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Ecological Sanitation and Health Capital: Impact of the Adoption of ECOSAN Toilets on the Health Costs of Households in Rural Areas in West-Central Cote d'Ivoire

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Abstract: The inadequacy of sanitation in developing countries has effets on the health capital and the living conditions of populations. The objective of this work was to assess the impact of access to ecological sanitation on the health expenditure of rural households. This study took place in west-central Cote d'Ivoire in ten villages in the Bouafle department during the implementation of the water supply and sanitation program for the millennium (PHAM). First, a descriptive statistical analysis was carried out to determine the socio-economic, environmental and health characteristics. Then the econometric analysis was carried out using a multiple linear regression of health expenditure linked to water-borne diseases on the age of the head of household, the provision of ecological sanitation toilets, and the household income per capita. Then finally, we used the double difference method to determine the impact of that program on health expenditure. The results showed that the prevalence of water-borne diseases and health expenditures saw a considerable drop thanks to PHAM. For the econometric results, we note that the advanced age of household heads increases health costs. Then also, a significant reduction in health expenditure linked to water-borne diseases is obtained thanks to the use of ecological toilets by households. This result is corroborated by the difference-in-differences method. This form of sanitation should be encouraged in developing countries for the eradication of water-borne diseases as well as the reduction in health expenses of rural households.

Keywords: Ecological Sanitation, Health Expenditure, Households, Cote d'Ivoire

1. Introduction

There are links between economic growth and health as a component of human capital [2]. Health is important for human capital, in the sense that investments in health have direct effects on productivity per unit of time, and thus on economic growth. Healthier individuals can, with additional capital and land, become more productive. They can work more intensively and more efficiently.

The World Health Organization (WHO) estimates that 24% of the global burden of disease and 23% of mortality are due to environmental factors [63, 64]. This global burden of disease is unevenly distributed, and much higher in developing countries [20]. Although environmental threats affect all ages, children are more vulnerable than adults, particularly during the first 5 years of life [7, 14].

The Human Development Report describes the damage to health, lost productivity and absenteeism suffered by poor countries as a result of inadequate sanitation [47]. These losses are enormous in the poorest countries. In sub-Saharan Africa, they represent around 5% of GDP, or some USD 28.4 billion a year [53]. The health impact of inadequate sanitation coverage worldwide is particularly acute. WHO estimates that 7% of the world's deaths and 8% of the global burden of disease are due to diseases linked to a lack of sanitation. Several studies have attempted to estimate the costs of poor sanitation in various countries around the world. At global level, a 2012 WHO study estimates the economic losses linked to the absence of quality water and sanitation systems at $260 billion every year, or 1.5% of global GDP (2.9% of GDP for South Asian countries and 4.3% of GDP for sub-Saharan African countries) [26]. Providing adequate sanitation would bring economic benefits, limiting the time spent finding a place to defecate (for people without toilets) and reducing mortality and health costs. Over and above the current economic losses due to poor sanitation, these same studies show that financing sanitation is a highly profitable investment. Worldwide, each EUR invested in sanitation brings a return of 5.5 EUR (8 EUR in East Asia and 2.8 EUR in sub-Saharan Africa), compared with a return of 2 EUR per EUR invested in drinking water. text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

2. Context of the Study

Coverage of basic sanitation facilities in rural areas in the department of Bouafle through the implementation of the component of the water and sanitation program for the millennium, was achieved through the combined approach of Community-Led Total Sanitation (CLTS) for Ecological Sanitation (ECOSAN) in 35 localities of the said department (village, camp). Indeed, the CLTS approach involves encouraging the community to analyze its own sanitation situation, defecation practices and their consequences, thereby sparking collective action aimed at achieving the state of defecation free in the open air, by the construction of latrines by the community without external subsidies and with available local materials [30]. Ecological sanitation results in the use of ecological compost latrines and ECOSAN compost and urine separation latrines [35]. The ECOSAN approach was adopted in response to the Millennium Development Goals (MDGs), developed at the United Nations Millennium Summit in 2000. The aim was to reduce poverty, ensure environmental protection and increasing access to basic needs such as primary education, health care and security of food resources [45]. The objective was to develop an approach adapted to the needs and conditions of the local context [60], which would save water, would not pollute and would return the nutrients released by humans to the soil [65].

