fact that some of the water supply points used to water livestock could also be used as sources of drinking water. In view of our findings not showing clear evidence on the net benefit for all farmers due to an increased number of water points, the high priority given to extending the water network for the purposes of increasing livestock productivity should be revisited.

The fifth paper, "Water management and pricing in the urban areas of Rwanda: The case of Kigali city", published in *Water Utility Management International* 7(3):13–17, concerns water management and pricing in the urban areas of Rwanda, using the capital city, Kigali, as a case study. In the capital, where the majority of the country's urban residents live, access to municipal water constitutes a critical issue. Even for the low proportion of households currently connected to the piped network, water provision is uncertain due to regular interruptions. The residents who are not connected to the piped network at all face higher average costs for their water and are generally even poorer than connected residents. In fact, these issues are likely to be related to the imperfections in the pricing mechanism in water supply. The problems are twofold: on the one hand, the current Increasing Block Tariff structure signifies that connected consumers pay low marginal tariffs that cannot generate revenues to cover both operating and long-term investments costs; and on the other, the poorest cannot afford the high one-off fee to be connected to the network, and prefer, due to liquidity constraints, to deflect their consumption to the alternative water sources – although these are much more expensive in the long run. Thus, to deal with this problem, better pricing instruments need to be settled so that the utility can finance capital costs for infrastructure and allow the poorest, who currently pay more on unsafe non-tap water, to connect to the water network in the first place.

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Paper I

Water demand by unconnected households in urban districts of Rwanda

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Abstract

In this paper, we analyse water demand by households in urban districts in Rwanda who currently lack a piped connection into their home. The analysis uses data from a cross-sectional survey. The demand function has been estimated in a two-step procedure for correcting selection bias (Heckman 1979). The results showed that public taps are the most widely used water source and that the demand from this source is more inelastic compared with that for other water sources. Although it happens that households combine different sources of water, the majority in the sample uses only one source. We use the full household income, and obtain results which indicate income elasticities higher than those obtained with monetary income. The full cost associated with alternative water sources is shown to be important for determining the choice of source – something which has been overlooked in most previous studies. Poor (unconnected) households cannot expect to be connected to the piped network in the short run; and improving the current non-tap distribution systems could be considered an alternative solution.

Keywords: coping sources of water, full income, unconnected households, unselected sources, water demand elasticity, urban districts, Rwanda

JEL Classification: L95, Q21, Q25, R22

1. Introduction

This paper presents a study on water use by Rwandan households in urban areas who are not connected to the piped municipal network. The research reported here extends previous research by using a more complete description of the decision problem facing these households. A household's decision about what water source to use and how much water to use is likely to be affected both by the characteristics of all available water sources – a fact which many previous studies have neglected – and by the full range of consumption options available to the household in question.

More specifically, the paper aims to investigate how unconnected households' simultaneous decision to use a particular source among others and a specified quantity of water from that particular source is affected by the total costs (the price of water and the value of the time) of the selected and unselected sources, the full household income, and other socio-economic variables. In this study, households generally rely on the public tap, protected springs, unprotected springs or on somebody else's private tap sources.

Access to clean tap water within the residence is far from universal in developing countries (Nauges and Strand 2007). In many of these countries, water is collected from communal sources which may or may not be safe (Gundry et al. 2004). Water-related diseases due to microbial contamination during and after collection continue to be a major health problem in such countries (Wright et al. 2004). In sub-Saharan African cities, only 35% of the urban population has piped water in the dwelling, plot or yard (Dos Santos and LeGrand 2012).

A similar situation exists in the urban areas of Rwanda dealt with in this study. The paper is about urban water use in Rwanda in general and, in particular, about water demand by households that are not connected to the piped network. In general, these households who lack piped connections spend a considerable amount of time collecting potentially unsafe water. This time could instead have been used to generate an income if water were available on the premises; so this time use has a considerable opportunity cost for the households in question. Thus, the time needed to reach a water source is likely to be an important factor in determining what water source households use. In their choice, households might also be influenced not only by the attributes of the chosen source, but also by those of the ones not selected.

The existing literature (as discussed in e.g. Nauges and Whittington 2010) largely ignores the characteristics of the water sources not chosen or used that might affect the choice model, but that element is considered in the present study. Thus, we consider the attributes of these unchosen sources in our model. Therefore, the demand for all kinds of water available to unconnected households is taken into consideration, whether or not they use a particular source. We found that households were less sensitive to changes in the cost of water from public taps, i.e. the main water source, than they were to changes in the cost of water from springs or from somebody else's private tap.

The *Full income* variable (the full value of an individual's time, given that individual's hourly wage, i.e. what an individual would make if s/he worked all the time) is used here instead of *Monetary income* (Becker 1965). As far as we know, the *Monetary income* variable rather than its *Full income* counterpart has been applied to all previous water demand models. In the present study, reference is made to the full value of a person's time; if monetary income only had been used, the value of the time used would have been ignored. Compared with when only *Monetary income* is considered, we find a higher income elasticity of demand for *Full income*.

From a policy perspective, the welfare impact of having access to one's own piped water is potentially huge. Also, extending the current tap-water systems so that more unconnected households have access to their own piped water instead of the sources people use now might be of great importance in terms of saving the money normally forgone by the time used to collect water. However, this extension requires large investments, whose benefit needs to be informed.

Given that the majority of unconnected households are poor and may not be able to pay the cost of these investments, improving the current non-tap distribution systems to improve poor households' access to safe and adequate water could be considered an alternative solution to that of extending the current tap-water system. However, detailed knowledge of currently unconnected households' water demand and their socio-economic characteristics might help the water utility and policymakers in the water sector enhance such households' access to a reliable water supply.

In Section 2, a short description is given of the current water situation in Rwanda, as a background. In Section 3, earlier water demand studies done in developing countries are briefly discussed. Section 4 describes basic data on the average types of coping sources[1] faced by unconnected households. According to the results, this group relies on a multitude of sources. However, in all districts, many unconnected households use public taps as their main coping source. Furthermore, unconnected households face higher prices and lower water consumption levels, compared with connected households. Also, water from coping sources needs to be carried to the dwelling; the results show that, in general. unconnected households spent more time on this activity, implying higher time costs for them. In Section 5, a water demand function is estimated by means of a two-step procedure for correcting selection bias and we present the results of the empirical estimations in Section 6. These results are discussed further in the conclusion.

2. Background

In developing countries, factors leading to water supply problems are numerous, complex, interrelated, and sometimes influenced by political decisions, instability, poverty, and civil war. The high rate of population growth, a lack of investment in water supply infrastructure, and limitations to natural water resources are the main reasons why water supply systems in large cities in these countries fail (Bruggen et al. 2010; Carter et al. 1999). Because of the lack of funds for extending the water supply infrastructure, many water utilities charge high fees for connecting new plots to the network. However, these fees, which need to be paid before the connection is installed, exclude the poor in particular from being connected to the network, and cause them to prefer sourcing their water from elsewhere – at a higher overall cost, but with less upfront payment than the piped water. Therefore, many households in developing countries lack in-house piped connections and lack access to safe drinking water (Ademiluyi and Odugbesan 2008). These unconnected households then rely on several types of unsafe non-tap water sources, such as public or private wells, public or (someone else's) private taps, tank trucks, rainwater collection, or water from rivers, streams or lakes (Nauges and Whittington 2010). This unreliable water exacts a high toll in health and coping costs. Regarding health costs, it has been noted (Wright et al. 2004) that low-quality water leads to poor health. About 1.8 million people – the majority of whom live in developing countries and are children under five years of age – die every year due to waterborne diseases like cholera (Toutouom and Sikod 2012). Thus, both the public sector health system and the household itself incur a variety of health costs, e.g. money spent on medicines, the medical practitioners' time treating illnesses, and lost earnings due to inability to work. The coping costs associated with non-tap water provision are those related to the amount of time and effort walking to water sources, and money to purchase water. To remedy this situation, changes in the forms of service and payment mechanisms for an improved water supply have been discussed, but, as Whittington et al. (2008) caution, the outcome of any intervention is likely to be context-dependent: an intervention that works well in one locality may fail miserably in another.

[1] According to Pattanayak et al. (2005), a *coping source* refers to all alternative supply and storage facilities adopted by households in response to deficiencies in the piped water supply system. Coping strategies include collecting water from different non-tap sources, purchasing water from vendors and neighbours, investing in storage tanks and filtration systems, and boiling water before drinking or cooking with it.

The water supply situation for developing countries described above applies to Rwanda as well. Rwanda remains a water-scarce country. The management of water in Rwanda has been a great challenge, despite the efforts made by the government in setting up strategic policies and regulations. The major issues in domestic water supply in Rwanda are mainly the increasing demand, pollution of water sources, and poor reliability of water supply systems. Projections show that nearly half a million additional people would need to be connected to adequate drinking water every year until 2015 in order to meet the country's Millennium Development Goals (World Bank 2012). Then, considering the current 2.75% population growth rate, rapid urbanisation and large-scale housing developments, projections show that, if the recommended minimum per capita consumption standard of 20 litres per person per day is respected, 73 million m^3 per year would be needed. However, the current daily per capita consumption is still very low – in the order of 6 to 8 litres (Republic of Rwanda 2011). This means that domestic water consumption would still be in the region of 29.2 million m^3. In brief, the availability of safe drinking water does not meet the population's needs, and distribution of what there is remains inadequate.

In Rwanda, public water supply is divided into two subsectors: the urban water supply system, and its rural counterpart. Kigali city and all other urban centres are supplied by the state-owned public utility, the Energy, Water and Sanitation Authority (EWSA). EWSA also manages all urban water services (Republic of Rwanda 2006). The rural areas are supplied by natural springs and some other projects by regional water utilities, but EWSA remains ultimately responsible for constructing new rural water supply infrastructure (Klooster et al. 2011).

Statistics show that around 32% of Rwanda's population have access to the piped network, but that only 3.4% has access to it within their homes or on site (Republic of Rwanda 2010), with the remainder using water from a public tap in their neighbourhood. Here, *public tap* means a public water point (stand post or kiosk) from which people can purchase water. In Rwanda's case, such water points are considered an alternative close to the piped water on the premises. These stand posts are mainly conceived for low-income households and those living in informal settlements. Water from kiosks is mostly sold in 20-litre jerrycans. Households who lack a piped connection inside their homes sometimes also rely on other the non-tap alternatives available, such as protected and unprotected springs[2] and tube wells[3] (Republic of Rwanda 2009a).

Water tariffs represent a heavy burden – particularly for the poor and for unconnected households. In fact, even the public tap – which constitutes the main coping source for most unconnected households – seems to be costly. The average cost of water from a public tap is US$1.23/m³ (RWF 14 per jerrycan), but it can go up to US$3.52/m³ (RWF 40 per jerrycan) for certain pumped systems.

Statistics show also that, in Rwanda, about one third of all households consume unsafe water from unprotected sources and are, therefore, exposed to worms, dysentery and cholera – all of which are associated with a lack of hygiene (Republic of Rwanda 2009b). Furthermore, the average time taken to reach a source of drinking water is estimated to be 25 minutes for the whole country, which varies for different parts of the country (Republic of Rwanda 2010).

This paper looks at households who currently lack piped tap water in their homes and who deflect their demand to the alternative coping sources available.

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2 *Protected* springs are typically protected from run-off, bird droppings and animals by a 'spring box' constructed of brick, masonry or concrete, and built around the spring so that water flows directly out of the box into a pipe or cistern without being exposed to outside pollution. *Unprotected* springs are subject to run-off, bird droppings, or the entry of animals.

3 A *tube well* is a deep hole that has been drilled with the purpose of reaching groundwater supplies. Water is delivered through a pump which is powered by human, animal, wind, electric, diesel or solar means. In the case of Rwanda, the pump is usually powered by human means (see http://www.wssinfo.org/definitions-methods/watsan-categories/, last accessed 6 March 2013).

3. Literature

In developing countries, many households rely on several water sources, each with its own particular characteristics, such as perceived quality, reliability, distance, and price (Whittington and Swarna 1994). In such countries, many households lack piped connections in their homes (Nauges and Whittington 2010) and, thus, rely on different coping sources.

Various means, including household surveys, experimental approaches and hedonic methods, have been used to model water demand behaviour in developing countries. However, modelling households' water access is complex: the accessible sources cannot necessarily be assumed to be exogenous.

For the case of Rwanda, for example, cheap alternatives to tap water have been developed within each district due to the failure of the current system to satisfy the growing demand in tap water. The alternatives developed in a specific district may depend on a variety of factors, such as the average household income, the state of infrastructure, and the location of the district. Similarly, unconnected households might have chosen to settle in a particular area taking into account the availability of water, among other factors.

Single-equation models of water demand have been used for data from developed countries, and several studies have tried to mimic this approach using data from developing countries. The results from the work by Hubell (1977) on water demand for metered households in Nairobi, Kenya, could be considered as preliminary evidence of reasonable price and income elasticities; however, as has been noted by Whittington and KyeongAe (1992), for example, the results have little applicability to cases where households collect water from non-tap sources.

In the western region of Saudi Arabia, Abu Rizaiza (1991) conducted separate estimates of water demand equations for residential water use in houses supplied by a public pipe network, and such use in houses supplied by tankers. His findings suggest that residential water use varies according to the difference in incomes, temperature and price of water. The estimated price elasticity was found to be close to values normally found in more industrialised countries, but the income elasticity was lower.

In Indonesia, Crane (1994) focused on separate water demand equations for households supplied by water vendors and those using hydrants. He found that neither household resale nor hydrants were perfect substitutes to the expanded piped water system due to the high costs associated with these types of water. He also found that the demand for vended water was significantly influenced by its price, the time required to collect it, and the capacity of the home water reservoir. The demand for hydrant water, on the other hand, was influenced by its price, the quantity of water purchased from vendors (the main substitute source), and the age of the head of the household. The price elasticities from both hydrant and vended water are in the same range as, and consistent with those found in, other developing countries. However, in Crane's model, water demand is not responsive to income variation, and is not significantly affected by differences in family size and other family and community characteristics.

In the Philippines, David and Inocencio (1998) estimated water demand equations for households supplied by vendors, and for those with a private supply connection. They first found that households relying on private waterworks generally belonged to a higher income group. Furthermore, in both cases, simultaneity problems due to the fact that the price variable (as one of the explanatory variables) is determined by both demand and supply factors were dealt with through the use of two-stage least squares in the estimation. Explanatory variables such as price, monthly household income, household size, distance from sources, and dummy variables representing mode of vending water and taste, respectively, were significant.

Rietveld et al. (2000) estimated a water demand equation for households with a piped connection in Indonesia. In their study, water consumed was a function of a set of household features, namely the marginal price of water and the virtual income.[4] Results showed that very low-income households appeared to be slightly more sensitive to price increases than their higher-income counterparts. Furthermore, water consumption depended strongly on household size.

Basani et al. (2008) estimated both an access-to-water-network equation and a water demand equation in Cambodia. For the water demand relationship, key independent variables were price, connection fee, household expenditure (as a proxy for income) and location dummies. However, the absence of substantial variation in the price measures led the authors to conclude that the estimates related to price elasticity of demand were to be treated with a bit of caution because of limitations of the available data.

However, where households rely on different water sources, a combination of the source choice model and a model of water use conditional upon source choice was found to be more helpful (Nauges and Whittington 2010). With data collected in Ukunda, Kenya, Mu et al. (1990) developed and estimated a discrete choice model of a household's water source decision, and compared it with the traditional demand model. The results showed that a household's choice of water source was influenced by the time it took to collect water from the various sources, the price of water, and the number of women in the household in question. However, household income was not significant.

Using data from Faisalabad in Pakistan, Madanat and Humplick (1993) modelled the relation between a household's choices of water supply and their connection decisions. Using a multinomial logit, two types of explanatory variables were included in the source choices model: *socio-economic attributes* (indicators of income, education, household size, and the presence of a storage tank) and *source attributes* (households' perception of the highest quality water source, state of repair of the hand pump, piped water pressure level, and change in piped water quality since connection). The results showed that different dimensions of a household's decision-making process were interrelated, but due to a lack of variability in the data, the coefficient associated with the household size variable was insignificant – although it was expected that larger households were more likely to use a more reliable source.

In her study, Hindman Persson (2002) analysed household choice with respect to the source of drinking water in the rural Philippines using a discrete choice approach. An analysis of the effects of input prices (time costs), taste and household size on the choice probabilities revealed that time costs had a negative and significant effect, but that taste (proxied by income) had an ambiguous effects on household choice.

By looking at the linkages between poverty, education, access to water and household water use in Madagascar, Larson et al. (2006) estimated a reduced-form water demand function for a household that was conditional in respect of the water source. Their results showed that better-educated and higher-income households relied significantly more on private water supplies and used significantly more water. When one applied the contingent valuation method, the findings suggested that the willingness to pay for improved access was price-sensitive.

However, as Nauges and Whittington (2010) point out, data collected for the purpose of modelling source choices made by households in developing countries that have multiple potential sources normally miss a step: they only include questions on the water source actually used by the household, and ignore attributes of those sources that are not chosen. Nauges and Whittington (ibid.) argue that a household's decision to buy water from a vendor, for example, will depend both on the price to be

[4] *Virtual income* is the monetary income plus the implicit income transfer given by the difference between what a household would pay if all units were charged at the price of the last unit consumed (the marginal rate) and what it actually pays.

paid for using that water, and on the time it might take to get water from a tube well. Thus, only studying the attributes of the water source actually chosen will paint a biased picture of the household's decision-making.

One of the few studies to include the attributes of sources not chosen is Nauges and Strand (2007), who studied water demand among non-tap households in Central American cities by first estimating the probability that a specific water source would be chosen by the household. They considered that unconnected households spent time hauling[5] water from coping sources, and that this time had an opportunity cost. Therefore, they transformed the hauling time into a corresponding pecuniary time cost by using the average hourly wage in the household as the shadow cost of time. The demand equation was described by the relationship between water consumption on the one hand and, on the other, the full cost of water, household income, family size, whether members of the household were literate, lot size, size of the constructed area, and the availability of electricity. Their results showed that the total water cost (the sum of the water price and the hauling time) had the traditional negative effect on water demand. Household demand was also found to be responsive to income variation, with bigger families showing lower per capita consumption.

However, although Nauges and Strand (ibid.) used the full cost of the water (price + time cost), they should also have used *Full income* rather than *Monetary income* as an explanatory variable. They were, in fact, inconsistent, given that the money foregone by the use of time spent on collecting water had to be added to the monetary income in order to constitute the full income. Otherwise, if one considers the monetary income together with the full cost of water, one risks ending up with a situation where people 'spend' more on water than they have actually received in monetary terms.

By using the multinomial logit model to estimate the non-tap water demand among unconnected households, the present study is close to that by Nauges and Strand (ibid.). However, in the present study, an additional assumption is included: the household's decision to purchase water from a public tap, somebody else's private tap, or a protected or unprotected spring depends not only on the price of any of these four sources, but also on the attributes of the other sources – whether chosen or not. In the present case, the *Full cost* (expressed as the difference in the full cost between a public tap and other coping sources) variable for each source has been in the model; and through it, we include the attributes of unchosen sources.

Thus, following the same reasoning as Nauges and Strand (ibid.), the household demand function for unconnected households is estimated by means of a two-step method in order to correct selection bias in the spirit of Heckman (1979).

4. Data

In 2011, Rwanda conducted an Integrated Household Survey which collected data on household water use as well as other household-level information. However, as with many other household surveys in developing countries, no information was collected as regards water sources other than the one which the household actually used. Therefore, we conducted an independent survey on urban water use.

The data set used here comes from a household survey conducted from January to April 2011 involving 700 households in five urban areas of Rwanda. The largest share (500 households) of the sample was based in Rwanda's capital, Kigali, which comprises the districts of Gasabo, Kicukiro and Nyarugenge. The remaining 200 households resided in two other selected urban districts, namely Huye and Nyagatare. The data collection was undertaken in a team together with eight research assistants. The types of questions asked during the fieldwork are summarised in Appendix B hereto.

[5] *Hauling time* refers to the time spent by a household to collect water.

For the sampling method, we first clustered the population into the five existing provinces. Since the targeted population were those living in urban areas, and since the capital city constituted the main urban centre, we considered Kigali Province as a separate cluster. With simple random sampling, we then selected two of the four remaining provinces, namely Southern Province and Eastern Province. In these selected provinces we randomly selected two urban districts, namely Nyagatare (Eastern Province) and Huye (Southern Province). Since Kigali city's population totals around 1,100,000, and the average household size is 4.4 persons in urban areas and the sampling ratio is 1:500, the sample size for the capital city became approximately 500 households. As Gasabo is the most populated district in Kigali city (with almost 530,000 habitants), using the same formula we selected a total sample of 237 households for that district, of which 189 were not connected to the piped network.

<Figure 1 about here>

The whole data set covers two groups of households:

- Those currently connected to the tap water system, but who still rely on a coping source in case their water is interrupted, and
- Those who are unconnected and use a variety of coping sources.

This study, which focused on the latter group, produced data on the water demand and related costs for 495 unconnected households. Data on the quantity and prices of water for unconnected households who rely on non-piped sources were based on self-reported information, which could induce errors in measurement. However, water is an important component of the full expenditure of many of these households, and it seems reasonable to assume that they will have a fair idea of the attributes of the various sources available. Households in the same area generally reported similar prices for the various alternatives available in that area, which indicates that the choice of water source is well-informed.

Table 1 describes variables to be used in further sections. Among the variables, the per capita water consumption was constructed by summing the total amount of water that households used in a month from all sources. The price of water was the unit price[6] for water purchased by households. The *Full income* variable is the full value of a household's time, given that household's hourly wage. We constructed the *Time cost* variable by transforming the monthly hauling time into a pecuniary time cost by using the average hourly wage (from monthly monetary income) in the household as the shadow cost of time. In fact, the source attributes (e.g. price and time cost) and household characteristics (full income, years of schooling, household size and lot size) were considered in the model to account for heterogeneity in preferences. There were alternative options, such as using the distance to water instead of time. However, we found in the pilot that households had problems estimating the distances to unchosen sources, but that they were able to estimate the time consumption. Therefore, we found it better to use the *Full cost* variable.

<Table 1 about here>

Table 2 describes the average monthly per capita water consumption and the average cost for each source for the unconnected household subsample. The weighted average consumption is 0.28 m^3 per capita per month; the weighted average monetary cost without a time cost became US\$0.40/m^3 per month; and the weighted average full cost including the time cost came to US\$1.81/m^3 per month. Unconnected households spend a lot of time collecting water from public taps and protected springs. Water from public taps is the most expensive – regardless of which cost measure is used.

