Elicitation of Determinants of Rural Households' Water Supply in Côte d'Ivoire: A Case Study

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Authors *Vassiki SANOGO; Senior Researcher, Florida State University-Center for Economic Forecasting and Analysis, USA, vassikisanogo@gmail.com, +1(850) 645-0190. Richard K. MOUSSA; Ph.D. Candidate, Université de Cergy-Pontoise, France.*

Abstract/Summary

Problems of accessibility and quality of water are serious issues in rural areas in all developing countries. In Côte d'Ivoire, only 11.6% of household in rural areas have access to safe drinking water and only 26.8% of household in rural areas have a water source at home. However, annual water expenditure in rural areas are 28130 XOF (56.26 US $) in average. In this paper, we conduct an economic evaluation of the water sector by pointing out the determinants of water source choice and water fees in rural areas in Côte d'Ivoire. By using the data from household living condition survey (2008), we estimated a multinomial logistic model and a Heckman selection model respectively to highlight determinants of households' water source choice and water expenditures. We find that education in household (reduces by 0.1382 the probability to choose ground of type 2), poverty status (reduces by 0.0273 the probability to choose safe drinking water), household and household's living house characteristics (household headed by women increases by 0.0468 it probability to choose safe drinking water) and time to water source are main determinants for choosing a water source (water source more than 15 minutes from house increases by 0.2215 the probability to choose ground water of type 1), while the water expenditures are determined by selected water source (the choice of ground water of type 1 instead of safe drinking water has no significant effect on annual water expenditures), household size (annual household water expenditures higher significantly with household size) and the distance to water source (Far the water source is, higher the annual water expenditures are).

Introduction

Guaranteeing that rural residents around the world do not have to walk for hours to collect sufficient and safe drinking water is a huge challenge for developing countries. This case study raises insights for researchers, and all others stakeholders including decision makers, who are involved in trying to improve rural water supplies, in particular the limited successes and areas where approaches need to be radically improved. Considerable investments have been made in rural water supplies. The springtides have been protected; boreholes have been dug or drilled, and fitted with handpumps; piped water schemes have been constructed. However, the thoughtful issue is that progress is still much too slow, and rural water supply coverage significantly lags behind that of urban water supply. Further, many of the constructed services have not continued to work over the time. It has been estimated that only two out of three installed hand pumps are working at any given time. According to Davis J. et al (2008), many rural water supply interventions in developing countries have been marked by a poor record of sustainability. Indeed, thousands of people, who once benefited from a safe drinking water supply, now walk past broken handpumps or taps and on to their traditional, dirty water point. Despite best intents of sector professionals and practitioners that have contributed towards this problem, there are a number of unsolved issues of the rural water supplies sector.

This work aims to address the stress related to the access of affordable and reliable safe water at village,

small town, local government or national scale in Côte d'Ivoire, by conducting an elicitation of the determinants of households' water supply choice and annual water expenditures. For this purpose, we should consider groups that are often marginalized such as the very poor, remote or pastoralist communities, as viewed by the 2009 report of the Water and Sanitation Program.
This study should help to understand the behavor of Ivorian's households related to rural water supply. Inherent in several papers in the literature on rural water supply services, it is assumed that "community management", the independent of external supports of any kind, is sufficient to keep systems running once they are installed (Lockwood, 2003; Schouten and Moriarty, 2003).
However, this assertive of community management approach has been challenged in the recent studies. Schouten and Moriarty (2003), for instance, conducted a series of case studies of communities in which rural water supplies projects were well planned (i.e., based on users' caressed needs and preferences and with appropriate technologies). In the authors' findings, they stated that ongoing external support was still necessary to sustain project outcomes over time, even the substantial investment in building community capacity for system management. A review completed by Lockwood (2003) on dozens of rural water project assessments, and shown that in merely a minority of these projects were provisions for any sort of postconstruction support established as part of the planning process. Among projects with postconstruction support components, many were not evaluated in such a way as to be able to draw substantive conclusions. Furthermore, those which were thoroughly evaluated appeared to be unusual projects that included some levels of postconstruction support funded by external donors. Approaches such as Lockwood (2003) argues, would be unfeasible at scale or over time in the developing countries.
Further recent studies, as Prokopy and Thorsten (2006) examined the effects of postconstruction support on rural water system sustainability in 99 communities across two areas of Peru. The water systems investigated all provided household level services (i.e., piped water connections in the yard or patio). The authors did not detect any effect of postconstruction support on functioning of water systems, but did note that households in communities that received more postconstruction support visits were more likely to pay their water bills regularly and to express satisfaction with their water supply services, as compared to those in communities who received fewer visits. The authors did not test for effects of the different types of post-construction support that were provided to communities (e.g., engineering assessments, hygiene promotion, and financial assistance).