3. Literature Review

This review of the literature aims firstly to take stock of environmental policy in Cote d'Ivoire, then to present the interactions between health capital and economic growth, then to make known the links between sanitation and health capital. Finally, to expose the determinants of health spending.

3.1. Inventory of the Environmental Policy in Cote d'Ivoire

Since independence, the political will of the State of Cote d'Ivoire has resulted in the establishment of an environmental governance framework at the legal and institutional level [41].

On a legal level, the Ivorian constitution, in title I, confers on citizens some rights, freedoms and duties. It is for this reason in its article 27, every natural or legal person benefits from a right to a healthy environment as well as a duty to its protection and the promotion of the quality of life, in its article 40 [17]. Added to this are the legislative and regulatory texts which create a favorable legal framework for environmental protection. We can cite for example law n°1996-766 of October 3, 1996 related to the Environmental Code; Decree No. 96-894 of November 8, 1996 determining the rules and procedures applicable to studies related to the environmental impact of development projects; Decree No. 98-19 of January 14, 1998 establishing and organizing the National Environmental Fund, abbreviated FNDE [41].

Also, the State of Cote d'Ivoire, aware of its place and the challenges of environmental problems on a global scale, has made international commitments by ratifying treaties and conventions linked to the environment, for example by adhering to the creation of World Environment Day in 1972 [15] by the United Nations General Assembly. The resolution adopted in 2022 at the United Nations Environment Assembly aimed at developing a binding legal instrument on plastic pollution, including in the marine environment.

Finally, in Cote d'Ivoire there is also a very dynamic institutional framework which constantly adapts to developments taking place in the world in terms of environmental protection. New structures are being created to meet the expectations of international partners, but above all to decisively attack national environmental problems [41].

3.2. Health Capital and Economic Growth

Educational capital has long constituted the preferred indicator of a good part of the economic literature studying the links between human capital and economic growth [34]. Today, the role of health in economic growth is widely accepted in the theoretical and empirical literature, especially since health, as well as education, is the sector which incorporates the main explanatory factors of endogenous growth such as Research & Development, human capital and public spending [5, 6-38].

The empirical literature studying the links between health and growth is quite abundant. Even if some studies highlight a negative or insignificant relationship between health and growth [1], most studies generally conclude that there is a positive and significant impact going from health to growth or vice versa, [31, 32, 40, 51]. Gyimah-Brempong, concludes

that there is a positive and significant link between public health spending and economic growth in African countries [21]. This result is confirmed by Heshmati; River [24, 49, 50], while it is refuted by Hartwig [22] for developed countries.

A widely used method to empirically test the effect of health on growth is to use cross-sectional data and regress the growth rate of real GDP per capita on the initial level of health [13].

In view of the existing literature, we confirm the results of Lorentzen, McMillan and Wacziarg related to the high causal effect of health on growth [39]. These results are in fact corroborated by several microeconomic studies on the consequences of disease eradication, including the work of Bleakley [10, 11] or Bleakley and Lange [12]. Weil, for his part, proposes an innovative approach: having estimated the macroeconomic impact of health improvements observed at the microeconomic level, he maintains that the health effects are insignificant [57]. However, this last analysis favors the impact of health on the productivity of the labor force, ignoring other economic dimensions (investment, fertility, etc.). Ashraf, Lester, Weil analyze in this regard the channels through which the reduction in mortality has an impact on GDP per capita, and carry out a simulation of the resulting income growth [4].

In recent years, economists have supported the theory that poor health leads to poverty, and they have demonstrated that poor health has a negative effect on households' income and economic growth rate [5]. Poor health would reduce the ability of households to earn income and accumulate wealth by limiting work opportunities, increasing medical expenses and reducing savings [40].

Additionally, economists, particularly those who advocate the theory of sustainable economic growth, increasingly recognize health as a type of human capital. As a result, better health increases the productivity of other types of capital and contributes to economic growth. Healthier children have higher school attendance rates and better cognitive development, which translate into higher rates of return on investments in education and make these investments more attractive [58].