<Table 2 about here>

[6] To standardise unit prices, we construct the variable price as the price per cubic metre.

The descriptive statistics show that unconnected households register a high consumption of water from somebody else's private tap. Rwanda has an increasing block tariff which is intended to ensure that all households have cheap access to water for their subsistence needs; however, compared with the first and lowest block, unconnected households actually pay more for their water from somebody else's private tap. In general, by adding the time cost – which is quite high for all sources – to the price of water, one could say that non-tap water is far more expensive than that from the piped network.

Table 3 shows the average monthly per capita water consumption across the selected urban districts. The results reveal that, in all districts, public taps are the main source of water for unconnected households. In the Nyagatare District, unprotected springs constitute a second preferred source. For this latter district, due to the long distances that household members need to walk to get to the nearest water point, there is a trade-off between hauling free water and buying expensive water from a public tap. Except for the Nyagatare District, somebody else's private tap constituted the second most common source for the remaining districts.

<Table 3 about here>

Overall, 87% of unconnected households use only one source (Table 4); 11% combine water from two sources; and only 2% combine three or more sources. For those who use only one source, the main share (53%) of water used comes from the public tap. In general, sources used vary across districts, while water availability and frequency vary across sources. For the subgroup of households using two sources, we see that one source dominates in most cases.

<Table 4 about here>

Non-tap water not only imposes extra costs compared with tap water; it may also expose users to the risk of disease. As has been reported by Nauges and Van den Berg (2009), the lack of safe water and all things related to inadequate sanitation facilities are amongst the main causes of precariousness of life in many developing countries. This can be applied to the case of Rwanda as well, where households who lack a tap water connection run high risks of contracting a water-related disease. Comparing both unconnected and connected households, the results from our own survey show that, for example, 33% of the former group fell prey to diarrhoea and 45% contracted intestinal worms during 2010, while for the other group 22% got diarrhoea and 40% suffered from intestinal worms.

From some basics statistics (see Table 5), it is clear that, compared with connected households, the unconnected subgroup registers lower household incomes, lower school enrolment rates, etc. In brief, all characteristics show that connected households are better off socio-economically than unconnected ones. The differences are statistically significant for income, education level, and hauling time for water.

<Table 5 about here>

5. Model specification and estimation procedures

As has been mentioned by, for example, Nauges and Whittington (2010), in developed countries where only one source of water is used, the residential water demand function in such countries can be specified as a single equation, as follows:

$$Q = f(P, I, Z) \tag{1}$$

The function (1) describes how the quantity of water used, Q, is determined by price P, income I, and a vector of socio-economic characteristics Z (to control for heterogeneity of preferences and other variables affecting water demand).

However, in developing countries, where households use water from several different sources, this equation cannot be directly applied; and different ways of deriving and estimating the demand function have been suggested instead.

In the present case, the demand equation is estimated for all sources of water used by unconnected households. However, for the choice of source, different factors might be observed as well as their impact on the demand function.

5.1 Assumptions

Considering previous background information, access to non-tap water sources should not be regarded as exogenous in the demand equation for unconnected households. Thus, in order to avoid selection bias in the demand function estimation for the unconnected households, various factors need to be controlled. Although it is common in all districts for households to use different sources of water, the preferences registered in respect of the sources available might be heterogeneous due to characteristics of the household or of the water sources.

In the current study, we control for variables such as education level, full income, full cost, size of household, lot size, district dummies, and attributes of sources that are available but not used. Factors such as full cost and full income will simultaneously determine the choice of source and the amount of water demanded. Previous studies on water demand in developing countries (see e.g. David and Inocencio 1998; Abu Rizaiza 1991; Larson et al. 2006; Nauges and Strand 2007) found a significant link between households' monetary income and their choice of what source to use as well as the quantity of water demanded. Specifically, higher-income households relied on more sources of water and used more water. In the present study, as noted previously, we use the *Full income* rather than *Monetary income* variable, so that we consider the full value of a household's time, given its hourly earnings.

Since not all existing non-tap water sources are equally accessible, the household size and lot size might determine both the selection and the outcome. For example, some previous findings (see e.g. David and Inocencio 1998; Nauges and Strand 2007) showed that the larger the family and the plot, the more likely a safer source would be used, and the lower the per capita consumption. Moreover, a household's decision to select a particular source might depend not only on the characteristics of that source, but also on the attributes of other sources. Furthermore, in order to control for potential differences in the effects of any of the variables on the water demand across the districts, we tried including interaction terms between district dummies and the other variables. However, referring to Nauges and Strand (2007), and by performing a Wald test of parameter equality, we could not find any differences in the effects of any of the variables across districts; we only included district-specific intercepts, therefore.[7]

Education level is also controlled for. This variable is a good predictor of water source choice, but has no direct effect on the per capita water consumption. Thus, this variable does not appear in the demand equation. Larson et al. (2006) found that better-educated households relied significantly more on private water supplies. In most of the literature cited previously herein, the demand was found to be sensitive to price change; hence, the *Price change* variable has been included in the demand model. However, as in Nauges and Strand (2007), the full price of water (water price + monetised hauling time) has been considered here and not only the monetary cost.

[7] The exact sample size from the various urban groups does not matter because the groups were very similar; thus, there was no need to weight the estimates by population size. The results for unconnected households were chi^2 (10) = 5.48, Prob. > chi^2 = 0.8570. The null hypothesis of parameter equality cannot, therefore, be rejected.

5.2 Estimation procedures

As seen previously, although unconnected households combine different types of coping sources, they rely primarily on one source, rather than on all available sources. A discrete choice framework is used here to assume that a household will select one of the four available water sources (someone else's private tap, a public tap, a protected spring or an unprotected spring) so as to maximise its utility. A household chooses coping source j among other alternatives if, and only if, the utility provided by j is greater than or equal to that provided by all coping sources i in the choice set; or stated mathematically, if $U_j \geq U_i$ for all $i \neq j$. A household then decides how much water to use from the chosen water source. This means that for each alternative j, there is an outcome Q_j of the form –

$$Q_j = X\beta_j + u_j \tag{2}$$

where Q_j is the total water demanded from coping source j, X is the vector containing all determinants of the variable of interest, i.e. $X = (P_j + T_j, I, Z)$, T_j the pecuniary time cost for source j, and β_j is the vector of unknown parameter to be estimated.

Households then derive utility from the option j, given by –

$$U_j = V_j + \mu_j \tag{3}$$

where V_j is the observable component of utility, and μ_j is the unobservable or stochastic component. Although the researcher cannot observe the respondent's utility, s/he can observe some attributes of the alternatives (such as the full cost) and some of the household's characteristics (like income, education level, household size, and lot size).

The observable or deterministic component of the utility estimated by the researcher is then a function of the attributes of alternatives, and of the respondents' characteristics.

The systematic component of the utility function can be written as $V_j = Y\gamma_j$, where Y is a vector of characteristics determining the respondent's choice of water source and γ_j a vector of alternative-specific parameters. These parameters relate the characteristics of a respondent (Y) to the respondent's utility for the jth choice. They are individual respondent-specific characteristics, i.e. the effect of independent variables varies across all source choices.

Thus, we have –

$$U_j = Y\gamma_j + \mu_j \tag{4}$$

From the above assumptions, our model reveals that a household's choice of coping source might be correlated with observed and unobserved household characteristics, and that the latter might be unobserved determinants of water demand. From this point of view, the disturbance term u_j in (2) will not be independent of all μ_j in (3). Our model might then suffer from selection bias and this problem will lead to biased estimates of the β parameter. Thus, least-square estimates of β would not be consistent in respect of these correlations between the explanatory variables and the disturbance term in equation (2). To deal with this problem, Heckman's (1979) two-step method is employed to correct for selection bias by using a multinomial logit to model the choice selection issue in the first step and a linear regression with selectivity in the second step.

5.2.1 First step: Multinomial logit as a selection model

The Multinomial logit is used here to explain the choice made by households for a particular source of water among other alternatives. This model is suitable since the dependent variable, i.e. various options of water sources available to households, has more than two outcomes without any natural ordering.

When one uses the multinomial logit model, there is an assumption that the unobservable part of the utility functions μ_j are independent and identically Gumbel[8] distributed (the *IIA hypothesis*; see e.g. Bourguignon et al. 2007). As described by McFadden (1973), this specification leads to the multinomial logit model, with probability as follows:

$$P(D = j|Y) = \frac{\exp(Y\gamma_j)}{\sum_i \exp(Y\gamma_j)} \qquad (5)$$

which define the probability that the utility from choice source j is greater than or equal to the utility from all of the other choices.

This expression enables one to obtain consistent maximum likelihood estimates of the (γ_j). The estimation of the model provides results that can be used to predict this probability for each household. However, the problem is to estimate the parameter vector β_j. In order to obtain a consistent estimate of β one has to incorporate a transformation of these predicted probabilities as an additional explanatory variable.

Various bias correction parameters have been proposed in the literature (see Bourguignon et al. 2007). Lee generalised Heckman's method to apply to the case where the selection is based on a multinomial logit model. Lee has developed a useful consistent two-step estimator that could be applied to multinomial logit–OLS[9] regression sample selection models. His method is based on a transformation of univariate order statistics.

For the present study, Lee's correction term and the two-step estimations have been implemented by first estimating the $(\gamma_j)s$ with a multinomial logit in order to form $Y\hat{\gamma}_j$ and then including that in the demand function in order to get consistent estimates of β and $r_j\lambda$ by least squares.

5.2.2 Second step: Linear regression with selectivity

Following the first step, the demand function becomes –[10]

$$Q_j = X\beta_j + r_j\lambda\left(Y\hat{\gamma}_j\right) + u_j \qquad (6)$$

where r_j is the covariance of the error terms, $r_j\lambda$ are the coefficient terms for the polychotomous correction of selectivity bias, and u_j is an error parameter orthogonal to the rest of the terms, with a mean expectation equal to zero. This property allows the use of OLS in the estimation.

Thus, the demand equation was estimated using the Lee correction method for bias (Lee 1983) and adds to the explanatory variables a series of variables obtained from the first step. These variables are consistent estimators of conditional expected values of the residuals derived from the multinomial logit model. The coefficients on these variables are functions of the covariance between the residual in the regression and the residuals (or some function of the residuals) from the multinomial logit model. Furthermore, in order to control and check the stability of the results, the standard errors were bootstrapped by using 500 replications.

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8 Their cumulative and density functions are, respectively, $G(\varepsilon) = exp(-e^{-\varepsilon})$ *and* $g(\varepsilon) = exp(-\varepsilon - e^{-\varepsilon})$.

9 Ordinary least squares.

10 The derivation of the function $\lambda(.)$ is in Appendix A.

6. Results

6.1 First-step estimation: Probability of choosing a specified source

Table 6 reports the results of the multinomial logit regression used to estimate the probability that a specified source will be chosen. It can be seen that the regressors are jointly significant at the 0.01 level, with a likelihood ratio test chi^2 (18) = 43.03. We found that, relative to using a public tap, with an additional year of education the typical household's probability of using a protected spring decreased by about 5%, while the probability of using someone else's private tap increased by about 8%. From this we can conclude that those with more education were more likely to use someone else's private tap source than a public tap, but at the same time they were more likely to use the public tap rather than the protected spring. As income increases, the probability of using a protected spring decreases relative to using a public tap. Furthermore, an additional member of the household will decrease the probability of using protected and unprotected spring sources, relative to using a public tap.

In order to shed more light on the partial effects of all of the above regressors on sources outcomes, i.e. on how these probabilities change as regressors change, we turn to Table 7. The tabulated results imply that, holding everything else constant (at the mean), a one-unit change in education, corresponding to a single additional year, increases – by about 0.01 each – the probability of using both a public tap and someone else's private tap as sources. Furthermore, a one-unit change in full income, equivalent to a US$1 increase in full monthly income, increases by 0.0002 and 0.0004, respectively, the probability of using a public tap and someone else's private tap source.

Again, the estimated marginal effects show that a US$1 increase in the full cost per cubic metre of water from a public tap decreases by 0.51 the probability of using water from that source, and increases the probability of hauling water from alternative sources, i.e. water from someone else's private tap or from a protected or unprotected spring. In fact, as Table 7 shows, if the cost difference[11] increases, households are more likely to choose water from someone else's private tap or from a protected or unprotected spring.

<Tables 6 and 7 about here>

We also considered the case where the cost of other alternatives changes.[12] Table 8 shows that, if the unit cost of the protected spring source increases by US$1, the probability of using it decreases by 0.03 and the probability of using someone else's private tap increases by 0.03. For the unprotected spring, the estimated marginal effect shows that a US$1 increase in the unit cost of water from that source decreases the probability of using it by 0.3, but increases the probability of using water from a public tap by 0.03.The probability of using the public tap source increases by 0.34, that of using unprotected increases by 0.1 and that of using someone else's private tap decreases by 0.4 if the unit cost of water from a private tap increases by US$1.

<Table 8 about here>

One of the most widely discussed aspects of the multinomial logit model is its assumed independence of irrelevant alternatives (IIA). The IIA assumption is limited in the case of commodities that are close substitutes. However, for the present study, we believe that coping sources currently used by

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11 The *cost difference* is defined as the cost of water from the public tap minus the cost of the alternative. Thus, if the cost difference increases, the cost of the public tap (in time and/or money) increases relative to the cost of the alternative.

12 We estimated, separately, the marginal effects of the same regressors as those in Table 7, but here we instead included the cost of each alternative. However, for the *Unprotected spring* and *Someone else's private tap* sources, we report only the marginal effect for the change of the cost on source outcomes.

households are quite different from each other (in terms of reliability, safety, cost, distance, etc.), and households cannot simply lump any two sources together as close substitutes, e.g. by choosing *Public tap* together with *Protected/unprotected spring*. This implies that the IIA assumption works for the present case. We used a standard test of IIA (Hausman and McFadden 1984) and all results were consistent with the IIA hypothesis.

6.2 The second step: Estimation of water demand function

Table 9a summarises the results of the water demand function estimates. The full income elasticity is observed to be 0.10. This is in line with previous findings in the literature. As mentioned by Nauges and Whittington (2010), income elasticity is generally found to be quite low, most often in the 0.1–0.3 range, in studies estimating water demand in developing countries. For the present study, the *Monetary income* variable was also used in comparison with its *Full income* counterpart. The results in Table 9b show that the monetary income elasticity is very low (0.03) compared with the full income elasticity.

A negative significant effect was found for household size, which means that the per capita water consumption decreased with the number of members in the household. As the number of bedrooms increased, the per capita consumption fell. These results are also in line with previous findings in similar literature. There might be evidence of selectivity in the latter result, since the estimated coefficient of the first Lee correction term is negative and significant. In their similar findings, Nauges and Strand (2007) highlighted the positive correlation between the disturbance term u_j in the demand equation and the disturbance term μ_j in the selection model. This reveals that some unobserved household characteristics are correlated with a household's choice and use of a coping source.

The total cost elasticities vary from -0.6 (protected spring, someone else's private tap) to -0.2 (public tap). These results primarily reflect an inelasticity of water demand in the present study. Furthermore, as the public tap is most convenient coping source, its demand becomes more inelastic than that of the other alternatives. These findings are again in line with previous findings in the literature.

For robustness checks, we examined how the main coefficient estimates behaved by including alternative variables. We found that the results for the main coefficients remained largely similar.[13]

<Tables 9a and 9b about here>

7. Conclusions

The current study reports results from cross-sectional data collected in various urban areas of Rwanda during a surveyed subgroup of 495 households without tap connections. These households used a variety of coping sources and sometimes combined water from different sources. Statistics show that 87% of the respondents used only one water source, while 11% used two sources, and 2% combined three or more sources.

The findings reveal that 57% of unconnected households used a public tap as their main coping source. Furthermore, the overall average consumption was 0.28 m^3 per capita per month, the overall average cost without the hauling time cost was registered at US\$0.40/m^3 per month, and that the average cost, including the value of hauling time and the time spent waiting one's turn at the source in question, was US\$1.81/m^3 per month.

Compared with connected households, unconnected households register a low income and a low school enrolment rate. Using the full income variable, results give an income elasticity of 0.10 for

[13] Results are not presented here, but can be provided on request.

these categories of households. The total cost elasticities vary between -0.6 (somebody else's private tap) to -0.2 (public tap).

For the unselected sources, the *Full cost* variable (i.e. the difference in the full cost compared with the public tap) was added as an explanatory variable in the logit. Our findings suggest that the more expensive public tap source made people more likely to choose water from elsewhere.

An alternative explanation is that people were more likely to choose the public tap source if water from someone else's private tap became more expensive. People using water from a protected spring as their main source were also more likely to switch to water from someone else's private tap if the cost of the protected-spring source increased.

From these findings, it is important to be able to predict what kind of potential and suitable improvements in water demand and management that might result from an appropriate policy. Here it can be assumed that, for the case of Rwanda, poor households (i.e. unconnected households) cannot expect to be connected to the piped network in the short run; thus, improving the current non-tap distribution systems could be considered an alternative solution. From assumptions made previously, one could therefore say, for example, that the welfare effect of extending public tap connections might be immense for this group of households.

For further applications, it might be interesting to do a cost–benefit analysis of, on the one hand, extending the current tap water systems so that more unconnected households can be connected, and on the other, improving the current non-tap distribution systems so that poor households' access to safe and adequate water is enhanced. In any case, it is important to make assessment for the welfare effects of having or not having tap water.

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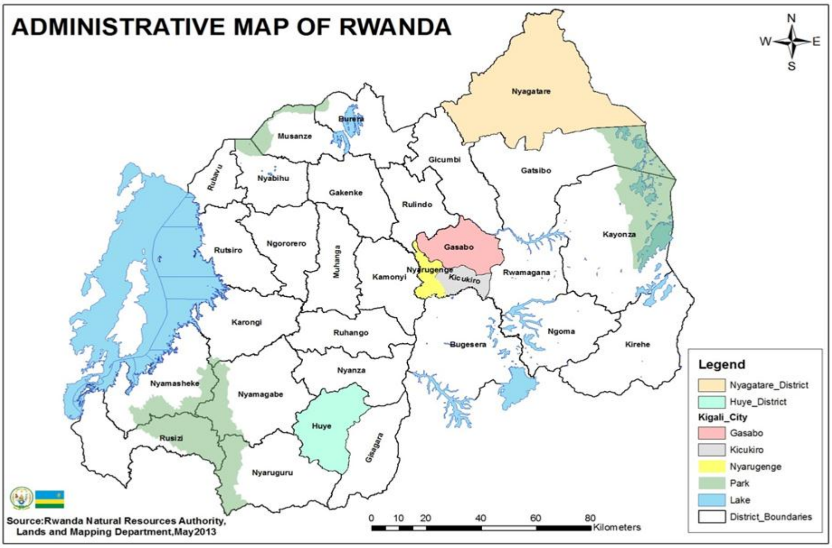
Fig. 1 Map of sampling sites



Source: Rwanda Natural Resources Authority, Lands and Mapping Department, May 2013

Table 1 Description of variables

Variable	Description	Related survey questions
Per capita water consumption (Q)	Average water consumption per household per month	Amount of water used by the household from their regular source each month
Price (p)	Average price of water	Price per cubic metre of water from the household's regular source
Full income (I)	Household's full income (monetary income + money forgone by hauling time)	• Amount of money remitted by a member of the household who works elsewhere • Hauling time in respect of regular source • Monthly monetary income
Time cost (T)	Cost of hauling time and waiting time	• Hauling time in respect of regular source • Monthly monetary income
Household size	How many members in the household	Number of male and females in the household (0–5 years, 6–9 years, 10–18 years, 19–35 years, 36–60 years, 60+ years)
Years of schooling	The respondent's level of education	If the respondent is educated, his/her level of education
Lot size	Number of bedrooms	Number of bedrooms in the house

Source: Author's survey

Table 2 Average water consumption and average cost

Sources	Average water consumption (m^3 per capita per month)	Average cost (price/monetary cost) without time cost (US$ per m^3)	Average cost (price/monetary cost) with time cost (US$ per m^3)
Someone else's private tap	0.40	0.46	0.48
Public tap	0.60	1.27	4.45
Tube well	0.01	0.02	0.46
Protected dug well	0.02	0.07	0.20
Protected spring	0.38	0.48	3.32
Unprotected spring	0.17	0.12[14]	0.90
Cart with small tank	0.003	0.02	0.12
Surface	0.03	0.10	0.11
Other	0.01	0.05	1.18
Weighted average	0.28	0.40	1.81

Source: Author's survey

14 For the *Unprotected spring* and *Surface* categories, the cost is related to the price charged by vendors who carry and sell water to households.

Table 3 Average water consumption across selected urban districts (m^3 per capita per month)

Variable	Kigali				
	Kicukiro	Gasabo	Nyarugenge	Huye	Nyagatare
Someone else's private tap[15]	0.22	0.45	0.48	0.47	–
Public tap	0.66	0.59	0.64	0.56	0.53
Tube well	0.02	0.001	–[16]	0.001	0.08
Protected dug well	–	0.004	0.01	0.002	0.01
Protected spring	0.08	0.13	0.07	0.11	0.04
Unprotected spring	–	0.05	0.02	0.10	0.48
Cart with small tank	0.002	0.01	–	–	–
Surface[17]	0.001	0.004	0.06	0.01	0.09
Other	0.0003	0.01	–	–	0.01

Source: Author's survey

15 Here, reference is made to piped water either into the dwelling or into the yard. Some 91% of respondents use water piped into their yard, while very few have water piped into their dwellings.

16 The source exists in the area, but was not used by any of the households in the study sample.

17 River, dam, lake, pond, stream, canal or irrigation channel.

Table 4 Households combining different types of coping source and the share of water for each source

Coping source		
One coping source used	**Share of water[18]**	
Someone else's private tap	11%	
Public tap	53%	
Protected spring	13%	
Unprotected spring	7%	
Other	2%	
Percentage of households using one source	*87%*	
Two coping sources used	**Share of water for the most common combinations[19]**	**Share of water coming from the main source**
Someone else's private tap combined with an additional source	7%	(Someone else's private tap water 62% of this)
Public tap combined with an additional source	4%	(Public tap water 77% of this)
Other combination	1%	
Percentage of households combining two sources	*11%*	
Three coping sources used	**Share of water[20]**	
Three coping sources used	2%	
Percentage of households combining three sources	*2%*	

Source: Author's survey

[18] Cubic metres per capita per month.
[19] Cubic metres per capita per month.
[20] Cubic metres per capita per month.