K. Komives et al. studied the impacts of postconstruction support for rural water supply systems in 200 villages located in two Ghanaian regions. The water systems included deep bore wells with handpumps. Many different postconstruction support programs were ongoing in the areas studied by the authors, which made isolation of effects for any particular type of support challenging. Generally, the authors concluded that the villages that received engineering oriented postconstruction support, training of the community members in maintenance and repair of the bore well, were more expected to have working water points as compared to those that did not receive such assistance. At the same time, the authors note that performance across the entire sample of communities was quite high, even in villages that did not receive postconstruction support.

With this study we contribute to first elisitate the determinant households' choise of water sources in Ivorian rural areas. In addition the study gave us significant insights of Ivorian houaseholds annual water expenditure.

Data were collected by the National Institut of Statistics, field data gathered using a household living condition survey that covered both rural and urban households in Côte d'Ivoire in 2008.

Context, aims and activities undertaken

For our study, water sources have been classified in three (3) major sources: (i) safe drinking water that includes private and collective taps, and resellers of piped water, (ii) ground water of type 1 that includes hand pumps and public water fountain or pump, and (iii) ground water of type 2 that is an unimproved water source and that includes unprotected wells, lakes, streams, etc. In this paper, we aim to study the determinants of households' choice of primary source of water and the annual water expenditures according to household characteristics for households living in rural areas.

Similarly to Fotue and Sikod (2012), we use a multinomial logistic model to describe major household characteristics that determine household choice of primary water source. We use this model because it better addresses qualitative dependent variable with more than two outcomes, and more specifically when theses outcomes are not ordered. Let Y denotes a choice of water source. Y can take three possible modalities that are safe drinking water, ground water of type 1 and 2. Let X denotes a set of household characteristics such as household poverty status[1], log of household total income, household size, number of household members that are literate, number of household members with college degree at least, household living house type, the number of rooms, the type of toilets, household region of residence, and the age and gender of household head. X also includes water sources characteristics such as time and distance to water source. Thus, the estimated multinomial logistic model has the following form:

$$P(Y_i = j) = \frac{\exp(X_i\beta_j)}{1 + \sum_{k=1}^{2}\exp(X_i\beta_k)} \quad \text{with } j = 1 \text{ or } 2; \text{ and } P(Y_i = 3) = 1 - \sum_{k=1}^{2} P(Y_i = k) \quad (1)$$

Where $P(Y_i = j)$ denotes the probability that household i chooses the water source j. Parameters are estimated by maximum likelihood method. The estimated multinomial logistic model must meet the underlying hypothesis of independence of irrelevant alternatives (IIA). We test for that hypothesis by the use of Hausman’s IIA test.