Health status affects the behavior of individuals at the microeconomic level through four main channels: labor supply, productivity, human capital and saving behavior [33]. Indeed, several studies have revealed that poor health reduces labor market participation [18, 46], as does mobility and professional transitions. In addition, the health status affects the duration of work through absenteeism, as well as early withdrawal from the labor market [37]. Poor health implies lower work productivity which prevents the worker from fully using their intellectual and/or physical production capacity [56].

To establish the relationship between health and productivity, indirect measures are used; that is why microeconomic studies generally use salary as an indicator for productivity. The empirical results, even if they remain fragile, most often conclude that the health status has a positive effect on the wage rate [3] and by extension on productivity at the individual level. The positive relationship between health status and human capital is mainly based on health status during the period of initial training; that is to say during childhood. The better the health status of the children, the higher the attendance of students and the lower the number of early exits from the school system. In addition, better health leads to longer life expectancy, which positively influences the return on education and therefore the incentives to invest in human capital. Ultimately, from a theoretical point of view, we do have a positive relationship between the health status and the level of human capital in the economy and therefore long-term growth. However, from an empirical point of view, the results are very mixed. If the strong correlation between human capital and health does exist, the literature suggests that it could be mainly explained by causality going from education to health. An improvement in life expectancy increases the incentive for individuals to save. Indeed, the longer their retirement period, the more they will be encouraged to save in order to benefit from a greater income. The increase in longevity therefore theoretically has effects on the agents' propensity to save throughout their life cycle and ultimately promotes investment and growth. However, the relationship between health and savings has not been studied enough empirically. Some studies have been able to confirm this relationship for developing countries [55].

3.3. Sanitation and Health Capital

The lack of sanitation has an impact on the health and living conditions of populations. To this end, the WHO estimates that 7% of deaths worldwide and 8% of the global burden of disease are due to diseases linked to a lack of sanitation [64]. With this same perspective, studies have been carried out to establish the effect of access to drinking water, sanitation, and hygiene (WASH) on the health of students in schools in developing countries. Thus, scientific work carried out by the Higher Institute of Population Sciences (ISSP) of Joseph Ki-Zerbo University revealed that WASH programs in schools in Burkina Faso have had a positive impact on the health of students, with a reduction in diarrheal diseases and other hygiene-related infections [29]. Also, as part of the evaluation of a WASH intervention in schools in Mali, Trinies et al. [57], also found lower levels of reported diarrheal episodes and symptoms of respiratory infections in intervention schools than comparison schools (control group). Furthermore, in another study conducted in Mali, Freeman et al. [19] show that the availability of a sanitation service at school, quality water and improved hygiene contributed to the reduction of reinfection with certain parasitic worms (helminthes) transmitted by the ground.

3.4. Determinants of Health Expenditure

The economic literature traces some main sources of determinants of health spending. These are income, demographic factors of the country's health care structure; non-medical factors of health; social characteristics and health status.

Individual healthcare expenditure generally increases with age, and this growth accelerates from the age of 60 for hospital expenditure and from the age of 50 for outpatient expenditure, notably medication expenditure [48].

4. Material and Methods

4.1. Study Area

This research took place in the Bouafle department, located in the west center of Cote d'Ivoire in the Marahoue region of which it is the capital, with an area of 4214.5 km2 [16]. It is located 60 km from the autonomous district of Yamoussoukro, the political and administrative capital and 310 km from Abidjan, the economic capital. Bouafle is limited to the east by Yamoussoukro, to the west by the department of Daloa, to the north by the department of Zuenoula, to the south by the department of Sinfra [16]. The relief is composed of low plateaus with some lowlands and hills with an average altitude of 260 meters. The hydrographic network is made up of the Marahoue or Red Bandama River which crosses the department from North to South, rivers and lakes. The climate of Bouafle is the Baoule type. It has two rainy seasons and two dry seasons. The average temperature is 25.30°celsius and precipitation varies from 1800 to 2000 mm [16]. The population of the Bouafle department amounts to 300,305 inhabitants including 161,857 men and 138,448 women with an average population density of 71.26 inhabitants/km² [42].