Table 5 Descriptive statistics among connected and unconnected households

	Unconnected		Connected	
Variable	Mean	Standard deviation	Mean	Standard deviation
Monthly full household income (US$)	267.97	370.77	385.03	511.73
Years of schooling	7.78	4.947	9.36	5.01
Household size	5.49	2.38	5.59	2.68
Number of bedrooms	3.20	1.16	3.24	1.27
Hauling time (minutes per month)	627.88	807.17	225.17	460.16

Source: Author's survey

Table 6 Multinomial logit estimation (public tap = comparison group)

Variables	Protected spring	Unprotected spring	Someone else's private tap	Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Household's full income (US$)	-0.00114**	-0.00103	-0.000402	
	(0.000539)	(0.000641)	(0.000641)	
Years of schooling	-0.0572**	-0.0206	0.0721***	
	(0.0312)	(0.0272)	(0.0277)	
Household size	-0.189**	-0.146**	-0.0570	
	(0.0738)	(0.0618)	(0.0625)	
Number of bedrooms	0.0787	0.00904	0.158	
	(0.153)	(0.112)	(0.140)	
Difference in full cost	2.259***	2.408***	1.412***	
	(0.623)	(0.644)	(0.511)	
Constant	-2.559***	-2.884***	-2.401***	
	(0.686)	(0.654)	(0.593)	
Measures of fit				
Log likelihood	-510.62233			
Likelihood ratio test, chi^2 (18)	43.03			
Prob. > chi^2	0.0000			
Observations	495	495	495	

Source: Author's survey

Table 7 Marginal effects on the probability of using each of the four non-tap sources

Variables	Public tap	Protected spring	Unprotected spring	Someone else's private tap	Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Household's full income (US$)	0.0002*	-0.0004*	-0.0001	0.0004*	
	(0.0001)	(0.0004)	(0.00008)	(0.00006)	
Years of schooling	0.0103***	-0.00227	0.000553	0.00861***	
	(0.00485)	(0.00305)	(0.00372)	(0.00278)	
Household size	0.0320***	-0.0155**	-0.0162*	-0.000295	
	(0.0116)	(0.00707)	(0.00834)	(0.00629)	
Number of bedrooms	-0.0174	0.00566	-0.00368	0.0155	
	(0.0226)	(0.0149)	(0.0153)	(0.0142)	
Difference in full cost (US$/$m^3$)	-0.504***	0.162***	0.275***	0.0667*	
	(0.146)	(0.0492)	(0.0757)	(0.0358)	
Observations	495	495	495	495	

Source: Author's survey

***Table 8** Marginal effects if the cost of only one of the alternative sources changes*

Variables	Public tap	Protected spring	Unprotected spring	Someone else's private tap	Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Household's full income (US$)	0.0002**	-0.0001**	-0.0001	0.0003*	
	(0.0001)	(0.0001)	(0.0001)	(0.00007)	
Years of schooling	0.072*	0.0188	-0.063**	0.050*	
	(0.042)	(0.0363)	(0.0429)	(0.048)	
Household size	0.033***	-0.0159**	-0.015**	-0.0001	
	(0.0117)	(0.0071)	(0.0082)	(0.0065)	
Number of bedrooms	-0.0186	0.0042	0.002	0.012	
	(0.0229)	(0.00427)	(0.0154)	(0.014)	
Cost of public tap	-0.0085***	0.0027***	0.005**	0.001**	
	(0.0024)	(0.0008)	(0.0013)	(0.001)	
Cost of protected spring	0.055	-0.026**	0.050	0.028**	
	(0.033)	(0.012)	(0.036)	(0.011)	
Cost of unprotected spring	0.025*	0.044	-0.338*	0.04	
	(0.149)	(0.031)	(0.209)	(0.031)	
Cost of private tap	0.345***	0.004	0.078***	-0.427***	
	(0.114)	(0.130)	(0.003)	(0.043)	
Observations	495	495	495	495	

Source: Author’s survey

Table 9a Estimation of water demand function (Full income)

Dependent variable: Monthly water use (log) per household member	Estimated coefficient[a]	Bootstrapped standard error[b]	Student's t-test
Constant	0.112	0.441	0.28
Log(total cost(public tap))[21]	-0.150**	0.060	-2.65
Log(total cost(protected spring))	-0.636***	0.282	-2.54
Log(total cost(unprotected spring))	-0.045	0.099	-0.54
Log(total cost(private tap))	-0.612**	0.274	-2.43
Log(full income)	0.103*	0.081	1.39
Log(lot size(number of bedrooms))	-0.475***	0.117	-4.06
Log(household size)	-0.169***	0.018	-8.72
Kicukiro dummy district	-0.072	0.116	-0.26
Nyarugenge dummy district	-0.280***	0.086	-2.82
Lee correction parameter 1[c]	-0.866**	0.379	-2.20
Lee correction parameter 2	-0.007	1.886	-0.06
Lee correction parameter 3	1.096	1.949	0.56
Lee correction parameter 4	-0.208	0.846	-0.24
Observations	495		
Wald test of parameter equality (four sources)	33.19		
p-value	0.001		

[a] ***,** and * significance at 1%, 5% and 10% level, respectively
[b] 500 replications
[c] Water sources: Public tap, Protected spring, Unprotected spring, Someone else's private tap
Source: Author's survey

[21] All costs and income variables are in US$, adjusted for purchasing power parity.

Table 9b Estimation of water demand function (Monetary income)

Dependent variable: Monthly water use (log) per household member	Estimated coefficient[a]	Bootstrapped standard error[b]	Student's t-test
Constant	0.223	0.576	0.39
Log(monetary cost(public tap))[1]	-0.128**	0.094	-2.36
Log(monetary cost(protected spring))	-0.704**	0.295	-2.38
Log(monetary cost(unprotected spring))	-0.053	0.059	-0.90
Log(monetary cost(private tap))	-0.717***	0.266	-2.70
Log(monetary income)	0.03*	0.044	1.48
Log(lot size(number of bedrooms))	-0.449***	0.117	-3.82
Log(household size)	-0.320***	0.075	-4.23
Kicukiro dummy district	-0.089	0.107	-0.83
Nyarugenge dummy district	-0.271***	0.084	-3.23
Lee correction parameter 1[c]	-0.753**	0.385	-1.95
Lee correction parameter 2	0.113	1.406	0.08
Lee correction parameter 3	-0.151	0.467	-0.32
Lee correction parameter 4	-0.336	0.999	-0.34
Observations	495		

[a] ***,** and * significance at 1%, 5% and 10% level, respectively
[b] 500 replications
[c] Water sources: Public tap, Protected spring, Unprotected spring, Someone else's private tap
Source: Author's survey

Appendix A: Lee correction

As has been underlined by Bourguignon et al. (2007), Lee (1983) suggests a generalisation of the two-step selection bias-correction method in the spirit of Heckman (1979). This model specifies that bias correction can be based on the conditional mean of u_j.

By defining $= \{Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\}$, we have –

$$E(u_j|\varepsilon_j < 0, (Y_{\gamma 1,}Y_{\gamma 2,\dots,}Y_{\gamma J})) = \int\int_{-\infty}^{0} \frac{u_j f\left(u_j, \varepsilon_j|\left(Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)\right)}{P(\varepsilon_j < 0, Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J))} d\varepsilon_j du_j = \lambda\left(Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)$$

Let us call $F_{\varepsilon_j}\left(.\,\middle|Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)$ the cumulative distribution function of ε_j. The cumulative $J_{\varepsilon_j}\left(.\,\middle|Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)$ is specified by the following transformation:

$$J_{\varepsilon_j}\left(.\,\middle|Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right) = \Phi^{-1}F_{\varepsilon_j}\left(.\,\middle|Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)$$

where Φ is the standard normal cumulative. By assuming that u_j and $J_{\varepsilon_j}\left(\varepsilon_j\middle|\Gamma\right)$ are jointly distributed, two assumptions have been developed:

1. **Lee's distributional assumption:** The joint distribution of $\left(u_j, J_{\varepsilon_j}\left(\varepsilon_j\middle|\Gamma\right)\right)$ does not depend on $\Gamma = \{Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\}$
2. **Lee's linearity assumption:** $E\left(u_j\middle|\varepsilon_j, \Gamma\right) = \sigma\rho_j J_{\varepsilon_j}\left(\varepsilon_j\middle|\Gamma\right)$

The expected value of the disturbance term u_j, conditional on category j being chosen, is given by –

$$E(u_j|\varepsilon_j < 0, (Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J)) = -\sigma\rho_j \frac{\phi(J_{\varepsilon_j}\left(0\middle|\left(Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)\right)}{F_{\epsilon_j}\left(0\middle|\left(Y\gamma_{1,}Y\gamma_{2,\dots,}Y\gamma_J\right)\right)}$$

with ϕ being the standard normal density. From the form for $\lambda(\Gamma)$ hypothesised above, a consistent estimator of β_j is obtained by running the least square on the following equation:

$$Q_j = X\beta_j - \sigma\rho_j \frac{\phi(J_{\varepsilon_j}(0|\,\Gamma)}{F_{\epsilon_j}(0|\,\Gamma)} + u_j$$

Thus, a two-step estimation of precedent equation is obtained by first estimating the (γ_j)s in order to form –

$$r_j\lambda\left(Y\hat{\gamma}_j\right) = \frac{\phi(J_{\varepsilon_j}\left(0\middle|\left(Y\hat{\gamma}_{1,}Y\hat{\gamma}_{2,\dots,}Y\hat{\gamma}_J\right)\right)}{F_{\epsilon_j}\left(0\middle|\left(Y\hat{\gamma}_{1,}Y\hat{\gamma}_{2,\dots,}Y\hat{\gamma}_J\right)\right)}$$

and then including that variable in the said equation to estimate β_j and $\sigma\rho_j$ consistently by least square.

Appendix B: Summary of type of information collected

B1. Background information on each respondent

Age
Gender
Marital status
Head of household or spouse
Education (Yes/No)
If educated, years of schooling
Primary occupation
Spouse's occupation
Personal possessions (Radio, TV, Bicycle, Motorcycle, Mobile phone, Landline telephone, Car, Gas stove, Electric stove, Fridge, Solar panels, etc.)

B2. Socio-economic profile of each household

a) Materials used as roofing (Concrete metal sheeting, Tiles, Thatch, Other)
Ownership of house (Family, Other)
House features (Number of bedrooms, Number of taps, Number of flush toilets, Number of bathrooms, Number of water storage tanks, Number of water heaters, Number of garages)
Monthly income
Source of income
Number of males and females
Ages of household members (0–5 years, 6–9 years, 10–18 years,19–35 years, 36–59 years, etc.)
Monthly expenditure (Food, Water, Fuel and lighting, Health, Education, Transport, Electricity, Telephone, Liquor and tobacco, etc.)
Principal type of cooking fuel (Wood, Cow dung, Straw, Coal, Kerosene, Gas, Electricity, etc.)
Number of members working elsewhere in the country and/or abroad
Amount of money remitted by members working elsewhere
Amenities (Electricity only, Water only, Water and electricity, No amenities)

B3. Water sources used

B3.1 Coping sources

b) What source of drinking water – e.g. Piped water into dwelling, Piped water into yard/plot, Public tap/standpipe, Tube well/borehole, Protected dug well, Unprotected spring, Rainwater collection, Cart with small tank/drum, Tanker-truck, Surface water (river, dam, lake, pond, stream, canal, irrigation channels) and Bottled water – was available to the household
c) If any of the above sources existed, how often the household used them
d) How much water the household used in a month
e) How much time it took the household each time they fetched water from any of the above sources
f) If the household stated they did not use the above sources, how much time would it take them if they were to use such sources
g) The main source of water used by the household for other purposes, such as laundry, bathing and house-cleaning
h) Who in the household regularly fetched water (Female adults, Male adults, Female children, Male children, Hired workers, Female and male adults, Female adults and male children, Female and male children, Anyone in the house)
i) Price of water from the regular source
Affordability of water from the regular source (Most affordable, Affordable, Unaffordable)

B3.2 Water quality and safety

j) Whether or not any member of the household had ever suffered from a waterborne disease (Diarrhoea, Worm infections, Typhoid, etc.) in the past year
k) How respondents rated the colour of the water from their regular source (Very clean, Clean, Dirty, Very dirty)

l) How respondents rated the taste of the water from their regular source (Excellent, Good, Poor, Bad)
m) How respondent rated the safety of water from their regular source (No risk, Little risk, Some risk, Serious risk)

B3.3 Piped water

n) Whether or not the household received piped water from the municipality
o) If the household chose not to avail themselves of municipal piped water, what their main reason was for not getting a connection
p) If the household received municipal piped water, what connection fees they had paid
q) Whether or not the household obtained water on the specified days on which the area was supplied with water

B4. Households connected to piped water

r) Whether or not households sometimes experienced interruptions in their water supply
s) If they experienced such interruptions, how often they did so
t) Whether or not households sometimes stored water they fetched for household use
u) If they stored such water, what the size of their storage tank was, what price they had paid to purchase the tank, and how long it had taken to install
v) If the household had ever had to rely on emergency sources of water because their stored water had been depleted
w) If they had relied on such emergency sources, how often their supply had been interrupted
x) The type of meter available (Private in-house, Private in yard, Both private in-house and in-yard, Communal, None)
y) Whether or not the meter worked (Respondents were asked to turn on their tap and check if the meter was working)
z) Whether or not households received water bill
aa) If households received water bills, what the most recent total of the bill was, how many months it covered, and what the volume in m^3 had been of their consumption
bb) Whether or not households found the current price of water affordable

B5. Household expenditure to improve the quality of drinking water

cc) Whether or not the household treated or filtered their water in any way before drinking it
dd) If the household indeed treated or filtered its water, how often they did so and what treatment they applied (Boiling only, Filtering only, Boiling and filtering, Addition of chemicals, Straining through a cloth, Solar disinfection, Allowing time for sediments to settle)

Paper II

Individual status quo modelling for a rural water service in Rwanda: Application of a choice experiment

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Abstract

In Rwanda, rural water supply is not uniformly distributed. Thus, for domestic water, rural areas are characterised by differences in the distance to the nearest water point and in water quality; for irrigation water, by watering frequency and water availability; and by the price for both. This means that a household's perception of further improvements in water supply will depend crucially on the current situation faced by that particular household. We used a choice experiment method to model how the individual status quo (SQ) affects preferences. We found that accounting for individual SQ information improves significance of the model relative to simply using the generic SQ parameter in the model, and that the willingness to pay increases. Not using this information leads to a downward bias – and, in some cases, statistical insignificance – in the estimates of households' valuation of health improvements linked to improved domestic water availability, as well as of increased watering frequency linked to the improved availability of irrigation water.

Keywords: choice experiment, domestic water, irrigation water, households, districts, Rwanda

JEL Classification: Q15, Q25, R58

1. Introduction

This paper is about the willingness to pay (WTP) for an improved supply of water for domestic and irrigation use in rural areas of Rwanda. For our analysis, we used a choice experiment (CE) in which individual status quo (SQ) information was used to improve the model fit. This is interesting to do since, from a policy perspective, considering existing individual baseline conditions in the valuation study might assist policymakers in responding better to individuals' real needs – a fact which many previous studies have neglected.

Previous studies applying stated preferences have primarily used hypothetical baselines. This was mainly because researchers either wanted to know how respondents would react if circumstances changed and a new policy were to be introduced, simply as a matter of their own convenience, or in order to minimise protest responses for a status quo condition which was controversial (Whittington and Adamowicz 2011). However, using hypothetical baseline conditions can cause confusion and spread misinformation among the studied population and could also influence the policy process itself in unfortunate ways (Whittington 2004). As discussed in Whittington and Adamowicz (2011), for example, using a hypothetical baseline render the results of the valuation study less policy-relevant if the respondent's preference and behaviour depends on the current baseline SQ condition rather than the state of the world described in the hypothetical baseline.

Following previous criticism, in this paper we used current information about the SQ and observed how this performed compared with the results obtained by using hypothetical SQ parameters.

More precisely, this paper aims to investigate whether the individual SQ situation affects preferences in terms of improvements in rural water supply. Heterogeneity in current rural water supply is especially observed through the price of water, distance to the nearest water point, watering frequency, and water availability. These attributes and other socio-economic variables have been included in the analysis.

We found that not using the individual status quo information limits the significance of the model in both domestic and irrigation water use and, in several cases, leads to downward bias in the sizes of the estimated coefficients. In fact, the estimates of both the conditional and mixed (or *random parameter*) logit models show that, in general, individual SQ information allows better results in terms of significance in the model.

In Section 2, a short description is given of the rural water supply in Rwanda as a background to the study. In Section 3, earlier CE studies, specifically on water valuation, are briefly discussed. In the same section, the literature on SQ information in the CE as well as the usefulness of using the SQ information is reviewed. Section 4 discusses the modelling issues. Section 5 gives details on the interview process, the attributes and attribute levels used in the CE, and the coding used for the individual SQ information. Section 6 describes the households' SQ situation for attributes and the respondents' socio-economic characteristics. Section 7 presents the results of the empirical estimation. In Section 8, we briefly conclude our findings.

2. Background

2.1 Domestic water

The domestic water in rural Rwanda is supplied under several management options, with wide variations across regions with regard to the quality of water, the price of water, and the distance to the nearest water point. At the time of the study in 2012, many households were collecting water from unprotected or otherwise unsafe sources. Statistics show that only 0.9% of rural households have piped water to their premises (Republic of Rwanda 2012), and that most households rely on other alternatives, namely public taps[1] (30%), tube wells[2] (19%), protected or unprotected springs[3] (28%), surface water (10%) and others (12%). Households that consume unsafe water are, therefore, exposed to worms, dysentery and cholera, all of which are associated with insanitary hygiene (Republic of Rwanda 2011).

The average time from a homestead to a drinking water source is estimated to be 29 minutes in the rural areas, with disparities through different districts (Republic of Rwanda 2010). The failure of the rural water access and delivery system reveals that financing mechanisms are not designed to allow revenues from water consumption to help cover supply costs. Thus, in order to improve water supply, most rural water consumers would need to pay more, in one way or another. Furthermore, the heterogeneous baseline status of access to water coupled with an individual's personal socio-economic characteristics might lead to variations in individual preferences for the same improved service. If the heterogeneity in current water access is taken into consideration, an optimal policy reform would need to take context into account rather than applying a regionally homogeneous solution.

2.2 Irrigation water

The uneven distribution of water for irrigation through different parts of the country has become an issue. For example, rainfall is high in the west, but low in the east. This situation explains why farming during dry seasons is very limited in some places. Furthermore, there is inefficient use of water in irrigation throughout the country, given that some households that farm during the dry season receive abundant water, while others lack sufficient water to grow crops during the same period. Thus, water availability and watering frequency differ among farmers and across regions.

Irrigation schemes in Rwanda can be classified into three broad categories: *hillside irrigation* (characterised by pressurised systems developed on privately owned hillside land, but managed by a group of farmers using common irrigation infrastructures); *marshland irrigation* (state-owned lands where farmers are allotted plots on lease and share a common irrigation infrastructure); and *small-scale irrigation* (small, privately owned garden plots) (Republic of Rwanda 2010). For each defined irrigation scheme, all water users are grouped into what are known as *Water Users Associations* (WUAs).[4]

At present, although there is a comprehensive irrigation development policy in place in Rwanda, small-scale informal irrigation – typically on the fringes of marshes – still dominates. Most of these arrangements were developed spontaneously with little or no technical outside assistance (Republic of Rwanda 2010).

Irrigation water comes mainly from rivers, streams, lakes, rainfall and aquifers. Farmers practising small-scale irrigation harvest rainwater in small earth dams with simple drip technologies.

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[1] A public water point, stand post or kiosk at which people can purchase water.

[2] A *tube well* is a deep hole that has been drilled with the purpose of reaching groundwater supplies. Water is delivered through a pump, which is powered by human, animal, wind, electric, diesel or solar means. In the case of Rwanda, the pump is usually powered by human means. See http://www.wssinfo.org/definitions-methods/watsan-categories/, last accessed 6 March 2013.

[3] *Protected* springs are typically shielded from run-off, bird droppings and animals by a 'spring box' constructed of brick, masonry or concrete, and built around the spring so that water flows directly out of the box into a pipe or cistern without being exposed to outside pollution. *Unprotected* springs are subject to run-off, bird droppings, or the entry of animals.

[4] Each such association is endowed with a legal personality in view of the management, enhancement and sustainability of the water resource and irrigation scheme. The Ministry of Agriculture and Animal Resources transfers responsibility for the operation and maintenance of an irrigation scheme to the WUA. The latter, together with the district in which it is located, signs a management transfer agreement. See http://faolex.fao.org/docs/pdf/rwa108341.pdf, last accessed 11 July 2013.

Given the current heterogeneity in irrigation practices due to differences in access to water, the ongoing strategic developments which prioritise the intensification of current production systems by mechanised irrigation (Republic of Rwanda 2010) need to incorporate the design of appropriate instruments that respond to the specific individual context.

3. Methodology

3.1 The choice experiment method

A *choice experiment* is a quantitative technique for eliciting individual preferences. It allows researchers to uncover how people value selected attributes of a programme, product or service by asking them to choose among various hypothetical alternatives (Mangham et al. 2009).

Research on the valuation of non-market goods has evolved over the years through the revealed preference (RP) and stated preference (SP) methods. The former method assesses the value of non-market goods by studying actual behaviour on a closely related market, while the second relies on individuals' stated behaviour in a hypothetical setting (Alpízar et al. 2003). The use of RP methods proved inefficient when foretelling demand for new services, i.e. in situations where the aim is to find out what people would be prepared to pay if a good's characteristics were to change in the future (Vloerbergh et al. 2007). This limitation raised an interest in SP methods, amongst which are the more well-known contingent valuation method (CVM) and the CE method used in economic valuation. In the CE method, respondents are asked to choose between a set of alternatives with different attributes, often including a (hypothetical) baseline alternative with the attributes currently facing an average respondent. The CE method constitutes a generalisation of the CVM in that respondents are asked to choose between cases described by several different attributes rather than choosing between a base case and a specific alternative (Adamowicz et al. 1998). The CE method's advantage over the CVM is that it relies on the representation of the choice situation in using an array of attributes, rather than on a specific change in the good or service. Conversely, a problem with the CVM is its reliance on the accuracy of the information and the impossibility of changing any errors in the information found after the fact (Boxal et al.1996). Furthermore, the CVM produces only one value for an overall change in environmental quality, while the CE provides a value for each individual attribute of an environmental programme (Poirier and Fleuret 2010).

