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Domestic Water Use by Rural Households without Access to Private Improved Water Sources: Determinants and Forecast in a Case Study for Benin

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Abstract

Accessibility to safe water remains a major concern in Benin, where only 23% of the population have improved drinking water within the residence. The problem is even more important in rural areas where households have no access to private improved water sources. Based on Benin's good level of per capita water availability (3815 m^3 per year in 2004), it is argued that efficient water management can highly contribute to increase the level of access to safe water. However, better understanding of factors explaining domestic water use, including forecasting how these variables will affect future water use, is an important step of efficient water management for rural developing countries. Accordingly, this study combines a Seemingly Unrelated Tobit (SURT) approach and Geographic Information System (GIS) techniques to determine factors affecting domestic water use in dry season, when water is at its scarcest level in rural areas. The focus is on rural households without access to private improved water sources in Benin. These households use either only free sources, only purchased sources or combine both free and purchased sources. Both socio-economic and geographic data were collected from 325 households in 27 villages.
Results confirm that SURT is appropriate to account for both censored nature of water demand and the correlation of error terms between free and purchased water use equations. Contrary to the importance of price effect on residential water demand, we find that purchased water demand is perfectly own-price inelastic due water scarcity in rural areas. Rather, the important determinants of water use are household size and composition, access to water sources, wealth and time for fetching water. However, the effects are different for households which use only free sources, households which rely only purchased sources and those which combine both free and purchased sources. Moreover, econometric and spatial analysis shows that the effect of population growth on future water scarcity will not be similar for all districts in the study area. We conclude that water management policy at district level is likely to produce better impact as compared to the usual national or basin based approach.

Keywords: Domestic water management, rural households, dry season, seemingly unrelated regression, censored models, GIS, Benin.

1. Introduction

Over one billion people do not have access to clean water and sanitation facilities (UN/WWAP, 2003). This increases sickness and morbidity, decreases available time and resources for productive activities, and thereby reduces population welfare. Therefore the benefits related to an

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improved water supply are quite immense. However for the household to fully benefit from an improved water supply, it must have access to safe and reliable water sources indoors. While this is almost true in developed countries, such access is far from reality in developing countries and especially in rural areas. In Benin, accessibility to improved water supply remains a major concern. Despite Benin's good level of per capita water availability (3815 m^3 per year in 2004), only 23% of the population have drinking water within the residence. Among other factors, the high rate of population growth (3.25%) tends to contribute to the increase of water needs and thus reduces the level of access to safe water. Therefore, efficient water management policy is important if health and welfare of the population, particularly in rural areas, are to be improved.

Efficient water management for rural areas requires a full understanding of existing pattern of water use as well as a forecast of future water consumption taking into consideration the different factors involved (NYONG and KANAROGLOU, 1999). To contribute to such knowledge, this study combines a Seemingly Unrelated Tobit (SURT) approach and Geographic Information System (GIS) techniques to determine factors affecting domestic water use in dry season, when water is at its scarcest level in rural areas. The focus is on rural households without access to private improved water sources in Benin. These households use either only free sources, only purchased sources or combine both free and purchased sources. Due to high rate of population growth, we also try to forecast the effects of increasing population on domestic water scarcity.

2. Estimation approach and data collection

To determine factors affecting domestic water use by rural households without access to private improved water sources, we estimate the demand functions for both free and purchased water. However to avoid potential inconsistency in the estimation of the demand function, two notes of caution are here in order. First, some households combine free and purchased water sources. These households are included in both the free and purchased water demand equations, and the error terms across these two equations may be correlated. Second, the dependent variables are non-negative and also left-censored because a considerable number of households did not use water from free sources or did not obtain water from purchased sources. For instance, households that use only free water sources have zero for the quantity of purchased water. Consequently, in the data set, we have several values of the dependent variables that are zero in both the free and purchased water equations. Therefore to account simultaneously for the censored nature of the dependent variables and the correlation between error terms across free and purchased water equations, we introduce a Seemingly Unrelated Tobit (SURT) approach. The merit of SURT is to be able to overcome the drawbacks of two popular approaches: the Seemingly Unrelated Regression (SURE) and the Tobit.

The study area includes the central and northern parts of the Oueme river basin of Benin Republic. The survey was carried out between April and August 2007, and a two-stage stratified random sampling technique based on location and water accessibility was used. Both socio-economic and geographic data were collected from 325 households in 27 villages. These data include mainly household characteristics, daily water use in dry season, water sources, time for fetching water and water price as well as geographic coordinates of family dwelling and water points. Using these data, we estimated the system of free and purchased water demand.

3. Results and discussion

Estimation results of SURT model of water demand function are presented in Table 1. The correlation coefficient (ρ) between the error terms is estimated to be -0.48. This value is significantly different from zero based on asymptotic t-tests. Furthermore, the model is globally significant at the 1% critical level. These empirical results show that the SURT is appropriate for both the censored nature of the water demand from different sources and the correlation between error terms across two water demand equations.

3.1 Determinants of water consumption in dry season

From Table 1, both free and purchased water consumption in the dry season were positively related to household asset expenditure, a variable found to be a good proxy for wealth in rural areas. This result supports the expectation of a positive relationship between wealth and water use and can be explained in two ways. First, the difference in water use between wealthy and poor people for activities such as cooking and washing may be important since poor people cook either less or rarely and have less clothing to wash. Secondly, better-off people have the ability to afford the higher cost associated with fetching water in the dry season. In fact, we have seen in the study area that better-off people may travel long distances by motorcycle to fetch water. This result clearly implies that poverty reduces water use, and poverty reduction strategies and development policy in rural areas should include an objective of water supply improvement.