4.2. Justification of the CLTS-ECOSAN Approach

The CLTS approach involves encouraging the community to analyze its own sanitation situation, defecation practices and their consequences, thereby sparking collective action to achieve ODF (open air defecation free) status [30]. This approach creates a need for toiletries. This is how an alternative is presented to the community to equip itself with urine-diverting dry toilets to make up for the lack of basic sanitation facilities. The latter is called the ECOSAN approach.

The unit of statistical analysis in our study is the household. A household is considered to be all the people who usually share the same accommodation and who have a common budget.

4.3. Study Population

The study population is all rural households residing in the Bouafle department which benefited from the CLTS-ECOSAN approach of the Millennium Water and Sanitation Program with the approach.

1) Inclusion criteria
   a. Households residing for at least 6 months in a village where the CLTS-ECOSAN approach took place.
   b. Households having actually used TSDU in the village where the CLTS-ECOSAN approach took place.
   c. Household having actually used the traditional latrine (endogenous latrine).
   d. Households residing in a village that has achieved ODF status.
2) Non-inclusion criteria
   a. Households not benefiting from the CLTS-ECOSAN approach.
   b. Households that did not give consent for the study.
   c. Households not residing in a village that has achieved ODF status.

4.4. Type and Duration of the Study

This is a longitudinal study with an analytical aim, which took place over the period from October 2013 to December 2016. The first pre-project survey took place from January 5, 2014 to January 31, 2014 to the inventory of the socio-economic and health characteristics of households and the second post-project survey from January 5, 2017 to February 25, 2017.

4.5. Specification of Variables and Data Sources

The study variables are presented in the table below:

Table 1. *Description of the variables in the study of the relationship between sanitation and health.*

Variables	Designation	Modalities
Sex	Sex	Woman Man
Occupation	Occupation	Agriculture Service
Marital status	Marital status	Single Couple Widow (er)
Level of study	Level of study	Unschooled Primary Secondary or higher
Housing	Type of housing	Cement brick Earth brick Clay
Lighting source	Lighting type	Others (Oil, Candle, Battery) Solar plate Energy CIE
Place of defecation	Place of defecation	Latrine Nature

Variables	Designation	Modalities
Prevalence of Waterborne diseases	Prevalence of Waterborne diseases	Number of cases
Average income per person	Average income per person	amount (CFA franc)
Health Expenditure (AHE)	Average health expenditure linked to lack of sanitation, hygiene and drinking water (Consultation, hospitalization, treatment)	amount (CFA franc)
Endowment in TSDU	Endowment in TSDU, it is a dichotomous qualitative variable.	Absence of TSDU Endowment in TSDU
Drinking water supply	Drinking water supply, it is a qualitative variable	Watercourse (River, River, Dam, Lakes) Well water PMH

4.6. Sample Size

4.6.1. Econometric Study

Depending on the inclusion criteria defined, ten localities (village, camp) were targeted as part of our study. Following the population census in these localities, we carried out a census of 425 households residing in each locality for all 10 villages while respecting the inclusion criteria. The sample size increased by 10% was obtained by the following formula:

$$n = N/ (1+Ne^2) \quad (1)$$

with N = size of the population and e = level of precision estimated at 5%

n = 425 / (1 + 425 x 0.05 x 0.05) = 227 households.

The 227 households in the sample were distributed proportionally to the respective weight of each locality over all 10 localities by the following formula:

n'i= n * Pi, with:

n: sample size (n= 227)

Pi: The weight of locality i in terms of household, with Pi= ni / N

ni: the number of households in village i

n'i: the number of households surveyed in village i

N: total number of households in the study (N= 425)

Thus, the number of respective households surveyed per village is distributed as follows:

Table 2. *Distribution of the sample by locality.*

N°	Locality	Household size (ni)	Weight of locality (%) (Pi)	Sample size (n'_i)
1	Adamakro	44	10	23
2	Broukro	66	15	34
3	Issakro	76	18	40
4	Kayegue	39	9	21
5	Konaliyaokro	36	8	18
6	Kouakoublekro	42	10	23
7	Kouamekouassikro	33	8	18
8	Salifoukro	28	7	16
9	Sinfla	28	7	16
10	Yobouekro	33	8	18
Total		425	100%	227

Source: Author

4.6.2. Impact Study of the Ecological Sanitation Program

To evaluate the results of the ecological sanitation program on heads of households, we carried out a before and after study over the defined study period. The sample size calculation for this study was based on the latrinization rate in the Marahoue region estimated at 25% [27].