The CE method, initially developed by Louvière and Hensher (1982) and Louvière and Woodworth (1983) on traveller trade-offs, is useful in valuing non-market goods. Choices and the analysis of aggregate consumer choice behaviour have been used increasingly in environmental and natural resource economics (Bateman et al. 2002). However, application of the CE method is relatively new in the field of water resource economics. Young (2005) presents a detailed discussion of conceptual issues related to water valuation, such as the use of water as an input to production. He notes (ibid.) that, for most goods traded in markets, prices reveal a product's scarcity via the signals they send; but for publicly provided goods and goods with a strong public good component, such as water, clear price signals are often lacking; in these cases, indirect valuation methods are needed. Using a series of CE methods and mixed logit models for domestic water demand, Hensher et al. (2005) studied WTP to avoid interruptions in water service and overflows of waste water, differentiated by the frequency, timing and duration of these events in Canberra, Australia. Their findings suggested that both frequency and the length of disruption were important attributes for the WTP for a reliable service. Willis et al. (2005) used the CE method to estimate WTP for service-level changes in the provision of water in the United Kingdom. Using conditional logit, conditional logit quadratic, nested logit and nested logit quadratic models, they found that the estimated values were quite similar for each service factor across models. Hanley et al. (2006) analysed the values that respondents placed on improvements to watercourses and tested the ability of the CE method for benefits transfer across two similar rivers. Attributes such as *River ecology*, representing aquatic life; *Aesthetics*, representing the amount of litter in the river; and *Quality of banksides* were selected. The results showed that people placed insignificantly different values on these three aspects, but that preferences and values differed significantly across samples.

For developing countries, there are very few studies using the CE method to analyse households' WTP for improved domestic water services. In their study, Tarfasa and Brouwer (2013) use the CE method to elicit households' WTP for improved water supply services in an urban area in Ethiopia. Their findings showed that, despite significant income constraints, households were willing to pay up to 80% extra for improved levels of water supply over and above their current water bill. Furthermore, women and poor households with the lowest service levels attributed a higher value to the improved water supply services.

Regarding water for irrigation, few studies so far have been made using the CE method. One was by Peterson et al. (2007), who designed and implemented a series of CEs to elicit the water quality trading behaviour of Great Plains crop producers in different situations. As attributes, the CE included market rules and features that might affect farmers' willingness to trade. Using the mixed logit model, the study found diversity in the way that the selected attributes affected farmers' choices. In another study, Rigby et al. (2010) examined the economic value of irrigation water to horticultural producers in southern Spain using a CE. Through the mixed logit model, findings revealed heterogeneity in the WTP values. Farm size was also found to affect WTP, with those managing larger holdings willing to pay substantially more for water. A study by Brebbia et al. (2010) elicited the most preferred water pricing method under different water rights, water prices and local irrigation water governance contexts in India. The results showed that, under conditions of improved water rights, there was an increase in the preference for volumetric pricing, while this preference decreased with the presence of a water user association. Furthermore, making the right combination of water demand management tools helped to increase WTP for an improved supply scenario. In India, Chellattan et al. (2011) applied the CE method to investigate farmers' preferences for and the efficiency of a given pricing method based on WTP estimates. Their findings revealed that farmers did not prefer the existing pricing system to any of the proposed alternative pricing systems, and that the volumetric-based pricing methods would probably be the most acceptable solution.

Up to now, researchers in CE have often used hypothetical baseline scenarios without considering their impacts on a respondent's welfare. However, Barton and Bergland (2010), studying the WTP for irrigation water among farmers in Bangladesh, found it useful to consider the individual SQ information in their model in that it helped improve the model significance. In their study, farmers were asked to choose between two alternative situations: one entailed an improved irrigation water supply at different charges, while the other entailed their existing situation, where water supply and water tax were as the individual farmers were already paying. The authors found that including farmers' current situation affected their estimated preferences for hypothetical water regimes and irrigation prices.

3.2 Individual SQ information

The current study also uses the CE technique, but in line with the Barton and Bergland (2010) study discussed above, we emphasise the impact of including individual SQ information on the WTP for new hypothetical alternatives. According to Barton and Bergland (ibid.), this method might help to better understand the SQ effect, and may capture otherwise unobserved heterogeneity, by virtue of which the potential limitation encountered by the CE modelling could be addressed.

A series of decision-making experiments showed that, when people are faced with different choices, they have a strong tendency to prefer that things remain unchanged (Meyerhoff and Liebe 2009). This behaviour, referred to as *SQ bias*, was first demonstrated by Samuelson and Zeckhauser (1988).[5]

[5] The authors define the *SQ option* as a decision to do nothing or to maintain one's current or previous situation.

CE studies have generally avoided using SQ information because individuals' preferences for SQ choices have been considered as a psychologically based deviation from rational choice. Thus, the use of SQ information has been quoted as a factor that might induce a so-called *SQ effect* (i.e. the equivalent of an SQ bias) relative to rational consumer behaviour towards and away from the SQ alternatives (Barton and Bergland 2010). According to Samuelson and Zeckhauser (1988), this SQ bias may be classified into three categories: (1) rational decision-making in the presence of transition costs and/or uncertainty;[6] (2) cognitive misperceptions;[7] and (3) psychological commitment stemming from misperceived sunk costs,[8] regret avoidance, or a drive consistency.[9] However, for demand prediction and in order to estimate the welfare change associated with policy proposals, the use of SQ information may be essential. Furthermore, the inclusion of SQ information means that respondents are not forced to choose only between hypothetical alternatives they might not actually want.

In general, SQ information used in the CE literature has been principally fixed and hypothetical, with no change in attributes across respondents. According to Barton and Bergland (2010), however, the simplification to a common SQ becomes problematic in the CE scenario when the actual SQ situation facing respondents is sufficiently variable. In their study, Barton and Bergland (ibid.) considered that, since irrigation water was a rival in consumption and was a common pool resource, every farmer had a different SQ water availability scenario, depending on his/her farm's location in the network of irrigation channels. It is the same with the current study: we noticed a large variation among farmers in respect of irrigation frequency, water availability, and payment for water used. For domestic water use, the wide variability across households is observed particularly keenly through the frequency of contacting waterborne diseases, through distance from the nearest water point, and through the cost of water. Thus, the use of individual SQ information is likely to be suitable for both domestic and irrigation water use for the present study as well.

For modelling issues, the SQ effect has been dealt with by applying the conditional logit model together with an alternative-specific constant (ASC), as discussed further in Section 4, or by applying the nested logit model – given that the first model helps to address systematic SQ effects, and the second the correlation across utilities of designed alternatives. As for the mixed logit model specification, both types of effects are flexibly and simultaneously addressed by inducing a correlation pattern in the utility of alternatives, and by capturing a systematic effect due to the SQ in the indirect utility (Scarpa et al. 2005). However, according to Banzhaf et al. (2002), including the individual characteristics of each respondent's opt-out alternative is more informative than including an interaction term between an ASC and respondents' characteristics. Furthermore, Barton and Bergland (2010) could not include an ASC for the SQ level, since it is highly correlated with the individual SQ attribute levels. Therefore, the present study is similar to that of Barton and Bergland (ibid.), but with an application to both irrigation and domestic water use.

For both irrigation and domestic water use, households in our study were requested to choose between two new alternatives for improved water supply at different prices and other attribute levels on the one hand, and a current situation in which water supply reflected the SQ level as reported by the household, on the other.

4. Model development

6 The individual's initial choice affects his/her preferences in the subsequent decision, and any switch from the SQ can be costly.

7 Individuals weigh losses more heavily than gains in making their decisions.

8 The larger the past resource investment in a decision, the greater the inclination to continue the commitment in subsequent decisions.

9 Past choices are rationalised, and the rationalisation process extends to current and future choices.

The choice analysis has often been described as a way of explaining variations in the behaviour of a sample of individuals – which is the key focus of the CE. In particular, recent research has emphasised the recognition of variance in utility over different choice situations (Greene and Hensher 2010). The next crucial point has been to find an appropriate model to help determine the influences that heterogeneity has on choice-making. In recent years, research has focused on how best to model that heterogeneity; rapid progress has recently been made in modelling heterogeneity in the CE.

4.1 Conditional and mixed logit models

The most common starting point in CE modelling is the conditional logit model, where a choice among alternatives is treated as a function of the characteristics of those alternatives (McFadden 1974). The conditional and mixed logit models have been popular in modelling qualitative choice behaviour. According to McFadden (ibid.), approximation is reasonably good with the conditional logit model – even in small samples. However, the main concern about the latter model is its assumption of independence from irrelevant alternatives (IIA).[10] Furthermore, with the conditional logit model, there is an assumption that disturbances are independent and homoscedastic. This assumption may be too restrictive, especially when the number of alternatives in the choice set is large.

The mixed logit model allows the parameter associated with each observed variable to vary randomly across individuals, and avoids the IIA assumption (Revelt and Train 1998). Furthermore, the mixed logit considers that unobserved individual-specific information can be used to induce correlation across alternatives, and changes among individuals. According to Carlsson et al. (2003), although the mixed logit models are less restrictive than their conditional counterparts, they are more difficult to estimate and the results can be heavily influenced by the distributional assumptions. In fact, the distributions of the selected random parameters can take a number of functional forms (e.g. normal, triangular, uniform and log-normal) and, due to the bias that could exist in real data, determining the true distribution empirically is challenging.

Considering, then, the advantages and disadvantages for the conditional logit and RPL models, we have reported both estimates for comparison purposes.

Considering the random utility framework, individuals choose – from the choice set – the alternative that maximises their utility.

Then the utility U obtained from, say, alternative i for individual h in choice situation *t* is –

$$U_{iht} = V_{iht} + \varepsilon_{iht} \tag{1}$$

where V_{iht} represents the deterministic part and ε_{iht} the stochastic or random component.

Since the stochastic part of the utility is unknown to the researcher, the best s/he can do is predict the final outcome in terms of probability. The probability that alternative i, rather than alternative j, is chosen from the choice set C by individual h is given as follows:

$$\begin{aligned} P_{ih} &= Prob(V_{iht} > V_{jht}) \\ &= Prob(V_{iht} + \varepsilon_{iht} > V_{jht} + \varepsilon_{jht}) \\ &= Prob\left((\varepsilon_{jht} - \varepsilon_{iht}) < (V_{iht} - V_{jht})\right) \\ & For\ all\ i, j\ \in C, j \neq i \end{aligned} \tag{2}$$

10 The assumption that the probability ratio of choosing between two alternatives does not depend on the availability or attributes of the other alternatives.

A probability density function must be imposed on ε_{iht} in order to be able to solve equation (2) with an appropriate discrete choice model.

4.2 The conditional logit models

The conditional logit models are appropriate when the choice among alternatives is modelled as a function of the characteristics of the alternatives, rather than as a function of the characteristics of the individual making the choice (Hoffman and Duncan 1988).

The conditional logit model assumes that the error term ε is independent and identically Gumbel-distributed,[11] (extreme value type I).The basic set-up is equation (1), –

$$\begin{aligned} U_{iht} &= V_{iht} + \varepsilon_{iht} \\ &= \beta x_{iht} + \varepsilon_{iht} \end{aligned} \tag{3}$$

where x_{iht} is a vector of observed attributes of an alternative within a choice set; and β is the vector of coefficients of these attributes, and is constant across choices for the conditional logit model. Then, when choice i is made, the probability P that household h will select alternative i can be represented as follows:

$$P_{ih} = \frac{\exp(\beta x_{iht})}{\sum_{j \in C_t} \exp(\beta x_{jht})} \tag{4}$$

In case the deterministic part is specified by including a constant, we have –

$$V_{iht} = \alpha_{ih} + \beta x_{iht} \tag{5}$$

where α_{ih} is an ASC for individual h and i alternatives $(i = 1, \dots, I)$.The ASC captures the average effect on utility of all factors that are not included in the model.

In order to capture possible preference heterogeneity, we can include the observable socio-economic characteristics in the systematic part of equation (5). However, such characteristics cannot be added to the model directly, given that they are constant across alternatives. We then allow them to interact with the ASC. From equation (5), we thus have –

$$U_{iht} = \alpha_{ih} + \gamma_i s_h + \beta x_{iht} + \varepsilon_{iht} \tag{6}$$

where s_h is a vector of socio-economic characteristics; γ_i is a vector of coefficients associated with individual characteristics; and $\gamma_i s_h$ is a vector of systematic parameters responsible for individuals' characteristics. Thus, systematic preference heterogeneity is captured as a function of individuals' characteristics.

4.3 The RPL models

The RPL models help to analyse how the characteristics of household h and those of choice i affect the probability that the household will choose alternative i. As in the conditional logit, the RPL models assume the error terms ε_{iht} are independent and identically Gumbel-distributed, but the vector coefficient β might vary across individuals due to preference heterogeneity. Consider the utility function in equation (3):

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11 Their cumulative and density functions are, respectively, $G(\varepsilon) = exp(-e^{-\varepsilon})$ and $g(\varepsilon) = exp(-\varepsilon - e^{-\varepsilon})$.

$$U_{iht} = V_{iht} + \varepsilon_{iht}$$
$$= \beta x_{iht} + \varepsilon_{iht}$$

The RPL is similar to a conditional logit model, except that it allows parameter estimates to vary across individuals. In the RPL models, the individual's utility is then –

$$U_{iht} = \beta_h x_{iht} + \varepsilon_{iht} \quad (7)$$

where β now differs across individuals.

The assumption regarding independent and identical Gumbel-distribution is restrictive in the sense that it does not allow for the error components of different alternatives to be correlated (Hensher and Greene 2003).However, the information contained in ε_{iht} could be sufficient to induce correlation across the alternatives. By breaking this assumption of non-correlation on ε_{iht}, the RPL partitions the stochastic component additively into two terms, where one term is correlated over alternatives and heteroscedasticity, and another part is independent and identically Gumbel-distributed over alternatives and individuals. Thus, we have –

$$U_{ih} = \beta_h x_{ih} + \eta_{ih} + \acute{\varepsilon}_{ih} \quad (8)$$

where η_{ih} is an additional random term that models the presence of correlation, and $\acute{\varepsilon}_{ih}$is a random term with zero mean that is independent and identically Gumbel-distributed over alternatives and individuals. According to Hensher and Greene (ibid.), η_{ih} can take on a number of distributional forms such as normal, log-normal, or triangular. We denote the density $f\ (\eta_{ih}|\theta^*)$ where θ^* denotes the (true) parameters of this distribution. For a given value of η_{ih}, the conditional probability that a person h chooses alternative i in period t is logit, since the remaining error term is identically Gumbel-distributed:

$$L_{ih}(\eta_{ih}) = \frac{\exp(\beta_h x_{iht} + \eta_{ih})}{\sum_{j \in C_t} exp(\beta_h x_{jht} + \eta_{jh})} \quad (9)$$

When β is not fixed and η_{ih} not given, then the unconditional probability of household h choosing alternative i is the integral of the conditional probability, over all possible values of η_{ih} and weighted by the density of η_{ih} expressed as follows:

$$P_{ih} = \int L_{ih}(\eta_{ih})\, f\ (\eta_{ih}|\theta^*) d\eta_{ih} \quad (10)$$

Within this form, the utility coefficients vary among individuals, but are constants among the choice situations for each individual (Carlsson et al. 2003). Furthermore, exact maximum likelihood estimation is not possible, given that the integral in equation (10) cannot be calculated analytically. Instead, an approximation of the probability method through simulation is appropriate. Using the Halton draws, a simulated maximum likelihood will be used to estimate the models.

In fact, although unobserved heterogeneity can be accounted for in the RPL, adding the interaction term helps to explain the source of heterogeneity (Boxal and Adamowicz 2002). Equation 8 has, thus, been used to allow attributes to interact with some socio-economic characteristics affecting the choice of the SQ. Then we have the following:

$$U_{ih} = \gamma_i s_h + \beta_h x_{ih} + \eta_{ih} + \acute{\varepsilon}_{ih} \quad (11)$$

Furthermore, following the same logic as we had with the conditional logit, we can consider a case where the deterministic part of the equation is specified by including an alternative specific constant in the RPL. Equation (11) then becomes –

$$U_{ih} = \alpha_{ih} + \gamma_i s_h + \beta_h x_{ih} + \eta_{ih} + \acute{\varepsilon}_{ih} \quad (12)$$

As in the conditional logit, we have included the socio-economic characteristics in the systematic part of equation (12) by allowing them to interact with the ASC.

In short, equations (6) and (12) have been used for models without SQ information. In these models, we included the ASC and allowed it to interact with the individual respondents' socio-economic characteristics.

Equation (8) has been used for RPL models with individual SQ information. In these models, we have excluded both the ASC and socio-economic characteristics. In fact, according to Barton and Bergland (2010), including the alternative specific constant in such models could lead to inflated standard errors of coefficients (ibid.).

For comparison purposes, in models with individual SQ information, we included the interaction terms between attributes and socio-economic characteristics. Equation (11) was used for such a comparison.

Furthermore, based on the real data at our disposal, we tested both normal and log-normal distributions in the RPL. Details of these results are given in Appendix B.

4.4 Willingness to pay

The main purpose of the CE method is to determine the individual's WTP for a unit-level change of a given attribute. This is the marginal value of change in an attribute. The marginal WTP (MWTP) for unit-level change is then the ratio between the parameter of the attribute and the parameter of the cost (Louvière et al. 2000). If, in this case, we separate the systematic part of the utility into cost and non-cost attributes, we obtain the following:

$$V(a, c) = \alpha + \sum_y \beta_y \, a_y + \beta_c c \quad (13)$$

where $\sum_y \beta_y \, a_y$ represents the marginal utility for y different attributes; $a_y (y = 1,2)$ in our case, and $\beta_c c$ is the marginal utility of the cost attribute. By differentiating equation (10) and considering the utility as fixed, the MWTP can be expressed as follows:

$$MWTP = \frac{\beta_y}{\beta_c} \quad (14)$$

In our case, we allow for heterogeneity in the definition of the status quo level for each respondent, the purpose of which is to estimate how this heterogeneous SQ affects WTP.

Individual characteristics were also included in the models as fixed coefficients. These coefficients were allowed to interact with alternative specific intercepts in models without individual SQ information. Furthermore, also for models without individual SQ information, we included one common ASC for hypothetical alternatives. However, for models with individual SQ information, we could not include an ASC.

5. Data collection

From 8 August to 8 September 2012, we conducted a survey in 13 out of 30 districts that comprise the country of Rwanda. For the sampling method, we first clustered the population into the country's four provinces, excluding the capital city, since the targeted population was that living in rural areas.

Consequently, considering a total population of 4,373,100[12] in all 13 districts, an average household size of 4.3 in rural areas and a sampling fraction of 1:1000, we randomly sampled 1,017 households. Thus, with simple random sampling, we selected 3 or 4 districts in each province to have a total of 13 districts. In each district, we randomly selected 3 sectors,[13] giving us 39 sectors in total. In 36 of these sectors, we randomly selected 26 households; and in the 3 remaining sectors, we randomly selected 27 households.[14] Due to the time constraint and given that the study covered areas scattered in different rural parts of the country, the data collection was undertaken by a team of 9 enumerators. Using the random walk method, we chose the sector headquarter as the starting point and begin walking from that point to the closest household[15] for the first interview. If no one was at home (i.e. the premises were empty), we substituted with the very next household. If the interview was refused, we used an interval of 10 to select a substitute household, counting houses on both the right- and the left-hand sides.

The survey addressed rural water supply (domestic and irrigation), and the respondents were the local inhabitants. The head of a household was targeted for responding to the questionnaire, but other adults were considered where the head was not available.

The questionnaire was divided into two parts. The first contained questions on respondents' socio-economic characteristics, while the second contained questions for the CE. Regarding the latter, enumerators first explained the questionnaire as well as the logic of the game, and respondents were asked to read the questionnaire carefully in turn and to make their choice among various alternatives. However, the enumerator had to make sure that the respondent was able to read and write; otherwise, s/he had to fill in the questionnaire according to the answers given by the respondent.

There were two different CEs: one on domestic water use, and the other on irrigation. We had the same questionnaire for everyone up to the point where the CE started. With the CE, participants responded either to the CE related to domestic water use, or to the one concerning water for irrigation.

In order to avoid a sample selection problem in the CE, we could not split respondents based on whether they carried out agriculture or not. Instead, we ran the CE on a rotational basis. Thus, we ran the CE on domestic water with the first, third, and fifth respondent in the village concerned; and accordingly ran the CE for irrigation water with the second, fourth, and sixth respondent in that location. However, for the CE for irrigation water, the rotational order sometimes could not be respected, given that some households did not irrigate. In such cases, we automatically switched to the CE on domestic water and instead used the CE on irrigation for the next household to be interviewed. Those who responded to the CE for domestic water numbered 785, and those for irrigation water, 232.

5.1 Attributes and attribute levels in the CE

A pilot study was carried out in order to allow us to define attributes and attribute levels, which were then used in the main survey. The pilot was run in 5 districts and 50 households, i.e. 10 in each district. Participants were then randomly selected.

Broadly speaking, we learned from the pilot that majority of households lack piped water into their houses, and used unsafe non-tap sources as a result. There was a high incidence of diarrhoea infections (about three cases per household member per year) due to unsafe water. On average, household members walked between a minimum of 1 km and a maximum of 3 km to fetch water from

[12] See http://statistics.gov.rw/search/node/EICV, last accessed 6 March 2013.

[13] The sector is a third-level administrative subdivision in Rwanda after the province and district levels.

[14] The three sectors belong to a district called *Nyagatare*, qualified as being the largest and second most populous district in Rwanda.

[15] If two households are at approximately the same distance from the starting point, a coin was flipped to decide between them.

the nearest water point. From these findings, we understood that health effects and distance to water sources would be relevant attributes for any policy reform. Due to the very limited access to domestic water, which, in turn, bears with it a high risk of infectious diseases, we assumed that households would be positive to policy reforms that could help them to get better-quality water. Under different tariff schedules, the new service could either help to alleviate the problem with the current unreliable service, or could solve the problem completely. There were scenarios in which the set of attributes as well as the price varied; where only two incidences of infectious diseases per household member occurred per year; and where no such incidences occurred. For the distance to the water point, the scenarios entailed distances of either 50 m or 20 m.

Regarding water for irrigation, information from the pilot showed that the practice of irrigation was very new in the country, and that, so far, not many farmers irrigated their crops. Those who did so usually employed irrigation on a small scale only: rainfall dams remained the most popular method of watering crops. Farmers generally do not pay for water used; those that do, usually pay a fixed amount for each season, but the amount is not related to the quantity of water used. Water is insufficient, however: the dry season typically lasts six months, but on average the irrigation water only lasts for two months. The watering frequency is three times a month on average during the time when water is available. Farmers manifested a high WTP for reform that might bring about an increased availability of water and watering frequency. Considering their current situation, we thus assumed two new alternatives, varying in different scenarios. Under different price schedules, the water availability in the previously described scenarios would last for either five or six months, while watering frequency would be either six or eight times per month.