The annual water expenditures can be null or unobserved for several households especially in rural areas. For that reason, we use a Heckman selection model to point out the determinants of the household annual water bills. This model is used because we face censored continue dependent variable. The Heckman selection model is based on the underlying assumption that there is non-random selection for observing the continue dependent variable. Let lwexp denotes the log of household annual water expenditures. Let D denotes the selection variable that is a binary variable that takes 1 if we observe water expenditures and 0 if not. Let X denotes household characteristics that are relevant for water consumption. These characteristics are household poverty status, log of household income, household size, household region of residence, and age of household head. X also includes water source characteristics such as type of water source and distance to water source. Let Z denotes household characteristics that impact selection for observable water expenditures. These characteristics are household poverty status, household size, household region of residence, and the type of water source chosen by the household. Thus the estimated Heckman selection model has the following form:

$$\begin{cases} \text{Regression model} & : \ lwexp_i = X_i\beta + \varepsilon_i \text{ if } D_i = 1 \\ \text{Selection model} & : \ \begin{cases} D_i^* = Z_i\delta + \mu_i \\ D_i = 1 \text{ if } D_i^* > 0 \end{cases} \end{cases} \quad (2)$$

Where the residual terms are $\varepsilon_i \sim \mathcal{N}(0, \sigma)$, $\mu_i \sim \mathcal{N}(0,1)$, $Cov(\varepsilon_i, \mu_i) = \rho$. The inverse Mills ratio is given by $\lambda = \rho\sigma$. ρ must be significantly different from 0 to validate the underlying assumption of non-random sample selection. Parameters are estimated by maximum likelihood method.

Main results and lessons learnt

The first part of this section establishes by giving some descriptive statistics, a state of accessibility and cost of water around rural areas in Côte d’Ivoire. Then we present and discuss results from our estimated models that assess determinants of safe drinking water accessibility and water bills.

Descriptive statistics

[1] A household was supposed to be poor if the total expenditures per capita per day is under 661 XOF (1.322 US $).

The 2008's living conditions survey in Côte d'Ivoire is a national representative survey that covers 12600 households in both rural and urban areas; with 56.95% of household surveyed in rural areas. It provides information on household living condition, house characteristics, water supply and consumption. In this paper, we focus on rural areas. Thus all statistics below are produced on household living in rural areas. The statistics are also weighted to given a national representative assessment.

Figure 1 provides accessibility statistics for rural areas per region while Figure 2 provides statistics on annual water expenditures in rural areas per region.
As we can see in Figure 1, in 25% of rural areas in Côte d'Ivoire, no household has access to safe drinking water while in only 10% of rural areas, 38.2% of household have access to safe drinking water. Regions that are more concerned with low rates of household having access to safe drinking water are the North, especially the North West, the East and the West. The South and the Center of the country have higher rates of household that have access to safe drinking water. For the annual water expenditures, the higher fees are paid in the Center and the South of the country. In rural areas in Côte d'Ivoire, only 27.6% of household pay fees for accessing water. Those households pay on average 28 130 XOF per year and 50% of them have an annual bill under 18 250 XOF.

Table 1 below gives statistics on accessibility and fees with respect to the selected water source. Only 11.6% of household in rural areas use safe drinking water and 58.9% of them have the water source at home. For these households, the average annual income is 1 405 700 XOF (2811.4 US $) and the average annual water expenditures is 29070 XOF (58.14 US $). The water source most used in rural areas in Côte d'Ivoire (used by 48.8% of households) is the ground water of type 2 (that includes lakes, unprotected well, etc.).

In rural areas in Côte d'Ivoire, only 26.8% of households have a water source at home (against 46.6% in general in Côte d'Ivoire). 26.6% of these household use safe drinking water. These household are less poor than the others (42.3% of poor, average annual household income of 1 203 700 XOF, i.e 2407.4 US $) and pay lower annual water fees (25200 XOF, i.e 50.4 US $). Note that 71.1% of households living in rural areas have no water source at home. They must walk less than 5 kilometers to find water source and only 6% of these water sources are safe drinking water source. There are also 2% of households in rural areas that have to walk more than 5 kilometers to find water source and only 2.9% of these water sources are safe drinking water source.

Household choice of water source
Household choice of water source has been modeled with a multinomial logistic model. The estimated model is globally significant with a pseudo R2 equal to 22.6%. The water source taken as reference in the estimation is safe drinking water source. As expected, household, living house, and water source characteristics affect household choice of water source.