To demonstrate a minimum OR (Odds Ratio) equal to 3, with a power of 80% and a confidence level of 99% (two-sided test), the sample size must be 94 households for each of the two groups according to the Epi Info calculation tool (version 7.1), according to the Fleiss formula. Thus, an experimental group (94 households) with the same characteristics as the control group (94 households) without TSDU was chosen.

4.7. Data Collection

It concerns data collected from rural households during the implementation of PHAM in Cote d'Ivoire in the department of Bouafle. To collect data, we carried out two household surveys using a questionnaire with heads of households or representatives before and after the project.

A pre-survey was carried out from December 10 to 11, 2013 among 20 heads of households in the village of Adamakro, in the study area in order to test the questionnaire, correct all errors and ambiguity. This pre-survey allowed the investigators to familiarize themselves with the different questions, have a common understanding of the questionnaire and understand the survey methodology.

The households to be surveyed were randomly selected in order to respect the principle of independence of the choice of households to be surveyed in relation to the interviewer through a systematic random sampling with a sampling interval of 2 households [23, 52]. In the household, the person interviewed was the head of household, represented by the father or mother. If during the survey these people were absent, the questionnaire was administered to an adult person in the household whose age is greater than or equal to 18 years and who has lived at least six (06) months in the household. If the people in the household were all underage (age < 18 years) or if the household did not consent, it was replaced by another household in accordance with the defined methodology.

Accompanied by a translator, the information collected concerns socio-economic characteristics, health expenditure incurred by households linked to the deficit in drinking water, hygiene and sanitation. The interview lasted on average 20 minutes per household and the different responses of the respondents are recorded on the questionnaire form.

4.8. Data Processing and Analysis

The data collected and entered related to socio-economic characteristics, health expenditure incurred by households, and the deficit in drinking water, hygiene and sanitation.

Statistical analyzes of these data were carried out with SPSS and STATA software.

The descriptive statistical analysis was carried out in order to know the profile of the population, to compare and verify the homogeneity of the two groups monitored in the case of the impact study.

4.8.1. Econometric Modeling by Linear Regression

The specification of the econometric model is as follows:

$$\ln y_i = \beta_0+\beta_1 x_{1i}+\beta_2 x_{2i}+\beta_3 \ln x_{3i}+\beta_4 x_{4i}+\beta_5 x_{5i}+\beta_6 \ln x_{6i}+\mu_i \quad (2)$$

With the endogenous variable "The health expenditure of household i linked to waterborne diseases" (y_i), and x_i the exogenous variables which are:

x_{1i}: Marital status of the head of household $_i$;

x_{2i}: Level of study of the head of household $_i$;

x_{3i}: Age of the head of household $_i$;

x_{4i}: Adoption of the TSDU in household $_i$;

x_{5i}: The source of drinking water supply of household $_i$;

x_{6i}: The annual household income per person in household $_i$.

β_0, β_1, β_3, β_4, β_5, β_6 are coefficients of the model to be estimated and μ_i is the error term.

4.8.2. Double Difference Method for Impact Study

Two population groups were compared before and after the implementation of PHAM to assess the causal effect of the ecological sanitation program (Ecosan). To avoid any selection or counterfactual bias, three conditions must be met: first the control group must be identical to the experimental group (socioeconomic characteristics are on average similar), then the two groups must react in the same way. Manner in the presence of the sanitation program, that is to say the prevalence of water-borne diseases or the health expenditure inherent to the lack of sanitation of the units of the treatment group must potentially decrease following a sanitation program. sanitation to the same extent as that of the units in the comparison group if they had also received the program, finally, the treatment and comparison groups should not be differentially exposed to other interventions during the period devaluation.