5.2 Coding the individual SQ information

Given that the pilot study showed a considerable heterogeneity in respondents' SQs, we found it useful to code the SQ alternative as specified by each respondent rather than devise a fixed or invariant code across respondents. In order to put the individual SQ information and the experimental design levels on the same attribute scale, we used interval coding for the individual SQ level. Thus, for domestic water, through three defined attributes – *Long-term health effect*, *Reduced distance to water point* and *Price* – Table 1 shows farmers' responses to the choice between two experimentally hypothetical scenarios and the SQ alternative they had described. For irrigation water, farmers were asked to make a choice between two hypothetical alternatives and their existing alternative with three attributes, namely *Water availability*, *Watering frequency*, and *Semi-volumetric water pricing*.[16]

<Table 1 about here>

Before the CE began, we first briefly introduced the purpose of the experiment by reminding respondents about the current rural water devolution policy. We also reminded them of their current status related to the unreliable water supply used in both the domestic sphere and in agriculture. From their current situation, we gave detailed explanations of the hypothetical attribute levels by informing them that the improved service required a price reform, i.e. that improved water provision would be costly, and that part of the cost would be passed on in the form of higher prices. These explanations as well as examples of the attributes and attribute levels are given in Appendix A.

With a total of six choice[17] sets divided into two blocks, each respondent responded to three choice situations on a rotational basis in the experiment. Each choice contained two new hypothetical

16 We calculated the annual semi-volumetric water price (RWF/ha/watering) as the product of the number of watering events per month and the months of available water in the scenario. Farmers could then compare this new hypothetical price with the existing seasonal tax paid.

17 With the FACTEX procedure in SAS software, we generated a complete factorial experiment (eight runs) with three factors, each at two levels.

alternatives for an improved water supply as well as the option to choose the existing situation as they had described it.

6. Descriptive statistics

6.1 Household's SQ for attributes

Table 2 describes the households' situation at the time of the survey in terms of domestic and irrigation water use. For domestic water use, statistics from the survey showed that only 1% of the sample was connected to piped water.[18] The majority of households (99%) in the sample relied on different types of non-tap water sources (public tap, tube well, unprotected springs, surface water, etc.), with some variations regarding distance to the nearest source. Overall, the average distance to non-tap sources was about 922 m, and the average unit cost of water approximately RWF 282[19] per cubic metre. On average, a household member contracted infectious diarrhoea three times a year.

Regarding water for irrigation, the statistics showed that the frequency of irrigation was twice a month on average, and water was available on an average of two months during the dry season. The average overall payment for irrigation was estimated at RWF 855 per season.[20]

<Table 2 about here>

From Figure 1, we can observe a large variation in current access to water for domestic and irrigation use. The distance to the nearest water point varies between 401 m and 3,000 m and only 1% walks less than 500 m. Furthermore, the majority of non-connected households (about 63%) obtain water at no monetary cost.[21] For 8% of households, the unit price is RWF 0–250/m^3, 7% pay RWF 250–500/m^3, 6% pay RWF 500–750/m^3, 10% pay RWF 750–1,000/m^3, 2% pay RWF 1,000–1,500/m^3, etc. As regards the number of cases of infectious diarrhoea reported for 2011, only 3% declared that no one in their household had experienced it at all; 4% had contracted it just once, and 27% twice. In 56% of cases, it had occurred three times in one household; 5% had experienced it four times; 2% had contracted it five times during the year, and 3% had done so six times. Figure 1 also shows a large variation in the irrigation frequency (0–6 times a month) and in water availability (0–3 months during the dry season). Regarding payment for irrigation, the amounts vary in the range of RWF 0–4,620 per season, with an average of RWF 1,250; the latter figure translates into RWF 250/ha/month. However, 59% do not pay for water to irrigate their crops.

Thus, the status quo varies dramatically for several of the variables in both domestic and irrigation water. It can be misleading, therefore, to assume that everyone has the same status quo.

<Figure 1 about here>

Figure 1 showed again that for domestic water, the distributions for number of diarrhoeal infections per household member per year look symmetric about the mean. According to the descriptive statistics in Table 3, the sample mean for the number of diarrhoeal infections per household member per year equal to 2.8, the median equal to 3 and the mode equal to 3 are close. This allows us to assume that the number of diarrhoeal infections per household member per year might be normally

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18 Households with a piped connection are not included in the analysis.

19 At the time of the survey, 1 RWF = 0.0016528926 USD; see http://www.xe.com/currencytables/?from=RWF&date, last accessed 8 August 2012.

20 The season for irrigation in marshlands is from June to October in Rwanda. The price for irrigation is a kind of lump sum tax that farmers need to pay to the district authorities each season.

21 For the few households that have piped water to their promises, there is heterogeneity in the unit price (RWF/m^3). This can be because rural water is supplied using several management options in each district.

distributed, but that the distance to the nearest water point and the price of non-tap water are assumed to be log-normally distributed. For irrigation water, the mean (2.4), the median (2.4) and the mode (2.5) are close, which allows us to assume a normal distribution for this attribute and a log-normal distribution for *Water availability* and *Price* (irrigation) attributes.

<Table 3 about here>

6.2 Respondents' socio-economic characteristics

From the descriptive statistics in Table 4, we can see that respondents were aged between 19 and 79 years, but had an average age of 40. Half the respondents were men, and half were women. Some 70% could read and write, and had an average number of four years of schooling. The average monthly household income was RWF 17,185. Regarding the WTP for improved service in water supply, we found that over 90% of respondents desired improved water for domestic use even if they would have to pay more, while 26% of them preferred the SQ for irrigation water. The average size of the household was five persons.

<Table 4 about here>

7. Results

With a simple logit model, we tried to estimate the probability of selecting the SQ based on some of the respondents' characteristics described in Table 5. Our results show that, in domestic water use, older respondents were more likely to choose the SQ. The more educated the respondent were, the less s/he preferred the existing situation. Male respondents were more likely to choose the SQ for both domestic and irrigation water. Households with a higher income were slightly less likely to choose the SQ alternative ceteris paribus. Being a member of the WUA increased the likelihood of preferring the SQ for irrigation water.

<Table 5 about here>

We estimated both conditional logit and RPL models using Limdep software. For the RPL model, we simulated the maximum likelihood by using Halton draws with 50 replications. We compared the models without individual SQ information with a model that uses this information. Furthermore, we allowed the price variable to be fixed and not randomly distributed, while other attributes were randomly distributed. Individual characteristics were also included in the models as fixed coefficients and the latter were allowed to be interacted either with alternative specific intercepts in models without individual SQ information, or with attributes in models with such information. The results of all these estimations are presented in Tables 6 and 7.

For domestic water, equations 6 and 12 were used to compare the conditional logit and the RPL models without individual SQ information. The results show that the mean coefficients for distance and health effect attributes are positive, revealing that respondents preferred these attributes. These results are presented in Table 6.

In respect of the socio-economic variables, educated respondents were more likely to choose the improved service. However, male respondents were less likely to choose improved services. Nonetheless, the latter variable is only significant in the RPL models. Older respondents were also less likely to choose the improved service, while respondents with higher incomes were more likely to choose the proposed new service.

In brief, comparing results from the conditional logit and the RPL models without individual SQ information, we can see that the intercept is statistically significant and positive for the RPL alone. The significance of the intercept implies that the new alternatives are, on average, preferred to the SQ alternative. Furthermore, comparing both models without SQ information shows that the significance of the coefficients in general is improved in the RPL model, which allowed us to use the RPL in the rest of the estimations.

If one now compares the results from both RPL models, i.e. those with individual SQ information and those without such information (equations 8 and 12), we can see that the significance of the coefficients is increased in the RPL models with individual SQ information. Furthermore, in the RPL models with individual SQ information, the significance of the estimated standard deviation is a sign of heterogeneity in respondent preferences.

Furthermore, using the interaction terms in the RPL model with individual SQ information, results show that, in general, respondents with higher levels of education were likely to prefer a water supply scenario with a higher level of health benefits and reduced distance to the water point. Thus, the preference for each attribute varies across different levels of education.

Brief, precedent results allow us conclude that using the RPL model with individual SQ information is more useful because it offers a better model of household behaviour, and allows us to estimate attribute coefficients more accurately.

<Table 6 about here>

For irrigation water use, using equation 6 and 12 to compare the conditional logit and the RPL models without individual SQ information, the results in Table 7 show a positive sign on both improved watering frequency and improved water availability attributes in the RPL models, which means it is more likely that respondents do not prefer the existing watering frequency and water availability.

Regarding the socio-economic characteristics, educated respondents were more likely to choose the improved irrigation service, while males were less likely to choose it. The latter variable was not significant, however. Furthermore, being a WUA member decreased the likelihood of choosing a new hypothetical water service in irrigating. This variable was only significant with the RPL model. Older respondents were less likely to choose the new service, while respondents with higher incomes preferred the proposed new service.

To summarise, we can first say that, by comparing the results from the conditional logit and the RPL models without individual SQ information, we see that intercepts are positively significant for both the conditional logit and the RPL. This implies that, on average, the new alternatives were preferred to the SQ alternative. Then, comparing both models without SQ information, we can observe the significance of the coefficients was improved in general when the RPL model was used. This allows one to use the RPL in the rest of the analysis.

When results from both RPL models, i.e. those with individual SQ information and those without such information (equations 8 and 12) are compared, we observe that the significance of the coefficients increased in the RPL models with individual SQ information. Furthermore, the significance of the estimated standard deviations in the RPL models with individual SQ information revealed heterogeneity in respondent preferences.

If one includes interaction terms in the RPL model with individual SQ information (equation 11), the results show that respondents with higher levels of education were more likely to prefer an irrigation water supply scenario with higher levels of frequency. Furthermore, the interaction between watering frequency and WUA membership was negative. This result is similar to that found by Barton and Bergland (2010) in Bangladesh.

From all these results, we concluded that using the RPL model with individual SQ information might be more useful than that using the said model without such information, given that the significance of the coefficients increases with the RPL, and the coefficients themselves are larger.

<Table 7 about here>

Our main interest lies in comparing the MWTP for a model without individual SQ with one that includes such information. Using the normal distribution for both domestic and irrigation water use, the results in Tables 8 and 9 show that a large difference in MWTP when it comes to the RPL without individual SQ information and the RPL model with such information. This is probably due to the fact that there is strong heterogeneity in the current situation; and this SQ situation might induce a strong heterogeneity in preferences.

Furthermore, comparing both RPL models, i.e. without and with individual SQ information, we found an increase in the size and significance of coefficients in the RPL model with individual SQ information for both irrigation and domestic water use.

Comparing the RPL without individual SQ information with the RPL with such information, we can see that, for domestic water use (Table 8), the MWTP for having water within a maximum distance of 50 m from the household is valued at 0.58% of average household income when SQ information is not taken into account, but at 1.08% of such average income when it is. In addition, one less case of diarrhoea per household member per year was valued at 1.93% of household income when the SQ is not taken into account, but at 3.95% when it was. For irrigation water, comparing the RPL model without individual SQ information and that with such information, we found – as the results in Table 9 reveal – that the MWTP for watering crops at least six times per month rather than twice per month was estimated at 0.25% of household total income when SQ information was not used, and at 1.05% when it was. The MWTP for having water for five rather than two months of the dry season was valued at 1.14% of household total income without SQ information, and 2.24% with such information.

We also noted that, if the SQ information were included in both domestic and irrigation water cases, the MWTP was at least twice as high as when SQ information was excluded.

In brief, using MWTP for the normal distributed coefficients results shows that, in general, the watering frequency and water availability attributes increase the average utility derived from an improved irrigation water service. In addition, long-run health effect improvements and reduced distance to a water point would, in turn, improve the average utility derived from an improved domestic water service. Households do not, in general, prefer the existing services in domestic or irrigation water. In fact, according to Whittington et al. (1990), it is commonly assumed that, as long as the cost does not exceed 5% of income, rural households might prefer to abandon their existing water supply in favour of the hypothetically improved system.

<Tables 8 and 9 about here>

7. Conclusion

The CE method has been used to evaluate how heterogeneity in a household's existing rural water use affected their preferences for a hypothetically improved situation. From basic statistics, 26% of respondents preferred the existing irrigation water supply system to a proposed new one. The likely reason might be that, with the current system, 61% of respondents did not pay for water used, but still practised some irrigation. However, for domestic water use, although 65% obtained water free of charge, in general they were not satisfied with the existing situation. In fact, only 10% preferred the existing system to remain, while the rest were willing to pay for improved water. Considering how households not connected to the piped network system were aware of their vulnerability, as manifested by the high frequency of water-borne diseases among their members, one can understand why the majority (90%) opted for change. In fact, if one compares the levels of satisfaction with the SQ for domestic and irrigation water, respectively, households were relatively satisfied with the existing irrigation system, but not at all satisfied with the existing domestic water supply. One could also say that, in both cases, the majority of households were not satisfied with the existing systems, but were even more discontented with the existing domestic water supply system.

If one considers the broad heterogeneity in the existing situation, the use of information on individual respondents was of great importance.

Comparing the conditional logit and the RPL models without individual SQ information, we saw that the proposed new alternatives were preferred, on average, to the SQ alternative for both domestic and irrigation water, and that the significance of the coefficients was generally improved in the RPL model. This revealed heterogeneous preferences for the attributes concerned.

Using the RPL models with individual SQ information, we found an increase in the significance of coefficients for both irrigation and domestic water use, compared with the results obtained when we used the RPL without individual SQ information.

For the MWTP, coefficients were larger and had higher statistical significance in models with individual SQ information than in those without such information. Furthermore, the overall situation showed that attributes in the CE increased the utility derived from an improved service, which means that, in general, respondents were willing to pay for new improved service. However, in terms of household's total income, the higher MWTP was obtained from models with individual SQ information rather than with models lacking such information.

From a policy perspective, not accounting for individual SQ information meant that an overall policy change might be undertaken without considering individual cases. If one refers to the results from the present study, not considering individual SQ information might work since the majority opted for the change. However, if one considers how the inclusion of individual SQ information affected the results through increased coefficient magnitude, there is a risk that, if SQ information is not used, the MWTP might be underestimated, which might discourage policymakers from designing appropriate improved services that respond to the real needs of the population. Care needs to be taken: both to ensure that changes in water provision do not worsen conditions for households with a favourable SQ, and so that changes in water provision that will improve conditions for households with an unfavourable SQ are in fact carried out. Thus, taking the heterogeneity in the existing situation into account in policy is important, both for those who have a favourable SQ situation and those who do not.

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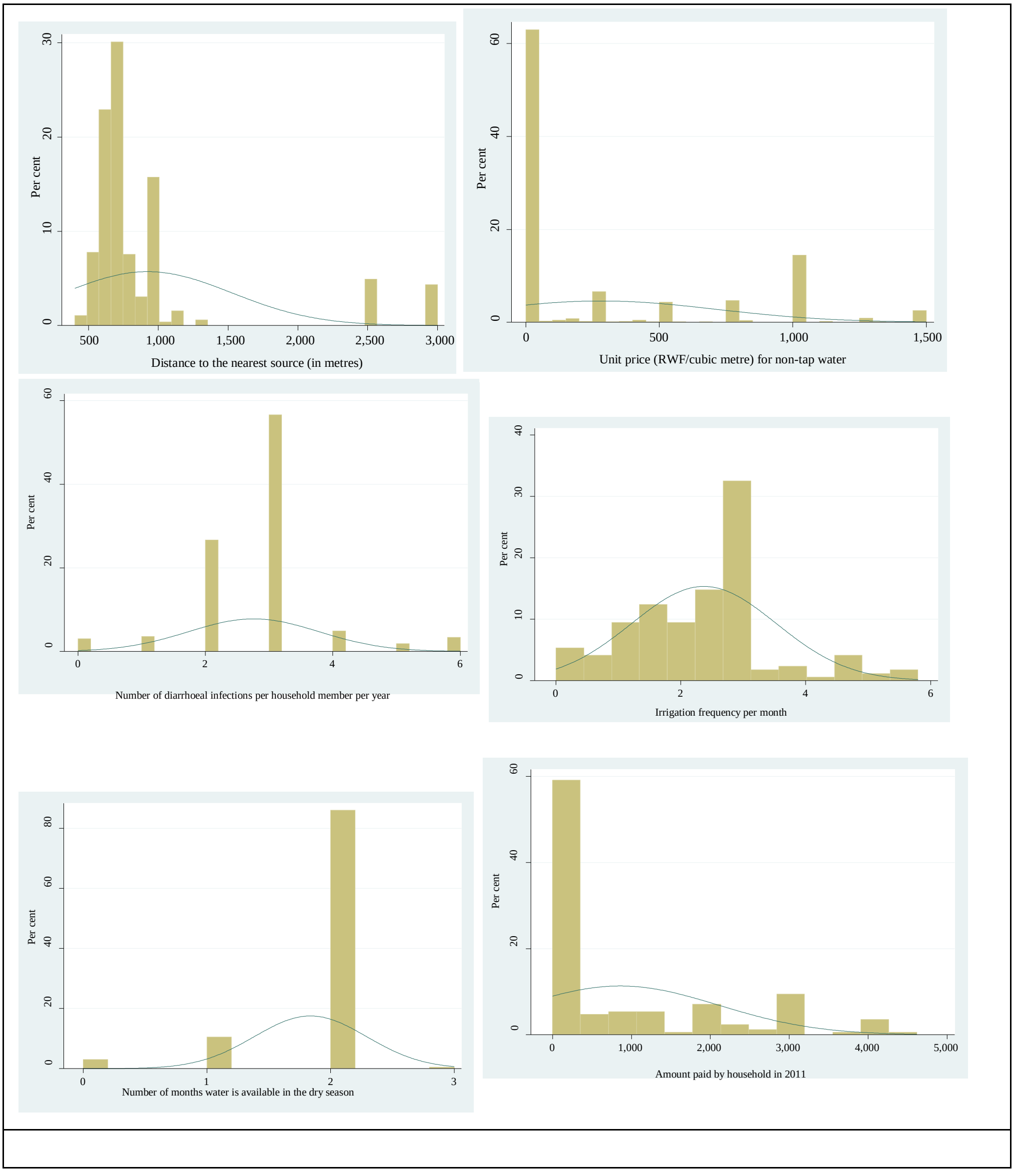

Fig. 1 Respondents' SQ, 2012

Table 1 Attributes and attribute levels – Domestic and irrigation water

Attributes	**Attribute levels in experimental design**	**Individuals' status quo levels**
Domestic water		
Long-term health effect	0 cases of diarrhoeal infection 2 cases	0 cases [0–2] cases [2–4] cases [4–6] cases [6–8] cases (Reference level)
Reduced distance to water point	20 m 40 m	[0–20] m [20–40] m [40–60] m [60–80] m [80–100] m [100–400] m [400–700] m [700–1,000] m [1,000–2,000] m (Reference level)
Price	RWF 300/m^3 RWF 1,000/m^3	Assumed linear (Not coded)
Irrigation water		
Water availability	5 months 6 months	[0–1] month (Reference level) [1–2] months [2–3] months [3–4] months [4–5] months [5–6] months [6–7] months
Watering frequency	6 watering events/month 8 watering events/month	0 watering events/month (Reference level) [0–2] watering events/month [2–4] watering events/month [4–6] watering events/month [6–8] watering events/month [8–10] watering events/month
Semi-volumetric water pricing	RWF 500/ha/watering RWF 1,000/ha/watering	Assumed linear (Not coded)

Source: Author's data collection

Table 2 Respondents' SQ, 2012

Variable	Description	Mean	Standard deviation	Minimum	Maximum
Domestic water					
Piped water	= 1 if respondent connected to piped water, 0 otherwise	0.01		0	1
Distance	Average distance (m) to non-tap sources	922.19	604.10	401	3,000
Price (non-tap)	Unit cost (RWF/m^3) of non-tap water	281.71	433.40	0	1,500
Health effect	Number of diarrhoeal infections per household member per year	2.76	1.024	0	6
Irrigation					
Price (irrigation)	Cost for irrigation (RWF) per year	855.15	1,250.78	0	4,620
Irrigation frequency	Irrigation frequency per month	2.43	1.235	0	6
Water availability	Water availability in dry season (number of months)	1.84	0.455	0	3
Number of observations	1,017				

Source: Author's data collection

Table 3 Mean, median and mode of attributes

Variable	Domestic water			Irrigation water		
	Distance	Health	Price	Irrigation frequency	Water availability	Semi-volumetric price
Mean	922.19	2.8	281.71	2.4	1.8	855.14
Median	701	3	0	2.4	3	0
Mode	700	3	0	2.5	2	0

Source: Author's data collection

Table 4 Descriptive statistics: Domestic water and irrigation water

Variable	Description	Mean	Standard deviation	Minimum	Maximum
Age	Respondent's age	40.138	12.340	19	79
Male	=1 if respondent is male, 0 otherwise	0.499		0	1
Children <5	=1 if household has children under 5 years, 0 otherwise	0.507		0	1
Education	=1 if the respondent has studied, 0 otherwise	0.692		0	1
Years schooling	Years of schooling	3.903	3.188	0	15
WUA	If the household is a member of the Water Users' Association	0.126		0	1
Income	Household's monthly total income	17,185	18,994.98	300	88,000
Household size	The size of the household	4.907	2.014	0	13
Status quo domestic	=1 if the respondent chose the status quo alternative for domestic water use, 0 otherwise	0.09		0	1
Status quo irrigation	=1 if the respondent chose the status quo alternative for irrigation water use, 0 otherwise	0.255		0	1

Source: Author's data collection

Table 5 Logistic regression of factors affecting choice of SQ

Variable	Water for domestic use	Standard error	Water for irrigation	Standard error
Household size	-0.031	0.022	-0.042*	0.023
Age	0.009***	0.004	0.006	0.004
Education	-0.343***	0.164	-0.260**	0.116
Male	0.220**	0.087	0.1820*	0.103
Income	-0.00001***	0.00001	-0.00007**	0.000006
WUA member			0.406***	0.101
Constant	-2.696***	0.199	-1.561***	0.258
Number of observations	7,065		Number of observations	2,088