Poverty status and household annual income have the expected sign. Being poor increases the probability to choose ground water of type 1 and 2 instead of safe drinking water source (poverty reduces by 0.0273 the probability to choose safe drinking water). But there are weak evidences (significant at 10%) that the higher the household income is, the lower the probability to choose ground water of type 1 or 2 instead of safe drinking water (a unit additional income increases by 0.0049 the probability to choose safe drinking water). However, household size has no significant effect on water source selection.

Demographics characteristics play important roles. For instance the gender, as we could see in Table 3 below, the households headed by women are less likely to choose ground water of type 1 or 2 instead of safe drinking water (finding: household being headed by women increases their probability to choose the safe drinking water by 0.0468). This finding might be explained by two underlying phenomenon that are (i) households headed by women have significantly lower size (3.9 with standard deviation 2.7) than that headed by men (5.2 with standard deviation 3.5), that can be their expenditures, and (ii) households being headed by women might often be due to the fact that their husband are migrant that move to urban areas to work. We capture education effects with the number of household literate members and the number of household members with at least college degree. We find that the higher the number of household members with at least college degree, the lower the likely to choose ground water of type 1 or 2 instead of safe drinking water (a unit increase in the number of household members with at least college degree increases by 0.0568 the probability to choose safe drinking water and reduces by 0.1 the probability to choose ground water of type 2). The higher is the number of literate household members, the lower is the likely to choose ground water of type 2 instead of safe drinking water (finding: a unit increase in the number of literate household members the probability to choose safe drinking water increases by 0.0293, the probability to choose ground water of type 1 increases by 0.1088, and the probability to choose ground water of type 2 reduces by 0.1382). This finding highlights not only the important role of being literate on household's choice, but also the important role of the school level. However the number of household literate number is not significantly discriminant for the choice of ground water of type 1 instead of safe drinking water.

Living house characteristics have also been analyzed. We find that living in high or middle standing houses instead of low standing house lowers the probability of choosing ground water of type 1 or 2 instead of safe drinking water (living in high standing house increases by 0.0801 the probability to choose safe drinking water and reduces by 0.1994 the probability to choose ground water of type 2; and living in middle standing house increases by 0.0319 the probability to choose safe drinking water and reduces by 0.0678 the probability to choose ground water of type 2). Comparatively to households living in house without toilets, households living in houses with toilets with or without flush are less likely to choose ground water of type 2 instead of safe drinking water (having toilets with flush increases by 0.2295 the probability to choose safe drinking water and reduces by 0.2598 the probability to choose ground water of type 2; and having toilets without flush increases by 0.0519 the probability to choose safe drinking water and reduces by 0.0584 the probability to choose ground water of type 2). However the type of toilets is not significantly discriminant for the choice of ground water of type 1 instead of drinking water. The number of rooms in the living house is not significant for the choice of water source.

The last set of variable to analyze is the characteristics of water sources. As we can see in Table 3 below, the higher the time to water source is, the higher the probability to choose ground water of type 1 or 2 instead of safe drinking water (having a time to water source less than 15 minutes increases by 0.3618 the probability to choose ground water of type 1 and reduces by 0.1108 the probability to choose safe drinking water; and having a time to water source high than 15 minutes reduces by 0.0706 the probability to choose safe drinking water). Households that have to go far to find water source are more likely to choose ground water of type 1 instead of safe drinking water than those with water source at home (having a water source at more than 5 kilometers of the living house reduces by 0.0507 the probability to choose safe drinking water and increases by 0.2215 the probability to choose ground water of type 1). These high variations in the probabilities highlight the important role of proximity to water source in the household's choice of water source. More the water source is close to the living house, more the households are likely to choose a safe water source.

Household annual water expenditures

The estimated Heckman selection model is globally significant. The residuals correlation term and the inverse Mills ratio are also significant. That validates our specification. The censored observations are around 72.4% of the overall rural sample.