The study of the impact of the TSDU allocation on health expenditure linked to the lack of sanitation was carried out using the double difference method. This method compares differences in outcomes over time between a population participating in a program and one not participating. In this study, the group that did not use TSDU with productive sanitation by-products is the comparison group. Thus, the adoption of productive sanitation is considered an indicator of reduction in health expenditure. The double difference method calculates the estimated impact according to the following steps: First we calculate the difference in result (Y) between the situation before and after for the treatment group. Next, we calculate the difference in outcome (Y) between the situation before and after for the comparison group. Finally, we calculate the difference between the difference in outcomes for the treatment group and the difference for the comparison group. Finally, the use of the contingency table allowed us to estimate the odds ratio between the two study groups before and after the project. The chi-square test was significant at the 5% level.

4.9. Ethical and Administrative Considerations

To carry out this study, a research authorization signed by the Doctoral School was obtained. This authorization was presented to the prefectural body and to the Departmental Director of Health of the Bouafle department. The various village chiefdoms of the Bouafle department were informed.

During the survey, each household was informed of the purpose of this study as well as the free and voluntary nature of their participation. Written informed consent was obtained from the different household heads before answering the questions. All those surveyed were reassured that the information collected in this study will remain anonymous and strictly confidential.

5. Results

5.1. Econometric Analysis of the Effect of the Ecological Sanitation Program on Households' Health Expenditure

The results of the multiple regression are presented in Table 3.

The explanatory variables (age of the head of household, Adoption of TSDU,) have P-values respectively equal to: 0.000; 0.001. They are all below the significance threshold of 5%, therefore the variable of interest "Ln (Expenditure on waterborne diseases) is statistically associated at the 5% threshold with these exogenous variables.

The age of the head of household is a factor that positively influences the costs of treating water-borne diseases. Indeed, the older the age of the head of household, the more the household is exposed to the risks of contracting waterborne diseases and consequently the expenditure linked to these diseases increases. A one-year increase in the head of household increases household spending on health per capita by 5 times.

The use of TSDU in households makes it possible to significantly reduce health expenditure linked to waterborne diseases by 1.12 times.

Table 3. *Multiple regression of health expenditure on exogenous variables.*

LnYi (Health Expenditure / inhabitant)	Coef	t	IC (95%)	P-value	Sig.
Marital Status	-0,19	-0,63	[-0,77; 0,40]	0,527	
Age of the head of household	5,11	4,99	[3,09; 7,13]	0.000	***
Level of study	-0,06	-0,25	[-0,57; 0,44]	0,806	
TSDU Adoption	-1,17	-3,26	[-1,87; -0,46]	0,001	***
Drinking water supply	-0,34	-1,02	[-0,99; 0,32]	0,307	

LnYi (Health Expenditure / inhabitant)	Coef	t	IC (95%)	P-value	Sig.
Income/inhabitant	-0,054	-0,18	[-0,64; 0,53]	0,858	
Constant	-15,64	-2,89	[-26,29; -4,98]	0,004	***

Source: According to the author's calculations, *** p<0.01

The supply of drinking water from protected water sources, household income per capita, level of education and marital status have a reducing effect on health expenditure linked to water-borne diseases. However, the variable of interest "The health expenditure of household i linked to water-borne diseases" is not statistically associated at the 5% threshold with these "the source of drinking water supply" variables.

5.2. Impact Study of Ecological Toilets on Health Expenditure Linked to Waterborne Diseases

5.2.1. Characteristics of ECOSAN Beneficiaries and Non-Beneficiaries

Considering the characteristics of the two study groups presented in Table 4, there is a similarity between the experimental group and the control group. Indeed, according to the analysis of the standard deviation of the different modalities of the following variables: sex, occupation, marital status, level of study, type of housing, source of lighting, location household defecation rate, prevalence of waterborne disease and average income per person there is little variation between the control group and the experiment group. Thus, the basic conditions necessary to compare these two groups at the start and end of execution of the sanitation program are established.

Before the implementation of PHAM, we carried out the descriptive study on two groups of households; a treated group composed of households benefiting from ECOSAN-type toilets and a group not benefiting from this type of work. According to Table 4, the two groups studied had similar characteristics for each of the variables.