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

Source: Author's data collection

Table 6 Model estimates for domestic water

Water for domestic use				
	Conditional logit without SQ information	RPL without SQ information	RPL with SQ	RPL with SQ interaction
Variable	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
Water characteristics				
Reduced distance[22]	0.03	0.03*	0.06***	0.06***
	(0.02)	(0.02)	(0.001)	(0.001)
Health effect	0.105*	0.108**	0.178***	0.176***
	(0.059)	(0.060)	(0.024)	(0.024)
Price	-0.0003**	-0.0003***	-0.0003***	-0.0003 ***
	(0.0008)	(0.0009)	(0.001)	(0.0008)
Distance*Education				0.023*
				(0.014)
Health*Education				0.007*
				(0.043)
Household characteristics				
ASC*Household size	-0.324	-0.353*		
	(0.253)	(0.360)		
ASC*Age of respondent	-0.026*	-0.032**		
	(0.043)	(0.073)		
ASC*Education	0.099	0.203*		
	(0.084)	(0.140)		
ASC*Male	-0.364	-0.327*		
	(0.339)	(0.292)		
ASC*Income	0.00001*	0.00002*		
	(0.00001)	(0.00001)		
Intercept	0.209	0.268 *		
	(0.163)	(0.167)		
Standard deviation				
Distance		0.01*	0.01**	0.06**
		(0.08)		
Health effect		0.168 *	0.195**	0.0103**
		(0.104)		

22 From *Far* (more than 1 km) to *Near* (20 m or less).

Water for domestic use				
	Conditional logit without SQ information	RPL without SQ information	RPL with SQ	RPL with SQ interaction
Variable	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
Log-likelihood =	-1750.805	-1749.267	-1753.286	
Number of respondents	702		785	
Number of observations	6,319		7,065	

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

Source: Author's data collection

Table 7 Model estimates for irrigation water

Water for irrigation				
	Conditional logit without SQ information	RPL without SQ information	RPL with SQ	RPL SQ with interaction
Variable	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
Water characteristics				
Water availability	0.324**	0.337**	0.482***	0.824***
	(0.181)	(0.132)	(0.088)	(0.097)
Watering frequency	0.02	0.075*	0.119**	0.312***
	(0.08)	(0.06)	(0.071)	(0.090)
Price	-0.002**	-0.001***	-0.0007***	-0.0002**
	(0.0002)	(0.0002)	(0.0001)	(0.0001)
Water frequency*Education				0.283*
				(0.186)
Watering frequency*WUA member				-0.071**
				(0.042)
Household characteristics				
ASC*Age of respondent	-0.214	-0.220*		
	(0.133)	(0.135)		
ASC*Education	0.141**	0.185**		
	(0.592)	(0.609)		
ASC*Male	-0.438	-0.499		
	(0.381)	(0.417)		
ASC*WUA member	-0.002	-0.005*		
	(0.112)	(0.132)		
ASC*Income	0.00006	0.00007*		
	(0.00004)	(0.00006)		
Intercept	0.285**	0.373**		
	(0.122)	(0.191)		
Standard deviation				
Water availability		0.129**	0.011**	0.009**
		(0.028)		
Watering frequency		0.074*	0.005*	0.11**
		(0.02)		
Log-likelihood =	-643.5253 232	-630.3350	-630.8271	
Number of respondents	232		171	

Water for irrigation				
	Conditional logit without SQ information	RPL without SQ information	RPL with SQ	RPL SQ with interaction
Variable	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
Water characteristics				
Number of observations	2,088		1,545	

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

Source: Author's data collection

Table 8 MWTP for levels in domestic water

	RPL without individual SQ information	RPL with individual SQ information	MWTP without individual SQ information as % of total income	MWTP with individual SQ information as % of total income
Variable	Coefficient	Coefficient		
Long-run health effect	331.346*	678.085***	1.93%	3.95%
Reduced distance	99.554*	186.247***	0.58%	1.08%

***,** and * significance at 1%, 5% and 10% level, respectively

Source: Author's data collection

Table 9 MWTP for levels in irrigation water

	RPL without individual SQ information	RPL with individual SQ information	MWTP without individual SQ information as % of total income	MWTP with individual SQ information as % of total income
Variable		Coefficient		
Water availability	195.42***	729.007***	1.14%	4.24%
Watering frequency	43.475*	181.193 **	0.25%	1.05%

Appendix A: Experiment[23]

1. Drinking water

For ten years, the Government of Rwanda committed itself to develop the rural water sector and to bring water to all. To achieve this goal, the Government decided to give more power to districts through decentralisation and give priority to public–private partnerships for the management of running water systems. However, as you might be aware, the district still faces a huge problem of enough and safe water, which has hindered you from developing in many aspects. In fact, we all know that, for example, diarrhoeal disease is among the causes of death for children under 5 years old. Unsafe water and poor hygiene are major contributors to the prevalence of diarrhoea. The more vulnerable people are those who use unsafe valley dams as their main supply of water.

Assuming the system is improved, water would be safe to drink; the risk of disease would be reduced; the high cost related to provision from different coping sources would be decreased; the hauling time would be reduced; etc.

(NB: Here the enumerator will go through all attributes and explain them briefly.)

[23] The script was translated from *Kinyarwanda*.

Attributes and attribute levels for domestic water

Attributes	Description	Hypothetical level		Specify the current level
		Alternative 1	Alternative 2	
Long-term health effect	The health and safety conditions of water are poor in the district. Better water provision will lead to an improved service with positive impact on health conditions for households.	Less risk: 2 cases of diarrhoeal infections per house member per year	No risk: 0 cases of diarrhoeal infections per household member per year	Number of diarrhoeal infections per house member per year
Distance to water	It is time-consuming for households to reach the nearest water point. The improved service with high water availability will reduce the distance to the water points.	40 m from home to the source	20 m from home to the source	………………… km/m
Price/cost	The improved water provision would be costly and that part of the cost would be passed on in the form of higher prices.	RWF 20/ jerrycan = RWF 1,000/m^3 (1m^3=50 jerrycans)	RWF 300/m^3	………………….. RWF

Questions for each choice set

For enumerators only: The blocks are to be presented to households systematically on a rotational basis so that each household interviewed sees only one of the blocks.

All choices have a code which allows you to double-check which block they are in, i.e. 1-1-1 means the respondent chose Block 1, Choice 1, Alternative 1.

NB: Enumerators will now present the choice sets to the respondent and wait for their responses. If the respondent is unable to read and write, the enumerator will help and guide him/her.

Assuming that the following two new sources of water were available in addition to your usual sources of water, which one would you prefer if you could choose?

Example of choice set

Attributes	Alternative 1	Alternative 2	Neither
Long-run health effect	0 cases of diarrhoeal infections per house member per year	2 cases of diarrhoeal infections per house member per year	Neither alternative 1 or alternative 2: I will fetch water from my usual source
Distance	20 m	40 m	
Price	RWF 300/m^3 (1 m^3 = 50 jerrycans)	RWF 20 per jerrycan	
Check only one box:			
Prefer alternative 1	☐		
Prefer alternative 2	☐		
Prefer existing source	☐		

Debriefing questions

Respondents who broke off the choice questions:

1. What are the reasons you did not want to continue?

0	Don't know
1	Situations were too unrealistic
2	Too many questions
3	Other (specify):

Respondents who answered "Existing source" at least once:

2. What are the reasons you preferred your existing situation in one/several of the choices?

1	Too poor to pay any water fee
2	Water should be free of charge
3	We have alternatives to tap, dug well or rainfall dam water
4	The water tariff is unrealistic
5	Other (specify):

Respondents who completed all choice questions:

3. Which characteristics of the situations were the most important to you when choosing?

Important		Characteristic	Most important
Yes	No	Health and safety	
Yes	No	Distance to water	
Yes	No	Price	

2. Irrigation water

Rwanda relies heavily on agriculture for its employment opportunities and the economic well-being of its people. Close to 90% of the population of Rwanda lives in rural areas. Achieving food security and increasing rural incomes will depend on increased productivity in this sector. Irrigation is, therefore, seen to be among the key instruments to raise agricultural productivity. By the way), assuming all benefitting farmers fully participate in the rational management of water infrastructure for irrigation purposes, your activities will provide the highest quality product that will generate more income to you.

(NB: Here the enumerator will go through all attributes and explain them briefly.)

Attributes and attribute levels for irrigation water

Attributes	Description	Hypothetical attribute levels		Existing level (specify)
		Alternative 1	Alternative 2	
Water availability	During the dry season, you only get water for 1 month. With the new system, water availability will be high	5 months	6 months	… months
Watering frequency	You normally water your crops once per month due to insufficient water. With the current improved system, you will get enough water to water your crops.	6 watering events per month	8 watering events per month	… watering events per month
Price/cost	The prices actually paid are inadequate and hamper rational water management. The improved service requires a price reform.	RWF. 500/acre/watering event	RWF 1,000/acre/ watering event	… RWF per watering event

Questions for each choice set

For enumerators only: The blocks are to be presented to households systematically on a rotational basis so that each household interviewed sees only one of the blocks.

All choices have a code which allows you to double-check which block they are in, i.e. 1-1-1 means the respondent chose Block 1, Choice 1, Alternative 1.

NB: Enumerators will now present the choice sets to the respondent and wait for their responses. If the respondent is unable to read and write, the enumerator will help and guide him/her.

Assuming that the following two new sources of water were available in addition to your usual sources of water, which one would you prefer if you could choose?

Example of choice set

Attributes	Alternative 1	Alternative 2	Neither
Water availability	5 months	5 months	Neither alternative 1 or alternative 2: I will irrigate as I do now
Watering frequency	8 watering events per month	6 watering events per month	
Volumetric water pricing	RWF 1,000/acre/watering event	RWF 500/acre/watering event	
Check only one box: Prefer alternative 1 ☐ Prefer alternative 2 ☐ Prefer existing practice ☐			

Debriefing questions

Respondents who broke off the choice questions:

1. What are the reasons you did not want to continue?

0	Don't know
1	Situations were too unrealistic
2	Too many questions
3	Other (specify):

Respondents who answered "Existing practice" at least once:

2. What are the reasons you preferred your existing situation in one/several of the choices?

1	Too poor to pay a water fee
2	Irrigation water should be free / low charge for farmers
3	We have alternatives to the suggested system
4	The volumetric water tariff is unrealistic
5	Other (specify):

Respondents who completed all choice questions:

3. Which characteristics of the situations were most important to you when choosing?

Important		Characteristic	Most important
Yes	No	1. Months of water in the irrigation zone	
Yes	No	2. Watering frequency	
Yes	No	3. Price per watering event	

Appendix B: Normal and log-normal distributions

For the log-normal specification, we denote from model equation (9) an element n of β_h that disposes a log-normal distribution. The coefficient becomes –

$$\beta_{hn} = \exp(b_n + s_n \mu_{hn}) \tag{15}$$

where μ_{hn} is an independent standard normal deviation.

The parameters b_n and s_n represent the mean and the standard deviation of $log(\beta_{hn})$ to be estimated.

The median, mean, and standard deviation of β_{hn} are then –

$$\exp(b_n);\ \exp\left(b_n + {s_n^2}/{2}\right); \text{and} \exp\left(b_n + {s_n^2}/{2}\right) \times [exp(s_n{}^2) - 1]^{0.5} \tag{16}$$

The coefficient for the log-normal derived in equation (15) helped obtaining the mean and the median for the log-normally distributed coefficients. To interpret coefficients, we used the marginal rate of substitution between attributes by using the price coefficient as numeraire; the ratios would then be interpreted as the marginal willingness to pay (MWTP) for a change in the attribute (Hanemann 1984).[1] Table 10 shows that the results are almost similar for the normal and log-normal distributions in respect of domestic water, but that the mean coefficient and MWTP for watering frequency in irrigation are much higher in the log-normal case. This is a common finding, given that many studies reveal that the log-normal distribution registers a higher mean MWTP than other distributions.

[1] The interpretation of coefficents is not straightforward, except for significance and relative size.

Table 10: Normal and log-normal distribution

	Domestic water					
	Normal distribution		Log-normal distribution			
Variable	Coefficient	Standard error	Coefficient	Standard error	Mean	Standard error
Price	-0.0003***	0.001	-0.0002***	0.0007		
Reduced distance	0.06***	0.001	-3.550***	0.481	0.08**	0.004
Health effect	0.178***	0.024	-1.919***	0.347	0.195***	0.05
Standard deviations						
Distance	0.01**	0.01	0.482**	0.83		
Health effect	0.195**	0.09	0.642**	0.564		
MWTP	Mean	Standard error	Mean	Standard error	Median	Standard error
Distance	166.567**	55.803	250.215**	83.625	86.882**	36.283
Health effect	668.408***	225.441	682.35***	281.518	654.668***	236.2129
	Irrigation water					
	Normal distribution		Log-normal distribution			
Variable	Coefficient	Standard error	Coefficient	Standard error	Mean	Standard error
Price	-0.0007***	0.0001	-0.0007***	0.0001		
Water availability	0.482***	0.088	-0.733***	0.179	0.486***	0.096
Watering frequency	0.119**	0.071	-0.118**	0.066	0.887***	0.058
Standard deviations						
Water availability	0.010**	0.030	0.080**	0.248		
Watering frequency	0.005*	0.033	0.006*	0.091		
MWTP	Mean	Standard error	Mean	Standard error	Median	Standard error
Water availability	727.741***	151.798	729.838***	168.630	727.694***	148.517
Watering frequency	179.797**	111.798	1344.878***	225.110	1344.850	225.110

***,** and * = significance at 1%, 5% and 10% level, respectively
Source: Author's data collection

Paper III

Social cohesion in Rwanda: Results from a public good experiment

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Abstract

In this paper we describe a public good experiment carried out in 20 rural villages in Rwanda. We find that contributions in different parts of the country are affected by the local intensity of the 1994 genocide, with more generous contributions being made in areas where violence was greater. This supports earlier research indicating that conflict experience leads to greater prosociality. However, we also find that people who have not been targets of violence themselves give lower contributions than people who have been. The considerable group-related and regional differences in social behaviour may have implications for the country's ongoing decentralisation policies and for the country's social cohesion in general.

Keywords: common property management, conflict experience, public good experiment, Rwanda

Classification: H42, Q25, R58

1. Introduction

In this paper, we study social cohesion in Rwanda by way of a public good experiment. We explore whether a participant's contribution to the public good is affected by his/her personal history and/or by local history. We find that these effects are indeed in evidence, and that there are substantial differences between the average contributions made by members of different groups. Earlier literature (Voors et al. 2012) has found that previous experience of violence can lead to increased prosocial behaviour; we find that this effect varies depending on whether one was the target of that violence or not.

There is ongoing decentralisation in Rwanda of the provision of various public goods. Decentralisation will demand a sense of community spirit from the local populations, which will be tasked with maintaining these goods; more generally, a sense of community spirit and a sense of responsibility for the well-being of the community as a whole are crucial for a functioning society. Thus, the fact that there are such pronounced differences in prosocial behaviour, depending on what group one belongs to, is worrying.

Rwanda has a long history of ethnic tensions. During the colonial era, the inhabitants of what is now Rwanda were subjected to differential treatment based on their classification as *Tutsi*, *Hutu*, or *Twa*, respectively; these categories had been based on social class before the colonial era, and reclassification due to social mobility was common, but the distinctions were perceived by the colonial rulers – first the Germans and then the Belgians – as immutable ethnic categories. Furthermore, the colonisers regarded the Tutsis as superior to the other two groups, and gave them preferential treatment. As a result, the Hutus rebelled in 1959. After Rwanda's independence from Belgium in 1961, the new government was dominated by Hutus, and ethnic violence continued. Some 700,000 Tutsis left the country between 1959 and 1990, mostly becoming refugees in neighbouring countries. This diaspora served as the core of a rebel group that came to be known as the Rwandan Patriotic Front (RPF), which fought the national government occasionally in the early 1990s. In 1994, the Tutsi genocide caused the death of between 500,000 and 1,000,000 Tutsis (estimates vary widely, with 800,000 being the most widely cited number), and led to a civil war which the RPF won. The RPF entered the capital, Kigali, in July 1994. Shortly after the new government had been installed, some 700,000 former international refugees were able to return to the country. Apart from these refugees, Rwanda also had numerous internally displaced persons who had fled from the ongoing massacres to rebel-controlled areas; very few of the Tutsis who stayed in their original places of origin survived the genocide.

There has since been relative peace within the country as well as considerable economic progress: growth rates have been among the highest in Africa, at over six per cent per year from 2000 onwards, and with per capita growth rates of over four per cent per year. All discussion of ethnicity has been banned, and ethnic groups can now only be referred to in the context of pre-1994 history. However, there is some evidence that tensions remain, and that people continue to perceive each other in the light of the pre-1994 divisions.

Positive developments in the post-1994 period include a revamping of the public sector; anti-corruption campaigns and performance-based financing policies that have largely been successful; and Rwanda's regular ranking by e.g. Transparency International as one of the countries in sub-Saharan Africa with the least corruption and best public sector service delivery. Furthermore, decentralisation policies are currently being carried out or are being planned for various utilities and common property resources – notably, for example, the supply of water.

Given that these public utilities work relatively well at present, at least by regional standards, the tensions that remain could potentially detract from the success of these decentralisation policies. Experiences from other countries with perceived or actual ethnic subdivisions indicate that such divisions can have adverse impacts on the provision of public goods (see e.g. Alesina and La Ferrara 2000; Easterly 2001; Okten and Osili 2004; Habyarimana et al. 2007; Fong and Luttmer 2011).

Possible reasons for this include (1) differences in language and culture leading to different preferences; (2) coordination problems owing to distrust; and (3) reduced utility from public goods if people from the 'wrong' group also use them. The first reason is unlikely to be a problem in Rwanda, where people share a common culture and language. However, the other two reasons could conceivably be issues in Rwanda as well. Since all the Rwandan decentralisation policies have been implemented relatively recently or are still in the planning stage, it is difficult to assess their success directly as yet. In order to study the issue, therefore, we conducted an economic experiment where we attempted to simulate the problem of managing a common property resource such as a rural water pump.

Experimental economics has been used in a few previous studies on ethnic fragmentation and conflict. In the study most reminiscent of ours in set-up and topic, Voors et al. (2012) used field experiments to study the effects of civil war in neighbouring Burundi and found that the experience of prior violence led people to become more generous to other participants, as well as more risk-seeking and more impatient. If these findings applied to Rwanda as well, one might actually expect public good provision to work *better* as a result of the previous conflict experience – at least if the increase in prosocial behaviour is large enough to offset the impact of the higher discount rates.

However, although the civil war in Burundi was caused by the same ethnic conflict as that in Rwanda, the conflict experience was substantially different. Burundi experienced several years of civil war, where violence was widespread on both sides and where the level of conflict intensity was affected by the distance to the capital, but not by other factors. Thus, in the Voors et al. (2012) study, participants from a specific location in Burundi were equally likely to have been the targets of violence, regardless of the group to which they belonged (or to which they were perceived to belong).

Rwanda, on the other hand, experienced one episode of armed conflict in the late 1950s, followed by a protracted period of relatively one-sided violence, and then a brief period of extremely intense violence – also largely one-sided – in 1994. Thus, the Rwandans in our experiment can be subdivided into different groups, based on the nature of their previous experience of violence. People who have lived in the same place as *permanent residents* all their lives will have experienced violence in 1994, but will not themselves have been the targets of that violence. *Former internal refugees* were targets of the 1994 genocide, and escaped being killed only by fleeing their homes. *Former international refugees* were targets of the earlier, lower-intensity, violence, but had left the country before 1994; so although almost all of them lost relatives in the genocide, they were not themselves the targets. In some cases, these international refugees had settled in *Burundi or the Democratic Republic of Congo (DRC)*, where they continued to be exposed to violence; in some cases they settled in *Tanzania or Uganda*, where they were safe from violence. Unlike the Voors et al. (2012) study, therefore, we can differentiate not only between different levels of conflict intensity, but also between different forms of conflict experience, and between people who were the targets of violence and those who were not.

2. Experimental design and procedure

2.1 Experimental design

In order to keep the experimental set-up as simple as possible, we followed a standardised set-up from experimental economics – a public good experiment. In such an experiment, a group of subjects is assembled, each receiving an endowment e. Each subject then decides how much of this endowment to keep and how much to donate to a 'public good' (hence the name, although the problem also has similarities to that of managing a common resource such as a water pump). The group's total donation to the public good is then multiplied by a preannounced factor f which is greater than 1, but less than the number of participants, and the resulting, larger amount is then shared equally among the group members.

The pay-off for an individual participant i is given by –

$$P_i = e - c_i + MPCR \cdot \sum_{k=1}^{N} c_k \tag{1}$$

where c_i is individual i's contribution to the public good, $MPCR$ (= f / N) is the marginal per capita return from a contribution to the public good, and N is the number of members in the group. The pay-off for the group as a whole is given by –

$$\sum_{k=1}^{N} P_k = \sum_{k=1}^{N} e + (f - 1)\sum_{k=1}^{N} c_k \tag{2}$$

Thus, since $f > 1$, the group as a whole will always gain from additional donations to the public good. Since $f / N < 1$, the individual participant will invariably lose from donating to the public good, and will primarily contribute to the public good from a sense of obligation to do so, e.g. either because s/he believes that others will also contribute, or because s/he feels responsible for the group's well-being. Exploring what factors determine c_i can, therefore, help identify levels of trust and the determinants of feelings of obligation.

2.2 Experimental procedure

The experiment was run in 20 different rural locations[1] during February and March 2011, with 15 people selected in each location. The selection process entailed that, in each location, people visiting the local market – which typically has a catchment population of some 5,000 to 10,000 people – were asked if they wished to participate in an economic experiment where they would get an sign-up reward of RWF 1,000 (corresponding to some four hours' average pay) simply for participating, but where they would also have the opportunity to earn additional money.

Each group of 15 participants was then assembled in a classroom, and were asked to fill out a short questionnaire about their personal characteristics, including their personal histories. We did not ask them about their perceived ethnic group, since any discussion of ethnic groups is now illegal in Rwanda. However, we did ask about their personal histories, and thus captured any former refugee status and conflict experience, as described in the introduction. The experiment was explained, including a brief description of how this linked to the ongoing decentralisation process in the country. After the set-up of the experiment had been explained, it was run in six rounds in all the various locations.[2] In each of the six rounds, every participant was given an initial endowment of RWF 250. Groups of five were then selected at random from among the 15. No information was provided to individual participants on who else was in their five-member subgroup. MPCRs of 0.4, 0.6 and 0.8 were randomly allocated among the three groups. Thus, participants could judge how much the group as a whole would benefit from their contribution, but – since they only knew what the 15-person group as a whole looked like – they did not know who the specific beneficiaries within the larger group would be, or what the individual characteristics of the other four members of the group were. After each round, participants were told how much the other members of the five-person group had contributed to the public good in total, and how much they had received in total from that experimental round. After that, the next round was run. The entire experiment lasted from two to three

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1 Rwanda has four rural provinces. We selected five districts at random in each of these four. However, the Northern Province only has five districts, all of which we used. We then selected a rural market at random in each of the selected districts.