Table 1. SURT results for free and purchased water demand (in liters day^{-1} $household^{-1}$) in dry season

Variables	**Free water demand** [a]		**Purchased water demand**	
	Coefficients	**t-test**	**Coefficients**	**t-test**
Household size	21.94***	4.82	4.77	1.21
Household size squared	-0.48***	-2.70	0.30*	1.91
Asset expenditure	0.03**	2.46	0.02***	2.68
Population	-4.87	-1.13	-5.90*	-1.87
Gender	-6.41	-0.34	-28.79*	-1.84
Ratio of children to adults	-3.80	-0.35	-1.67	-0.23
Occupation for users of free and purchased water	-58.52***	-4.58	-59.66***	-5.48
User of improved sources	4.52	0.32	32.93***	2.79
Literacy	-20.80*	-1.71	-1.97	-0.22
Access to public well	10.12	0.67	-7.00	-0.64
Education	-10.29***	-2.65	2.94	0.98
Access to clinic	11.41	0.93	26.81***	2.72
Access to own opened well	39.19**	2.08	-	
Time for fetching water	-0.02	-0.86	-	
Water price	-		-2.17	-1.56
Queue time	-		0.09***	4.81
Walk time	-		-0.39	-1.32
Access to public pump	-		15.91*	1.81
Constant	52.32**	2.00	68.62***	3.06
Correlation coefficient ρ	-0.48 (-2.16)**		Log-likelihood	-2471.69
χ^2 (df=16)	361.17***		Observations	325

* p<0.10, ** p<0.05, *** p<0.01. [a] Some non significant variables are not presented here.

Unsurprisingly, household size positively affects free water demand. This implies that the bigger the household, the greater the free water consumption. In the free water demand model, a negative relationship is found between the total time for fetching water and free water consumption as expected, but the coefficient is not significant. This demonstrates that free water consumption will not be significantly reduced due to an increase in fetching time. A likely reason is that water sources are also social meeting points for the rural population. Women may go to water sources not only to fetch water but also to socialize. Therefore, they may prefer water sources where waiting times are long, allowing them the convenience of exchanging social information. Water price has a negative effect on purchased water use, but the coefficient is not significant (P = 0.119). In addition, price elasticity is low (-0.10). Therefore, purchased water demand is perfectly price inelastic. This implies that the importance of price for purchased water demand in the dry season is negligible, which means that higher prices will not lead to a significant decrease in water use. This is plausible, because of water scarcity, households are willing to pay more to improve the rural water supply.

Village population is found to be negatively correlated with both free and purchased water consumption in the dry season, and the coefficient is significant at 10% for purchased water. This shows that people in villages with more inhabitants will consume less water. Additionally, the marginal effect of population is calculated to be -5.61 for purchased water. It means that an increase in population by 1000 inhabitants will lead to a decrease of about 6 liters in daily household consumption of purchased water. This result is quite interesting since it can be used to forecast the effect of population increase on water use or scarcity.

3.2 Water consumption forecast

Similar to other Sub-Saharan African countries, the annual population growth rate in Benin (3.25%) remains among the highest in the world. This population growth will likely, *ceteris paribus*, lead to more frequent water shortage. Based on econometric and spatial analysis, we forecast the effect of population growth on future water scarcity. Figure 1 highlights the effect of population growth on water scarcity by comparing the proportion of economically water scarcity households for the periods 2007 and 2025. It shows that the effect of population growth on water use will be high. Indeed, while only 7 districts have more than 30% of households using less than 20 liters of water per capita per day in 2007 (Fig 1a), this is likely to increase to 17 districts in 2025 (Fig 1b). This result reveals that water problem in rural Benin is likely to increase in the future and it implies that increasing water accessibility and water use should be included in development policy. We found also that effect of population growth will not be similar for all districts and this shows the shortcoming of global models which generate average value for country or river basin.

Figure 1a. Percentage of household using less than 20 liters of water per capita per day in 2007.

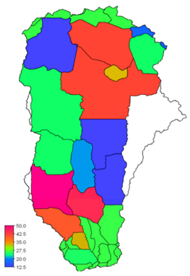
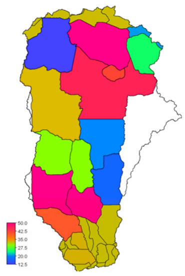


Figure 1b. Forecasted percentage of household using less than 20 liters of water per capita per day in 2025.



Source: Own results.

4. Conclusion and policy recommendations

Empirical results confirm that the SURT approach is appropriate to account for both the censored nature of water demand and the correlation between error terms of free and purchased water use equations. We find that purchased water demand is perfectly own-price inelastic due water scarcity in rural areas. Rather, the determinants of water use are household size and composition, access to water sources, wealth and time for fetching water. However, the effects are different for households using only free sources, only purchased sources or combine both. Econometric and spatial analysis shows that the effect of population growth on future water scarcity will not be similar for all districts in the study area. A policy implication is that water management at district level is likely to produce better impact as compared to the usual national or basin based approach.

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