Table 4. *Characteristics of the study population.*

Variables	Designation	Control group (%)	Experiment group (%)	Standard deviation
Sex	Women	2%	3%	0,0075
	Man	98%	97%	0,0075
Occupation	Agriculture	99%	100%	0,0075
	Service	1%	0%	0,0075
Marital Status	Bachelor	2%	3%	0,0075
	Couple	96%	96%	0,0000
	Widow (er)	2%	1%	0,0075
Level of study	Unschooled	53%	62%	0,0601
	Primary	38%	27%	0,0827
	Secondary or higher	9%	12%	0,0225
Accommodation	Cement brick	1%	1%	0,0000
	Earth brick	76%	84%	0,0600
	Clay	23%	15%	0,0600
Lighting source	Others (Oil, Candle, Battery)	47%	46%	0,0075
	Solar plate	53%	54%	0,0075
Place of defecation	Latrine	17%	14%	0,0225
	Nature	83%	86%	0,0225
Prevalence of Waterborne Diseases	Number of cases of waterborne disease	96	89	4,9497
Average health expenditure of household i linked to waterborne diseases	In monetary unit (CFA franc)	9095	9410	315
		49%	51%	1,2036
Average daily income per person	In monetary unit (CFA franc)	356	360	2,2928
		49,72%	50,28%	0,3950

Source: According to our calculations

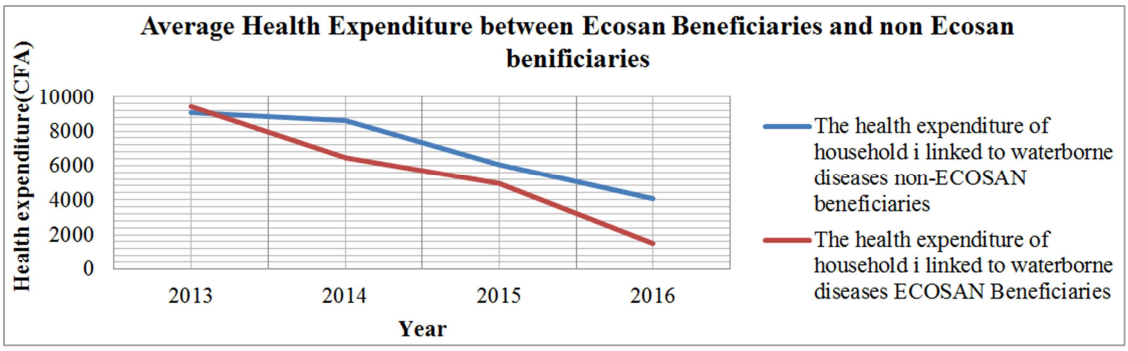

Figure 1. *Average Health Expenditure linked to lack of sanitation, hygiene and drinking water.*

5.2.2. Evolution of Household Health Expenditure in the Groups Studied

Both population groups have certainly benefited from the sanitation program, namely the implementation of the CLTS approach for a change in behavior with a view to adopting good hygiene practices, treatment of drinking water and improved toilet usage. However, households benefiting from the ECOSAN program (the experimental group) recorded a sharp drop in health spending as shown in Figure 1.

5.2.3. Difference in Outcome (Y) Between the Situation Before and After for the Treatment Group and for the Comparison Group

To assess the impact of ecological sanitation on health expenditure linked to water-borne diseases, we applied the difference-in-differences method on the two types of households. The results are presented in Table 5 below.

We observe a drop in average health expenditure linked to the lack of sanitation among both TSDU beneficiaries and non-beneficiaries. However, there was a sharp drop in health spending for the experimental group.

Indeed, the result of the double difference is -2875, which reflects a positive impact of the ecological sanitation program on the beneficiary group in terms of reduced health expenditure.

In the treatment group, health expenditure increases from 9410 CFA franc before the project to 1532 CFA franc after the project. The difference in health spending before and after the project is significant (p = 0.000). Productive sanitation is a protective factor because OR = 0.36 (0.34-0.39). This means that households with a TSDU are practically 3 (1/OR) times less likely to incur health expenses linked to lack of sanitation.