2 The main reasons for running several rounds in each location were to generate more data for the analysis, and to explore if there were any learning effects linked to initial uncertainty among participants about how the experiment worked. Separate regressions were run for the initial round only, and although they are not displayed here, the results were qualitatively similar to those shown for the entire data set in section 4, "Results". The average contribution remained largely unchanged throughout all six rounds.

hours in each location, after which the participants received their earnings from the experiment. The average earnings from the experiment (including the sign-up fee) were some RWF 4,000 per participant, corresponding to two days' average pay for less than three hours' work, so it is reasonable to assume that the participants took the experiment seriously. The average contribution was approximately 50% of the initial endowment, similar to that seen in many other public good experiments (Levitt and List 2007).

3. Empirical model

Determinants of contributions to the public good were examined using random effects at the individual level. We included all the background variables collected through our questionnaire (age, gender, years of education, income, and the number of children) in all specifications. The MPCR might be expected to matter for the individual's contribution to the public good: the individual participant will always lose from contributing more, but will lose less the higher the MPCR is; so individuals with low prosociality might nonetheless choose to contribute more when the MPCR is higher. In addition, since the experiment was run in several rounds, it is likely that experience from previous rounds might matter; we deal with this by including the return from the public good in the previous round of the experiment. Thus, we include both these variables, but for robustness we also check what happens when the previous round's return is excluded.

Notably, however, experience of previous conflict might matter for people's sense of responsibility and/or generosity towards the rest of the group. Therefore, we try –

- one set of specifications where previous status as a refugee is included as an explanatory variable
- one where former refugees are subdivided further into (a) former international refugees, and (b) former internal refugees, and
- one where the former international refugees are subdivided further into former refugees to Burundi or the DRC, and former refugees to Tanzania or Uganda.

Former international refugees would have fled from pre-1994 violence and lived outside the country during the genocide, experiencing lower-intensity violence in Burundi or the DRC, but avoiding it in Tanzania or Uganda, while former internal refugees would have lived through the genocide but survived. In line with Voors et al. (2012), who include the share of the local population killed during the civil war, we also include the share of the local population killed during the genocide as an explanatory variable.

4. Results

<Table 1 about here>

Descriptive statistics for the entire experiment population are shown in Table 1. The average age of our participants was some 36 years. The average length of schooling was approximately nine years. A total of 60% of the participants were permanent residents who had lived in the area all their lives, while 40% were former refugees. Of the latter group, approximately 70% were former internal refugees, and 30% former international refugees, with the former international refuges coming in roughly equal numbers from Burundi and the DRC, on the one hand, and Tanzania and Uganda on the other. Former refugees are, on average, better educated and have higher incomes than permanent residents, although the differences are not statistically significant.

<Table 2 about here>

Results from the estimated regressions are presented in Table 2. The MPCR is statistically significant in some of the specifications, but not when the rate of return from the previous round is included. The return in the previous round is statistically significant in all specifications where it is included. None of the background variables are statistically significant in any of the specifications.

However, more importantly, we find that the participants' personal history matters, as does the local history in the area. If the group is only subdivided into former refugees and permanent residents, former refugees contributed an average of some RWF 12 to RWF 15 more in each round in comparison with permanent residents. These higher average contributions from former refugees are primarily from former international refugees. For former internal refugees, the average contribution is also higher than that for permanent residents, but is not significant in all specifications and is lower than the contributions from former international refugees, which are statistically significant in all specifications. When the participants are subdivided further, we find that former international refugees to Tanzania and Uganda have the highest average contributions, former refugees to Burundi and the DRC have lower contributions, former internal refugees have lower contributions still, and permanent residents have the lowest contributions; however, the differences are in some cases not statistically significant.

The results for other variables are largely similar in all specifications when we include the share of people killed locally in the 1994 genocide. The effect of this variable is to increase the average contribution; this effect is statistically significant in all specifications. The share of people killed locally ranges from 1.4% to 69%; the estimated impact of this difference is to change the contribution by some RWF 40 to RWF 50, about a third of the average contribution and far more than the effect of any of the dummy variables included in the regressions.

5. Discussion and conclusion

In this study, we ran a traditional public good experiment in six rounds in 20 different rural locations in Rwanda. In line with the findings in Voors et al. (2012), we find that local experience of violence matters: contributions in different parts of the country are affected by the local intensity of the 1994 genocide, with more generous contributions being made in areas where the violence was greater. However, we also find that people who were themselves the targets of violence give higher contributions than people who were not. Former refugees who were targeted in the violence are more generous than permanent residents who were not targeted, and it also appears that there may be additional differences among the former refugees depending on the type of violence to which they were subjected. It remains to be explored in future research whether these outcomes can be ascribed to the sense of responsibility felt for the group as a whole (due either to the degree of prosociality or of concern regarding future group strife), to beliefs about how other people will behave, or to some other cause. However, that the behavioural impacts are there seems clear: experience with previous violence matters – especially for those who were the targets, but also for those who were bystanders.

These effects on prosocial behaviour may have implications for the decentralisation policies being carried out. The assumption underlying the implementation of these policies is that they will allow local communities to be better poised to identify their most important priorities, and that they will therefore feel a sense of responsibility for maintaining the public goods thus decentralised. However, whether the policies will work depends crucially on whether local populations actually feel that sense of responsibility for the well-being of the group as a whole. One obvious concern in Rwanda is that this sense of responsibility may be affected considerably by historical experiences that are difficult to overcome. Whether this is the case is difficult to explore directly, but the results of our experiment indicate that their influence can indeed be felt. This may also affect how people act in practice with respect to such decentralised public goods, and could be an important factor affecting the success of Rwanda's decentralisation policies.

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Table 1 Descriptive statistics

	Full data set		Permanent residents		Former refugees		Former internal refugees		Former international refugees		Former international refugees to Burundi and the DRC		Former international refugees to Tanzania and Uganda	
Variable	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Age of respondent	36.253	11.964	35.608	12.050	37.235	11.814	35.439	10.834	41.216	13.022	38.500	13.535	44.625	11.383
Gender (0 = Female, 1 = Male)	0.480		0.475		0.487		0.561		0.324		0.389		0.312	
Years of schooling	9.103	4.070	7.884	3.541	10.958	4.134	10.890	4.295	11.108	3. 806	12.667	3.325	9.188	3.410
Income (RWF per month)	68,673	98,263	47,453	73,160	101,236	120,815	110,113	134,527	82,281	82,906	88,858	85,683	69,060	76,640
Number of children	2.893	2.160	2.834	2.088	2.983	2.270	2.695	2.130	3.622	2.465	2.889	2.166	4.250	2.793
Share of local population killed	0.187	0.156	0.202	0.177	0.163	0.116	0.162	0.111	0.167	0.127	0.186	0.152	0.117	0.029
Average contribution per round	129.50	51.30	124.60	47.67	136.96	55.77	133.95	56.05	143.65	55.33	140.19	58.89	148.12	49.807
Number of observations	300		181		119		82		37		18		16	

Source: Author’s survey, apart from the share of local population killed, which was calculated from Republic of Rwanda (1994, 2004, 2007, 2008)

Note: Full data set includes the subsets *Permanent residents* and *Former refugees*; *Former refugees* includes *Former internal refugees* as well as *Former international refugees*; *Former international refugees* includes *Former international refugees to Burundi and the DRC*, *Former international refugees to Tanzania and Uganda*, and three participants (not reported separately) who stated that they were former international refugees, but did not state what country they had lived in. Six respondents (three of the permanent residents and three of the former internal refugees) did not respond to the income question.

Table 2 Regression results

Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Marginal per capita return	33.882* (18.202)	34.3409* (17.777)	27.529 (17.665)	28.201 (17.592)	34.293* (18.220)	34.768** (17.792)	28.030 (17.676)	28.717 (17.601)	32.529* (18.235)	32.079* (17.742)	26.090 (17.595)	25.974 (17.497)
Return in previous round			0.0229*** (0.00776)	0.0208*** (0.00776)			0.0229*** (0.00776)	0.0207*** (0.00776)			0.0238*** (0.00783)	0.0214*** (0.00783)
Share of local population killed in genocide		71.499**** (18.559)		64.083**** (18.399)		71.626**** (18.569)		64.243**** (18.402)		76.580**** (18.669)		68.980**** (18.447)
Former refugee (international or internal)	11.605* (6.579)	14.918** (6.483)	12.247* (6.376)	15.224** (6.406)								
Former internal refugee					9.016 (7.322)	12.239* (7.199)	9.125 (7.093)	12.019* (7.112)	8.651 (7.312)	11.889* (7.159)	8.750 (7.045)	11.673* (7.050)
Former international refugee					17.442* (9.778)	20.979** (9.592)	19.290*** (9.472)	22.476** (9.476)				
Former Burundi/DRC refugee									13.343 (13.164)	15.377 (12.818)	15.709 (12.683)	17.559 (12.622)
Former Tanzania/Uganda refugee									22.643* (13.573)	30.075** (13.330)	23.790* (13.077)	30.518** (13.129)
Age	0.042 (0.262)	-0.014 (0.256)	0.044 (0.254)	-0.005 (0.253)	0.018 (0.264)	-0.039 (0.258)	0.0153 (0.255)	-0.0349 (0.255)	-0.075 0.266	-0.149 (0.259)	-0.084 (0.256)	-0.150 (0.255)
Gender	-2.745 (5.978)	-2.728 (5.838)	-2.414 (5.795)	-2.431 (5.770)	-1.999 (6.053)	-1.954 (5.910)	-1.514 (5.865)	-1.506 (5.839)	-2.015 (6.049)	-2.115 (5.885)	-1.513 (5.829)	-1.638 (5.797)
Years of schooling	0.714 (0.914)	0.524 (0.894)	0.710 (0.887)	0.546 (0.884)	0.627 (0.921)	0.434 (0.901)	0.605 (0.893)	0.438 (0.890)	0.735 (0.930)	0.598 (0.906)	0.708 (0.896)	0.591 (0.892)
Income	1.16e-5 (3.59e-5)	1.32e-5 (3.51e-5)	1.77e-5 (3.48e-5)	1.92e-5 (3.47e-5)	1.57e-5 (3.63e-5)	1.75e-5 (3.54e-5)	2.26e-5 (3.52e-5)	2.43e-5 (3.50e-5)	1.73e-5 (3.63e-5)	1.98e-5 (3.53e-5)	2.46e-5 (3.49e-5)	2.68e-5 (3.47e-5)
Number of children	0.190 (1.436)	0.108 (1.402)	0.052 (1.391)	-0.022 (1.386)	0.070 (1.444)	-0.016 (1.411)	-0.092 (1.399)	-0.171 (1.393)	0.227 (1.451)	0.173 (1.411)	0.089 (1.398)	0.040 (1.390)
Constant	96.133**** (16.863)	84. 639**** (16.722)	90.217**** (16.489)	80.816**** (16.639)	97.219**** (16.927)	86.070**** (16.780)	91.539**** (16.544)	82.151**** (16.691)	100.223**** (16.930)	88.735**** (16.709)	94.469**** (16.461)	84.793**** (16.573)

Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Number of observations	1,764	1,764	1,470	1,470	1,764	1,764	1,470	1,470	1,746	1,746	1,455	1,455
Wald $\chi 2$	10.96	26.33	21.29	33.61	11.60	27.04	22.29	34.68	11.95	29.45	23.30	37.56
Prob. > $\chi 2$	0.1405	0.0009	0.0064	0.0001	0.1702	0.0014	0.0080	0.0001	0.2164	0.0011	0.0097	0.0001
R^2	0.0233	0.0534	0.0495	0.0683	0.0247	0.0549	0.0511	0.0703	0.0256	0.0597	0.0536	0.0755

*, **, *** and **** denote statistical significance at the 10%, 5%, 1% and 0.1% level, respectively

Source: Author's experiment

Note: Numbers in brackets below coefficient estimates denote standard errors.

Paper IV

The value of access to water:
Livestock farming in the Nyagatare District, Rwanda

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Abstract

In Rwanda, access to water is seen as a significant constraint to development in both urban and rural areas. The government and foreign donors give priority to improving access to water for agricultural use. In this paper we study whether and, if so, to what extent profitability in livestock farming in the Nyagatare District is affected by the distance that cattle need to go in order to reach the nearest water point. Our findings suggest that this distance does not affect the profitability of livestock farming much, meaning that improved access to water is not a major constraint to livestock farming at present. Therefore, other water needs can be given greater weight.

Keywords: livestock farming, revenue function, Rwanda, water economics

1. Introduction

In this paper, we study how the availability of water affects revenue from livestock farming in Rwanda. Specifically, we study how the distance to the nearest water point affects the revenue generated by livestock for farmers in the Nyagatare District in eastern Rwanda, in order to assess the value generated by establishing additional water points in the District.

There are many competing demands on Rwandan water policy; there are different potential uses for the water itself, but also different ways in which funds for water infrastructure could be used. The overall availability of fresh water per capita per year is 638 m^3; by comparison, the United Nations estimated minimum requirement per capita is 1,700 m^3 per year, i.e. the average Rwandan receives under half of the annual minimum requirement. Thus, it is vital that Rwanda manages its water resources with great care. An even more important constraint, however, is the poor state of much of the country's water supply infrastructure, which leads to high technical losses.

In many countries, agriculture is one of the main consumers of water. Nonetheless, water policy and agricultural policy are frequently seen as completely separate issues. These separate approaches often lead to water being used wastefully in agriculture, but also towards creating a lack of water for other uses (see e.g. Lange 1998 for research on this aspect in Namibia). In Rwanda's case, some 68% of the country's current annual use of fresh water from rivers and lakes is estimated to be consumed by agriculture. Moreover, the provision of water for agriculture is an important use of investment funds for water infrastructure: land pressure is increasing, and improved water access in agriculture is seen as a way of improving productivity. However, given the severe overall constraints, both on water availability per se and on the available funds, the benefits of agricultural water supply for its recipients are worth exploring.

2. Water use in the Nyagatare District

<Figure 1 about here>

The Nyagatare District is located in Rwanda's Eastern Province (Figure 1). The entire District was part of the Akagera National Park until 1994, when the Park's size was reduced and a portion of the area was opened up for human settlement. Many of those settling in the new District have been former refugees returning from neighbouring countries who have brought livestock with them. However, there are also some migrants from other parts of the country (Niyonzima 2009). The government initially gave land in the District to newcomers. With increased land scarcity, markets have developed for renting land as well as for purchasing it outright. Of the farmers interviewed for the dataset used in this study, over 80% reported having been given at least part of their current plot from the government; almost 30% had either purchased some of their land from another private landowner, and/or been given some of their land by relatives who had owned it previously.

The importance of livestock development in Nyagatare can be attributed to the dedication of the bulk of the District to cattle when land was redistributed after the 1994 genocide. The existence of vast areas has facilitated the development of cattle breeding; in more densely populated farming areas in Rwanda, where land is scarcer, livestock farming is less widespread. Indeed, grazing is banned in most other parts of the country. The District has, therefore, become one of the country's main livestock-producing areas, and supplies almost half of Rwanda's milk. Government and numerous foreign donors have invested considerable amounts in infrastructure for processing both dairy and meat products (Rutamu 2008).

However, access to water has been perceived as an important constraint to expanding livestock production in the District. The local, traditional livestock breeds can typically walk long distances every day for water and grazing. However, the modern, improved livestock varieties introduced into the Nyagatare District after 1994 yield more milk and meat than the traditional varieties, but are also more sensitive to walking long distances for water. Thus, rural development schemes have included investments in improved storage dams for rainwater, as well as dams supplied with pumped groundwater. The Livestock Infrastructure Support Programme (LISP) for 2011–2015 lists improved water supply first among its infrastructure targets for livestock farmers, and entails setting up over 70 new livestock watering points, with the investment costs in Nyagatare District budgeted at some 4 million USD for 2013.

The funds devoted to these dams could have been spent on other rural development activities or on other water supply measures. For example, many District households still lack access to potable water and purchase their water from private vendors. Investment in domestic water supply in the District is less than US$3 million annually for the current planning period, so this is not a hypothetical trade-off: the funds spent annually on improved water infrastructure for livestock in Nyagatare are greater than those spent on improved water infrastructure for people. Apart from the trade-off in funding, there is also a more direct trade-off in terms of the water itself: some of the new water supply points use groundwater which could have been used as a source of drinking water. Thus, although increased water use for livestock may not translate directly into more scarce and more expensive water for households, it does have important indirect effects on the water scarcity facing households because of these trade-offs.

Despite the importance of water, when given a choice, households in the Nyagatare District tend to settle on the top of hills, some distance from water points, rather than occupying the lower levels closer to the water. This is because lower-lying areas have commonly been prone to malaria and livestock diseases. Those households that have settled close to water are often relative latecomers to the District, and have been forced to settle in former common land areas. Such common land areas were previously located around water points, but are now disappearing due to the individualisation of land rights and increased overall pressure on the land. The water points themselves remain communal, with access open to all, but the land surrounding them is, thus, increasingly being privatised.

The fact that livestock from many different herds assemble at the same water points increases the risk of disease contagion between herds, especially for those farmers whose livestock spend a large part of their time close to the water points. This means that establishing new water points is not necessarily a net positive for all farmers. A new water point will reduce the average number of livestock visiting each water point and, thus, reduce overall disease transmission. However, the number of livestock visiting the vicinity of the new water point will increase, and farmers who are near the new water source may well see their livestock becoming more susceptible to disease as a result. Thus, while the overall impact of improved water access on productivity should be positive because the overall exposure to disease is reduced, the individual farmer might experience reduced productivity if the changes in herding patterns lead to increased susceptibility to disease for that farmer's herd.

The clear priority given to expanding access to water for livestock, over e.g. water for domestic use, might be justified if it leads to dramatic increases in productivity. However, the two main channels through which productivity might improve are through reduced walking distances for cattle, which is only relevant for a fraction of the overall herds, and the reduced susceptibility to disease for those herds that are affected positively, which will be partly outweighed by increased susceptibility to disease for other herds. It is useful, therefore, to examine how much improved access to water actually contributes to profitability in the livestock industry.

3. Materials and methods

The data for this study come from a survey carried out in the Nyagatare District in 2006 as part of an earlier study by Niyonzima (2009). A total of 180 farmers were interviewed for the survey. Of these, 140 actively farmed livestock and are included in this data set; the remaining 40 were crop farmers and are not included in our analysis.

The variables included in the data set include the annual revenue from selling different types of livestock products such as meat, milk and live animals; the head of household’s gender, year of settlement, marital status, and years of education; the household size; the plot size; the size of the livestock herd; and the distance to the nearest water point.

Over 80% of the heads of household interviewed are male. The average number of years they had spent in school is 2.3, so the average individual in the sample has not completed primary school. Over 70% of the respondents in the sample are married. The average number of persons in a household is approximately six. The size of the farmed plot varies considerably, ranging from 0.45 ha to 80 ha. All 140 interviewees settled in the area after 1994. The average distance to a water point is approximately 3 km, with the closest farmer only 50 m away, and the most distant farmer 7.5 km away. However, the data show that many farmers rounded off their answers to this question; for instance, some 31% stated that their cattle had to walk exactly 1 km in order to reach the nearest water point.

A commonly used approach in economics to estimate the value of a free, but limited, input would be to estimate a profit function with the available quantity of the free input as one of the variables in the profit function (see e.g. Sadoulet and De Janvry 1995). However, as input prices are not available for the current study, we estimate a revenue function rather than a profit function, but using the same approach.[1]

For simplicity, we have employed the widely applied Cobb-Douglas statistical specification (Cobb and Douglas 1928), using the following as explanatory variables:

- Labour, measured using the number of household members as a proxy
- Capital, measured as the value of the livestock herd, and
- Land, measured as the area of the household’s plot.

[1] Despite being widely used in agricultural economics, as well as in other fields of economics, revenue functions can in fact be problematic if different farms have dramatically different types of production techniques (Daunfeldt and Rudholm 2009). However, as farming practices are largely similar throughout the area studied in this case, albeit with different endowments of land and livestock, the approach can safely be used here.

In order to examine the impact of access to water, we estimate a separate regression where this variable, measured as the distance in kilometres to the nearest water point, is also included along with the other regressors. Since the improved productivity linked to shorter walking distances and the increased risk of disease transmission near water points might act in different directions, we also estimate a third regression, where possible nonlinear effects of the distance to water are included by using an additional quadratic distance-to-water term. Thus, the specifications estimated were as follows:

- ln (revenue) = a_0 + a_1 ln (persons in household) + a_2 ln (capital) + a_3 ln (land)
- ln (revenue) = b_0 + b_1 ln (persons in household) + b_2 ln (capital) + b_3 ln (land) + b_4 ln (distance to water), and
- ln (revenue) = c_0 + c_1 ln (persons in household) + c_2 ln (capital) + c_3 ln (land) + c_4 ln (distance to water) + c_5 (ln (distance to water))^2.

We also tried other specifications and combinations of variables, with largely similar results.

4. Results

The results from the statistical analysis are provided in Table 1. In all three specifications, we find that the coefficients are, jointly, statistically significantly different from 0 at a 0.1% level of significance. Distance to water, our main variable of interest, does not have a clear impact on revenue. In the linear specification, distance to water is not statistically significant at all (and has a positive sign). In the nonlinear specification, the linear term is positive and statistically significant, while the quadratic term is negative and significant. The sizes and signs of the coefficients suggest that revenue increases with increasing distance to water, but only up to a distance of some 2.7 km; it declines with greater distance.

<Table 1 about here>

Access to labour does not appear to be a major constraint to farming: household labour is not statistically significant at the 5% level in either of the specifications used. Indeed, this is a frequent finding in densely populated farming areas. The size of the livestock herd matters for revenue, not surprisingly, and so does the size of the farmed plot. The results for these three variables are almost identical for the two specifications – and remain similar if the water access variables are dropped altogether.

5. Conclusions

In this paper we examined the impact of improved access to water on the profitability of livestock farming in the Nyagatare District in Rwanda. Donors and government agencies currently give priority to improved water availability for livestock; in Nyagatare, for example, which was the focus of our study, more money is currently being spent on improved water availability for livestock than on improved water availability for people. It is worthwhile, therefore, to examine how much difference improved water access actually makes.

Our results do not provide convincing evidence that the distance to the nearest water point matters for livestock farming in the Nyagatare District, at least not with the distances that are currently relevant. Our results even suggest (at least in our nonlinear specification) that close proximity to water might be a net negative, which might be linked to the increased risk of the animals contracting diseases. One should perhaps not overemphasise this result, given that a fair number of the farmers rounded off their answers so that the exact distances are difficult to ascertain for those farmers who are close to a water point. Nonetheless, these findings definitely do not show conclusively that being close to water is important for the profitability of livestock farming in the area.