In the selection model, all coefficients have the expected sign. Thus, using ground water of type 1 or 2 reduces the probability to have water bill. Poor households are less likely to pay water bill. Higher the household size is, higher is the probability to pay water bill.

From the water expenditures regression model, we find that selected water source affects the annual water expenditures. The choice of ground water of type 2 instead of safe drinking water reduces significantly the annual water expenditures. This finding holds because household that uses ground water of type 2 most often pays only few fees for treatment. However, the choice of ground water of type 1 instead of safe drinking water has no significant effect on annual water expenditures. Far the water source is, higher the annual water expenditures are (having a water source at more than 5 kilometers far from the house increases the annual water expenditures). But there is no significant difference in water expenditures between household with water source at less than 5 kilometers and those with water source at home. This finding is justified by the fact that water source that are far from house involve direct cost such as transportation fees.

The study shows that the households annual water expenditures are significantly related with household size and are significantly less related with the poverty of households. That highlights the effect of household size on the water consumption. Household annual income level and household head characteristics do not significantly affect the water consumption.

Households living in the North, Center North, Center West, and Center East of the country have significantly lower annual water expenditures than those living in the district of Abidjan. This finding is the fact that in those areas except the district of Abidjan, households use paid water only to cook and drink; but for others uses (such as washing, cleaning…), they use free water sources.

Conclusions and Recommendations

This study analyzed the determinants of household's choice of water source and the determinants of water bills in rural areas, in order to assess the need and pricing of rural water supply in Côte d'Ivoire. We estimate a multinomial logistic model and a Heckman selection model to reach this goal. We control for region disparities and we account for the main factor such as economic status, demographic characteristic, education, living house characteristics and water source characteristics that are determinants for the choice of water source and the annual water bills.

We find that education in household, especially the number of household members with at least college degree, is an important determinant of household's choice of water source. Poverty status, living house characteristics also play important role. Another important determinant for choosing a water source is the time to water source. Policy makers must conduct a policy of construction of water source closer to households in rural areas; that will allow household to choose a safe drinking water source. The households' water bills are determined by selected water source, household size and the distance to water source. Thus by reducing distance to water source, we can significantly reduce the water bills for household in rural areas.

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Conflict of interest
The authors have no conflicts of interest to declare.

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Contact Details

Name of Lead Author: Vassiki SANOGO
Email: vassikisanogo@gmail.com

Name of Second Author: Richard K. MOUSSA
Email: moussakr@gmail.com

Further guidance: Tables and Figures

- **Tables** should be set up in Word, referred to as 'Table' and numbered consecutively

Table 1 : Difference in accessibility and fees by water source in rural areas

Water type	Proportion	Proportion of household with water source at home	Water expenditures (in x1000 XOF)	Household annual income (in x1000 XOF)
Safe drinking water	0.1163	0.5887	29.07	1405.7
Ground water type 1	0.3959	0.0679	27.69	738.9
Ground water type 2	0.4879	0.3293	28.43	932.5
Total	1	0.2560	28.13	911.2
Number of Obs. (weighted)	1 819 407			

Table 2 : Water accessibility by area

Area	Distance to water source	Proportion	Proportion of household using fresh water	Household annual income (in x1000 XOF)	Household size	Proportion of poor	Water expenditures (in x1000 XOF)
Rural	At home	0.2681	0.2664	1203.7	5.07	0.4227	25.2
	Less than 5 km	0.7112	0.0606	792.9	5.02	0.5285	28.6
	More than 5 km	0.0206	0.0286	762.6	5.53	0.6099	29.3
Overall	At home	0.4659	0.5863	1957.1	4.88	0.2661	41.5
	Less than 5 km	0.5188	0.1782	929.2	4.86	0.4715	32.4
	More than 5 km	0.0153	0.1726	1281.2	5.34	0.5354	34.7

Table 3 : Determinants of household's water source choice (Multinomial logistic regression)

Variables	Safe water source	Ground water type 1			Ground water type 2		
	Margin	Coef.	Std. Err.	Margin	Coef.	Std. Err.	Margin
Poverty status (Ref = not poor)	-0.0273***	0.4663***	0.1384	0.0289	0.3865***	0.1312	-0.0015
Log of household income	0.0049*	-0.0785*	0.0402	-0.0031	-0.0734*	0.04	-0.0018
Household size	-0.0007	0.0019	0.0192	-0.0028	0.0155	0.0185	0.0034
Gender of household head (Ref = male)	0.0468***	-0.6058***	0.149	-0.0218	-0.5926***	0.1395	-0.025
Age of household head	-0.0001	0.0043	0.0044	0.001*	-0.00004	0.0042	-0.0009
Household members literate	0.0293**	-0.1302	0.2331	0.1088***	-0.6691***	0.22	-0.1382***
Household members with college degree	0.0568***	-0.6981***	0.2679	0.0432	-0.9935***	0.267	-0.1**
House standing (Ref = low standing house)							
High standing house	0.0801***	-0.5256**	0.2112	0.1192***	-1.2375***	0.1988	-0.1994***
Middle standing house	0.0319***	-0.3545**	0.1473	0.0358**	-0.5728***	0.1386	-0.0678***
Type of toilet (Ref = No toilet at home)							
Toilets with flush	0.2295***	-1.4073***	0.342	0.0302	-2.1093***	0.2997	-0.2598***
Toilets without flush	0.0519***	-0.6705***	0.131	0.0065	-0.7946***	0.1249	-0.0584***
Number of rooms in house (Ref = 1 room)							
House with 2 to 4 rooms	0.0034	-0.1037	0.1507	-0.0208	-0.0171	0.1423	0.0174

Variables	Safe water source	Ground water type 1			Ground water type 2		
	Margin	Coef.	Std. Err.	Margin	Coef.	Std. Err.	Margin
House with 5 or more rooms	0.0118	-0.122	0.2048	0.0147	-0.2092	0.1971	-0.0265
Distance to water source (Ref = at home)							
Less than 5 Km	-0.0184	0.7632***	0.2516	0.1717***	-0.0114	0.2533	-0.1532***
More than 5 Km	-0.0507***	1.6996**	0.7144	0.2215***	0.8657	0.7168	-0.1708***
Time to water source (Ref = at home)							
Less than 15 minutes	-0.1108***	2.4972***	0.2619	0.3618***	0.8223***	0.2499	-0.251***
More than 15 minutes	-0.0706***	2.4679***	0.4606	0.1687***	1.8918***	0.4559	-0.0981
Region of residence (Ref = District of Abidjan)							
Center north	0.0743**	-0.6485**	0.3041	0.0389	-0.9736***	0.2925	-0.1133***
Center west	0.011	-0.3772	0.2695	-0.079**	-0.032	0.2538	0.068**
North east	-0.0362**	1.1567***	0.4149	0.2186***	0.2934	0.4082	-0.1824***
North	-0.0105	0.4677	0.3505	0.132***	-0.0824	0.338	-0.1215***
West	-0.0124	0.1498	0.3543	-0.0153	0.2402	0.336	0.0277
South	0.0709***	-1.1822***	0.2427	-0.1307***	-0.6855***	0.2267	0.0598*
South west	-0.0223	-0.5355*	0.3102	-0.2476***	0.7939***	0.2805	0.2699***
Center	0.1824***	-1.0924***	0.2727	0.1256***	-2.1471***	0.2796	-0.308***
Center east	0.0566**	-0.9227***	0.2758	-0.1043***	-0.5179**	0.2565	0.0477

Variables	Safe water source	Ground water type 1			Ground water type 2		
	Margin	Coef.	Std. Err.	Margin	Coef.	Std. Err.	Margin
Intercept	-	0.9909	0.6175	-	30.4569***	0.5966	-