The funding currently being devoted to expanding access to water for livestock in the Nyagatare District could be used to improve access to domestic water for households in Nyagatare or elsewhere. Some of the water used for watering livestock also has alternative uses. Thus, the finding that extending access to water for livestock farmers in Nyagatare does not have a measurable impact on livestock productivity suggests that the current priorities in water policy should be reconsidered.

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Fig. 1 Rwanda and the location of the Nyagatare District

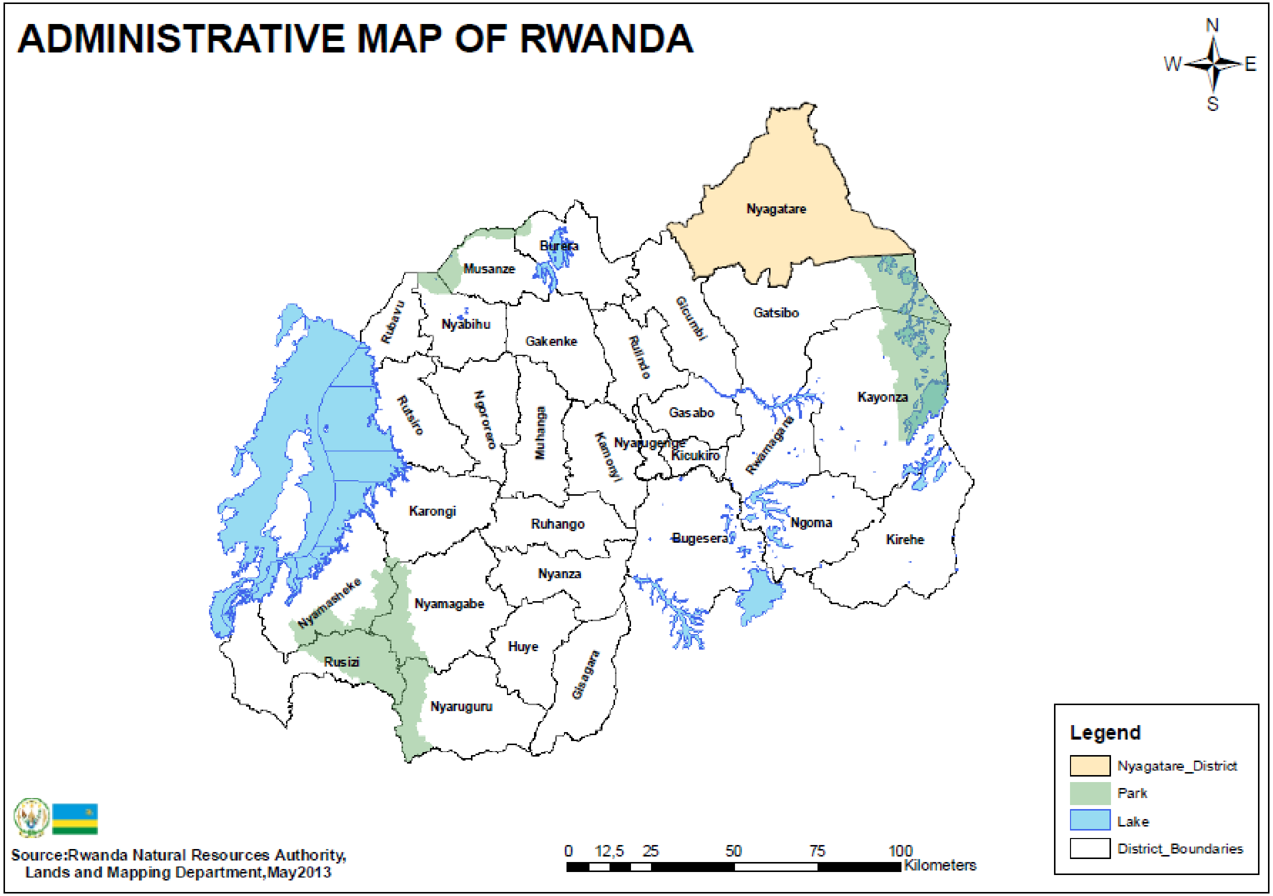

Table 1 Results of the statistical analysis

Variable	**Coefficient**		
	Specification without distance to water	**Linear specification**	**Nonlinear specification**
ln (Persons in household)	0.3004 (0.1704)	0.3071 (0.1727)	0.2132 (0.1519)
ln (Capital stock)	0.5373*** (0.0846)	0.5404*** (0.0854)	0.5604*** (0.0862)
ln (Land size)	0.4285*** (0.0892)	0.4130*** (0.0893)	0.3913*** (0.0902)
ln (Distance to water)		0.0574 (0.1263)	0.8741** (0.3281)
$(\ln(\text{Distance to water}))^2$			-0.4421* (0.1782)
Intercept	3.6690** (1.0348)	3.5730** (1.0342)	3.2461** (1.0494)
R^2	0.6923	0.6975	0.7072
	$F(3,132) = 127.22$	$F(4, 128) = 91.79$	$F(5, 127) = 83.12$

*, ** and *** denote statistical significance at 5%, 1% and 0,1% significance levels, respectively

Paper V

Errata

Stage, J. and C. Uwera (2012): Water management and pricing in the urban areas of Rwanda: the case of Kigali city. *Water Utility Management International* 7 (3):13-17.

Page 14, Section2.

1) 2nd paragraph, line 6:
   Change “5 m^3 per year” to “5 m^3 per month”.

2) 2nd paragraph, line 8:
   Change “some two litres a day” to “some twenty seven litres a day”.

Page 14, Table1.

Change “0 m^3 per year” to “0 m^3 per month”.
Change “5 m^3 per year” to “5 m^3 per month”.
Change “20 m^3 per year” to “20 m^3 per month”.
Change “50 m^3 per year” to “50 m^3 per month”.
Change “100 m^3 per year” to “100 m^3 per month”.

Water management and pricing in the urban areas of Rwanda: the case of Kigali city

Water tariffs ideally generate enough revenue to cover operation and maintenance costs, as well as long-term investment, but in the case of Kigali in Rwanda the block tariff structure means people pay less than cost recovery price for their water, and connection fees lead the poorest to source their water from elsewhere, at a higher cost than the piped supply. **JESPER STAGE** and **CLAUDINE UWERA** discuss a study undertaken into the current water pricing system and evaluate the potential for efficiency gains, and for greater numbers to connect to a piped supply, by moving to other alternatives.

The pricing of water has drawn the attention of many economists. An important topic of research has been how to ensure efficiency, effectiveness and equity – in allocation as well as management – through the selection of suitable policy instruments. Although no single policy can serve as a guideline for all situations, a few recommendations can nonetheless be made from the economics literature for water pricing in developing countries.

Economic theory suggests that an efficient price structure is one that encourages an efficient allocation of resources in the economy via the signals that it sends to consumers and producers. If the price of a good does not reflect its social marginal cost, i.e. the additional cost to society of providing one more unit of the good in question, consumers do not receive appropriate information about the social cost of a marginal increase in demand. Thus, efficient prices need to reflect marginal costs. As a consequence, economists often recommend the application of uniform rate tariffs for water, set to reflect the marginal cost of providing water. Regardless of whether or not this is actually implemented, consumers should at least face a price corresponding to the marginal cost of additional water provision when they make decisions about their marginal water use. In practice, an important additional objective for most water utilities (see e.g. Diakité et al., 2009) is cost recovery: tariffs should be set so as to generate revenue that will cover not only at least the operating costs in the short-term, but also, ideally, the long-term investment costs.

However, concerns about distribution are also important. In many developing countries, full marginal cost pricing for all water could have unacceptable impacts on the poorer members of society. Because of this, the use of increasing block water tariffs is widespread in developing countries. An increasing block tariff (IBT) is a price structure in which a commodity is priced at a low initial rate up to a specified volume of use (block), then at a higher or several increasingly higher rates for additional blocks used. However, the use of IBTs by water utilities has been criticised for several reasons.

First of all, setting the size of the initial block remains a challenge. An optimal IBT from an economic perspective would normally be a two-step tariff where the first block is set below marginal cost, and is set such that relatively few users terminate their consumption in this block. This means that the provision of cheap water would be limited to water use which is crucial for all households. However, it is politically complicated for utilities to limit the size of the initial block for residential users, due to pressure from politicians and special interests (Boland and Whittington, 2000). As a result, the revenue loss associated with the first block – and, hence, the problems that IBTs pose for the revenue generation mentioned earlier – is an even greater problem than it would otherwise be. Another limitation is that the IBT is normally not adjusted for the number of consumers using a specific connection.

Secondly, and most fundamentally, poor households are often not connected to the water network at all and, hence do not receive the subsidised service. As discussed by Sterner (2002), the cost of providing water services to an individual consumer often entails large fixed costs for distribution, connection, metering, administration and control. Furthermore, when the demand grows and exceeds the supply capacity of the current system, expensive new investments may be necessary to provide the necessary supply.

Field work done by SANO during October 2007. Credit: Jean Bosco Kanyesheja.

Hand pump use during fieldwork in 2011. Credit: Claudine Uwera.

Even when poor households have connections, they use less water than their richer counterparts, thus receiving a smaller subsidy in absolute terms (Whittington et al., 2009).

Whittington (1992) discusses this issue in detail, arguing that IBTs can be expected to affect poor households negatively. IBT structures can only work if each household (rich or poor) has a metered private water connection. However, a large proportion of households in many cities in developing countries occur in slums, where the cost of living compels them to share expenses. In these cases, poor households are less likely to have individually metered connections, due to the connection cost itself, and are obliged to obtain water either through a shared connection or by purchasing water from neighbours who have such connections. Thus, if all households in a building use the same water connection, and if an IBT is applied, their high joint rate of use pushes the water bill for the building as a whole into the higher-priced blocks. The marginal price paid for water increases, and so does the average price paid. The household selling water may have either metered or unmetered connections. Metered connections are often billed through an IBT structure, while unmetered connections are billed via a flat rate – regardless of the level of consumption. A household that has an unmetered water connection can sell water to other households at essentially zero marginal cost. Obviously, unmetered connections can cause significant losses of revenue to the water utility. On the other hand, if household connections are metered, the seller has to adjust the price to the high IBT rate and indirectly tax the buyer by increasing the price of the water provided. As a consequence, the poor – who are the most likely to lack their own water connections and who are obliged to purchase their water from neighbours or commercial vendors – often pay the most per unit for it.

In addition, the reduced revenue due to the lower tariffs will lead the utility to reduce or recoup costs elsewhere. If the utility aims at full cost recovery, a frequent outcome will be higher tariffs for establishing connections in the first place (see e.g. Griffin and Mjelde, 2011). This would penalise newcomers to the city, who are frequently among the poorer segments of the population. If the utility is partly subsidised by government, it will nonetheless be pressurised to keep costs down, and this often leads to limited reinvestment and, in the longer term, to a dilapidated distribution network. This means that the benefits of providing reliable access to safe water for all households – public health effects, time savings, and so on – are frequently not realised.

Thus, the ideal tariff structure should achieve several policy goals at once: cost recovery; efficiency (marginal cost) pricing for most or all users for marginal water use; and socially acceptable distribution outcomes. Admittedly, doing all of these at once is difficult, and few utilities in developing countries have managed to tackle them all simultaneously.

Water pricing and water use in the urban areas of Rwanda

Urban households in Rwanda experience many of the problems discussed above firsthand. The country's water supply sector is divided into two subsectors, which are separate entities: the urban water supply system; and the rural water supply system. Potable water in urban areas is supplied by the state-owned Energy, Water and Sanitation Authority (EWSA, formerly Electrogaz). EWSA is responsible for the provision and distribution of electricity and water, and has a monopoly in both sectors. EWSA is a semi-autonomous public company with a Director General appointed by the government. However, principal decisions like investment, planning and development budgets are taken at ministry level.

EWSA maintains a joint IBT system structure for all urban areas in the country, regardless of the cost of provision to the individual urban area (Table 1). The cut-off rate for the first block is set at 5m3 a year. For an average-sized household of six persons, therefore, a per capita consumption of some two litres a day – the minimum amount of potable water required for survival – is covered by the lowest rate. However, the cut-off rates and tariffs for the subsequent tariff blocks are set administratively, and are not closely linked to the cost of water provision. In a study a few years ago (Electrogaz, 2006), the average (not marginal) cost of water provision was estimated at some 750 Rwandan Francs ($1.25) exclusive of

Table 1: Tariff schedule in urban areas in Rwanda

Lower bound of tariff	Upper bound of tariff	Tariff level (including 18% value added tax)
0m^3 per year	5m^3 per year	RwF 283 ($0.47) per m^3
5m^3 per year	20m^3 per year	RwF 354 ($0.59) per additional cubic metre
20m^3 per year	50m^3 per year	RwF 472 ($0.78) per additional cubic metre
50m^3 per year	100m^3 per year	RwF 767 ($1.27) per additional cubic metre
100m^3 per year	No limit	RwF 873 ($1.45) per additional cubic metre

Source: EWSA (2012)

Table 2: Access to water network

Access to	Share of respondents (%)	More direct connection available, but unaffordable (%)	Average household size	Per capita water consumption in household per month (m³)	Average water cost per m³ (RwF)	Average monthly income (RwF)
Piped connection into house	6.6	Not applicable	5.4	8.14	905 ($1.5)	324,200 ($538.5)
Piped connection to yard / plot, but not (1)	40.6	27.4	5.6	4.25	1412 ($2.35)	166,500 ($276.6)
Public tap, but not (1) or (2)	34.0	29.6	5.5	1.20	1549 ($2.57)	187,200 ($311)
Other protected water (well, protected spring, etc.) but not (1), (2) or (3)	14.4	12.0	5.3	0.26	628 ($1.04)	143,900 ($239)
Unprotected water only	4.4	4.4	5.6	0.034	205 ($0.34)	261,100 ($433.7)

Source: Authors' survey, Kigali, Rwanda, 2011

VAT; with inflation, it is likely to be higher now. This means that all customers pay less for their water – even their marginal water use – than the cost of providing that water to them. On the other hand, the connection fee which households pay to have a connection to the network installed is based on the actual cost associated with that particular connection, and has to be paid before the connection is installed.

No estimates exist for the long-term costs including reinvestments and new investments, but the overall revenue collected by EWSA has long been insufficient to finance maintaining the existing network – let alone expand water provision. Water management in Rwanda has, therefore, been a great challenge for policymakers. The difficulties are not caused by water scarcity per se, but by the problems associated with financing water supply and treatment operations. It is estimated that more than a third of the country's drinking water supply infrastructure needs urgent rehabilitation (Republic of Rwanda, 2010).

The major issue in the water sector is in distribution. It is estimated that approximately 15% of the water is lost because of technical issues such as broken pipes, poor maintenance and general breakdowns, as the system is in disrepair. Another 15-20%, depending on the area, is lost for other, non-technical reasons. Of the non-technical losses, 70% are related to fraud and illegal connections. In addition, the poor functioning of the electricity sector plays a role in the water sector's poor performance, as the lack of reliable electricity to run the pumps and distribute the water have caused the public to have no access to water for long periods at a time (USAID, 2005).

Some two thirds of the urban residents of Rwanda live in Kigali. In 2011, a survey was conducted and 500 Kigali residents interviewed on their water use. Based on this survey, it can be concluded that, despite the low marginal tariffs facing most users currently connected to the network, costs are an issue (Table 2). Only 6.6% had a private connection to their house, with an additional 40.6% being connected via the plot in which their house was located. Sizeable shares reported that they could get a more direct connection, but found the connection fee too expensive, and relied on public taps or other sources for their water. It may be noted that the average income is substantially higher in the first group than in the other groups, and that the households that get their water from the water network – albeit not from a private tap – pay a higher average cost per cubic metre of water and use less water than the households who have a private tap.1 Thus, despite the distributional considerations built into the IBT system, the overall distribution impact is regressive when the effect of the high connection fee is included.

Considering how much more expensive the alternative water sources are, why do respondents use them rather than pay the one-off fee for connecting to the distribution network through a private connection? The survey respondents hint at a reason in the question about time preferences: the vast majority stated that they preferred to receive RwF 100,000 ($166) at once rather than RwF 200,000 ($332) three months from now, suggesting that many of the households in our sample are highly constrained in their access to liquidity. Thus, the considerable future savings that would be generated by a private connection are not enough to justify the high short-term expense of establishing the connection.

As in many cities in developing country, water provision in Kigali is uncertain (Table 3). Of the 500 households in the sample, only one stated that its members experienced pre-announced water outages and never unannounced ones. Some 89% of the respondents in the sample respond to these interruptions by storing water when it is available – putting additional pressure on the distribution network – and consuming the stored water during supply interruptions until water becomes available again. However, those who are able to store enough for the entire shortage are a minority, and 83% report that they rely on alternative suppliers for at least some of their emergency supplies during water shortages. Such alternatives include a neighbour who has the capacity to store water, a water kiosk, a water tanker, or a mobile vendor. Those who are not able to store water to meet their full needs during a supply interruption are, again, usually the poorest. As may be noted from Table 3, many households report average water costs that are higher than even the highest of the rates in the IBT schedule, reflecting their reliance on other, more costly water sources.

Possible alternatives

Looking at the current water provision situation in Kigali and the problems currently facing water users and the main

Table 3: Reported frequency of interruptions

Once a month	22.9%
Once every two weeks	7.6%
Once a week	20.6%
Twice a week	25.6%
Three days a week or more	23.2%

Source: Authors' survey, Kigali, Rwanda, 2011

water provider, two obvious issues arise from an economic perspective. One is the tariff levels in the IBT, the other is the high connection fee.

The tariff levels are set sufficiently low to ensure that all connected households – who, again, tend to be middle- rather than lower-class households – pay less than what it costs to provide water to them, even for their marginal water use. This contributes heavily to a situation where the water utility cannot afford to pay for necessary maintenance, and where, as a result, almost all water users suffer from planned and unplanned water shortages. If the quantity threshold for the first block were kept at the current $5m^3$ per year but all consumption above that level were priced at marginal – or at least cost recovery – rates, this would either reduce water consumption, reducing the excess demand in relation to capacity, increase revenue, making more funds available for maintenance and investment, or both. Regardless of which of these outcomes played out, water availability through the network would improve. Notably, even with such a price increase, the water over the subsistence level would still cost less than what most households currently pay for emergency water.

Even more importantly, the high connection fee deters users, but especially the poor, from connecting to the water network in the first place, and means that most of the beneficiaries of the IBT system are relatively well off. Given the tight liquidity constraints that most of the respondents faced, and their willingness to pay high interest rates in the future for increased consumption today, an obvious alternative policy would be for them to pay the connection fee in instalments on the monthly water bill rather than pay it in full in advance. An instalment scheme could be set up where, after a connection is established, the overall monthly cost includes interest and a partial amortisation of the connection cost, but such that the monthly cost remains lower than the cost of water purchased from private vendors. This would still generate sufficient revenue to pay off the water utility's capital cost for establishing the connection.

The exact repayment time would of course depend both on the extra cost imposed on households in order to pay for the connection, and on how sensitive the households are to reductions in the cost of water. Presumably, a drastic reduction in the per-cubic-metre cost of water would lead to increased water use, but the exact increase is difficult to estimate a priori. However, an extreme upper bound to a household's water use after such a price reduction is the per capita water use of the households that are already connected, since they face an even lower water price – having already paid their connection fee – and have a higher income. A lower bound is the household's current water use. Assuming arbitrarily (Table 4) that an extra cost of 100% of the IBT rate is added to the IBT rate for each level, and that the connection fee is the RwF 124,000 ($206) fee currently stated as the estimated average cost of connection by unconnected households in the sample, households that currently get their water from nearby connections in their plot or yard would repay their connection fee in about 10 to 24 months, depending on how much their water use increases as a result of the price reduction. Households that currently have a public tap as their main water source would, even if they do not increase their water use at all, repay the connection cost over a span of less than nine years. If their water use did increase, as seems more likely, repayment would be faster.

These simple numerical examples only give rough indications of the economic benefits of improved water services from more efficient water pricing. In practice, these benefits will depend on how sensitive consumers are to the suggested changes in pricing. However, there appears to be scope for improving households' overall welfare. We do not know precisely how much households are prepared to pay for an improved piped network or for getting access to the network in the first place, but we do know how much they currently pay for emergency water when the piped network does not work; and we also know that, aside from the private cost and time savings generated by a more reliable network, there would be important public health improvements (see e.g. Whittington et al., 2009).

Expanding the network and providing more households with private connections and individual meters would be unambiguously positive from a distribution perspective, as the unconnected households are predominantly poor. Higher tariffs are more complicated, but given the current uncertainty in delivery, if the additional revenue from a tariff increase is used to improve security in water provision, households should still be better off as a result.

Conclusions

There is clearly imperfection in the pricing mechanisms in water supply in Rwanda. The current unreliable water service is mainly due to the government's inability to finance capital costs for infrastructure, which is in turn at least partly due to the current mispricing of water. For this reason, better pricing instruments could help water management. Changing the current tariff blocks could increase revenue, making maintenance of the network easier to finance, and could at the same time reduce pressure on the network by reducing demand. Similarly, changing the way in which new connections are financed – letting households pay in instalments rather than up front – could make it easier for households to connect to the water network in the first place.

Residents in Kigali, the capital city and main urban centre, suffer from water delivery problems which are similar to those in many other developing countries. Given the importance of water access for household welfare and for health, this poorly functioning water delivery is an important social problem. However, analysis suggests that relatively small changes could improve the situation considerably. ●

Note

The final group also included some affluent households who had bottled water as their main source of drinking water. Despite the inclusion of these affluent households, the average income in this group is lower than in the first group.

Table 4: Numerical example of the speed of recouping connection fee in instalments if a five-member household gets a private tap connection and pays off the connection in instalments, using a 5% real interest rate, using the average connection fee reported (RwF 124 000), and assuming that a surcharge of 100% is added to the IBT rate

User category	Assumed monthly household use	Total monthly water cost until connection repaid	Current monthly water cost	Number of months until connection fee repaid
Households currently using plot or yard connection	40.7m^3 (same as current private tap users)	32,993 ($54.8)	30,005 ($49.8)	10
	21.25m^3 (same monthly household use as now)	14,868 ($24.7)	30,005 (49.8)	21
Households currently using public tap	40.7m^3 (same as current private tap users)	32,993 ($54.8)	9294 ($15.4)	10
	14.1m^3 (same monthly cost as now)	9294 ($15.4)	9294 ($15.4)	34
	6.0m^3 (same monthly household use as now)	3540 ($5.9)	9294 ($15.4)	102

Source: Authors' calculations

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