Pseudo R^2 = 0.226 ; Wald chi2(52) = 1235.26 ; Log pseudo likelihood = -1241806.9; *** : significant at 1% ; ** : significant at 5% ; * : significant at 10%; Water source reference = safe drinking water; Margin = marginal effects of multinomial logistic regression

Table 4 : Determinants of annual water fees (Heckman selection model)

Variables	Regression model with log of household water expenditures		Selection model for water expenditures observation	
	Coef.	Std. Err.	Coef.	Std. Err.
Water source (Ref = safe drinking water)				
Ground water type 1	0.1269	0.1055	-0.4262***	0.0684
Ground water type 2	-0.4292**	0.1879	-2.3236***	0.0837
Log of household income	0.02	0.0185	-	-
Poverty status (Ref = not poor)	-0.1683**	0.0666	-0.1863***	0.0536
Household size	0.0418***	0.0097	0.0338***	0.0077
Age of household head	-0.003	0.0019	-	-
Distance to water source (Ref = at home)				
Less than 5 Km	0.0883	0.1012	-	-
More than 5 Km	0.4463***	0.128	-	-
Region of residence (Ref = District of Abidjan)				
Center north	-0.276**	0.1349	1.2444***	0.1275
Center west	-0.825***	0.1654	0.6187***	0.1156
North east	-0.1733	0.1307	0.9978***	0.1188
North	-0.4719***	0.172	-0.1503	0.1486
West	-0.0936	0.1547	-0.081	0.1274
South	-0.1986	0.1284	0.9877***	0.11
South west	-0.102	0.1938	-0.0529	0.1431
Center	-0.1005	0.1332	1.5284***	0.1187
Center east	-0.3583**	0.1442	1.2204***	0.1192
Intercept	9.5992***	0.3011	-0.4397***	0.1139
Rho (residuals correlation term)	0.1275***	0.0349		
Sigma (standard error of regression residual)	1.0118***	0.0448		
Lambda (Inverse Mills Ratio)	0.129***	0.0376		

Censored observations = 72.41% ; Wald chi2(17) = 151.0 ; Log pseudo likelihood = -1313487

*** : significant at 1% ; ** : significant at 5% ; * : significant at 10%;

- **Graphs or diagrams** that were originally composed in Excel, should be linked as an object in the Word file, **and sent as a separate file**. Data should be displayed in greyscale or with patterns rather than colours; they should be in 2-D. Graphs and line images should be referred to as 'Figure' and numbered consecutively.

Figure 2 : Accessibility rate (in %) by region

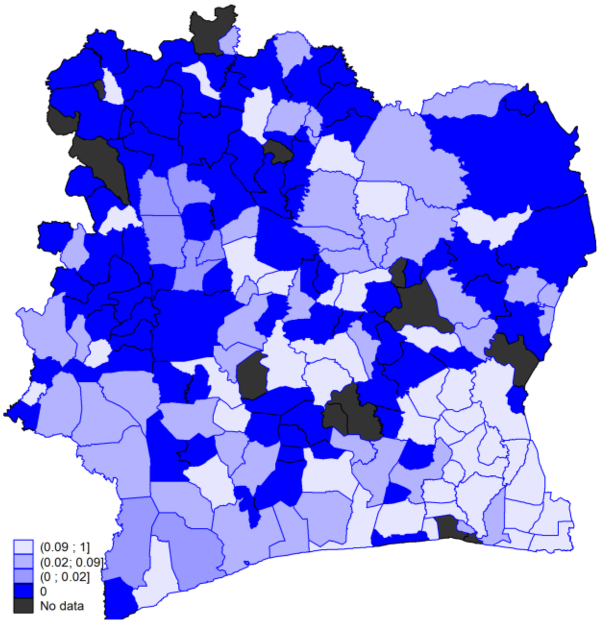

Figure 2 : Annual water expenditures (in x1000 XOF) per region