Table 5. *Impact of ecological sanitation on health expenditure linked to waterborne diseases.*

Population group	Before year 2013	After year 2017	Difference	OR (IC95%)	χ^2	P-value
Participants	9410	1532	-7878	0,36 (0,34-0,39).	970,17	0,000
Non-participants	9095	4092	-5003			
Difference	315	-2560	-2875			

Source: According to our calculations

6. Discussion

Sustainable human development is a great challenge that humanity must achieve by achieving the SDGs by 2030 [28]. These objectives are interdependent. It is for this reason that the issue of water, sanitation and hygiene is also linked explicitly or indirectly to all the other SDGs. Indeed, sanitation is essential for health, child development and socioeconomic progress [44]. Poor sanitation conditions cause illness and death, which can result in significant financial costs: unreimbursed expenses and travel costs for households seeking health care; implicit government subsidies in health care provision; loss of income due to illness; loss of productivity linked to time spent searching for a place to defecate in the open air [44]. Our study revealed that lack of sanitation has a cost on the health of rural households. This situation is reflected by the high amount of health costs linked to water-borne diseases observed at the start of the PHAM compared to those at the end phase of the project where the communities managed to have a clean, healthy, hygienic and clean-living environment., and to practice hand washing. The CLTS-EcoSan approach therefore enabled households to increase their health capabilities. Access to the functionalities that are: training in healthy living, drinking water, hand washing, household waste management, and the use of EcoSan latrines in rural areas, helps to reduce vulnerability, poverty and household inequalities. Amartya Sen expresses the capabilities of man as his possibility of achieving his well-being and of acting [54]. Rural households now have the opportunity through TSDU to satisfy their needs while respecting their dignity during their existence.

The urine diversion dry toilet in its design as an ecological toilet meets the criteria for an improved toilet. It has a positive impact on coverage of improved sanitation facilities [36]. Thus, households with TSDU are no longer in direct contact with their excreta, they are less exposed to water-borne diseases and consequently health expenditure linked to these diseases will decrease. The work of WHO clearly shows that an improved sanitation system has positive effects on reducing health expenditure, i.e., a gain of 2% [61]. This explains the negative sign of the coefficient of the explanatory variable "TSDU endowment" in the econometric regression. This result is also reinforced by the study of the impact of TSDU on health expenditure linked to water-borne diseases using the double difference method.

This method reveals a reduction in health expenditure linked to water-borne diseases of 2875 CFA francs. Academic work has demonstrated that any sanitation system that puts an end to the practice of defecation in nature generates an improvement in the living conditions and health of populations [44]. For the sub-Saharan African region, a dollar invested in the water sector would yield $2.8 in net economic benefits compared to $6.6 for a dollar invested in the sanitation sector [25]. In recent years, economists have supported the theory that poor health leads to poverty, and they have demonstrated that poor health has a negative effect on households' income and economic growth rate [5]. Poor health would reduce the ability of households to earn income and accumulate wealth by limiting work opportunities, increasing medical expenses and reducing savings [9].

With regard to the experimental study between the two groups, our results showed that households which have a TSDU have practically 3 (1/OR) times less risk of incurring

health expenses linked to lack of sanitation. This could be explained by the effectiveness of EcoSan technology in breaking the cycle of transmission of diseases contained in human excreta (Beaudry P. L., 2011) [8]. This could also be due to the use of sanitation by-products such as organic fertilizers which would increase the agricultural productivity of farmers, and thus their income [66]. Also, TSDU offer numerous environmental, economic and social advantages. Ecological toilets prevent contamination of groundwater, which helps destroy and isolate pathogens found in feces [65].

Finally, age is a determining factor in the evolution of health spending. Indeed, as the population ages, this has consequences for the health care system. Age contributes to increasing medical treatment costs, because it is at the end of life that health expenses are heaviest [43].

7. Conclusion

Our research shows that the age of households in terms of aging leads to an increase in the cost of treatment linked to water-borne diseases. We also note the positive effect of the ecological sanitation program on the health of rural households in terms of reduction of expenses (consultation, care and hospitalization costs). Improved sanitation therefore leads to a saving of household resources in terms of a reduction in health expenses inherent to water-borne diseases and consequently, reduces the poverty of rural populations. TSDUs are an innovation in the implementation of sanitation programs with a view to improving the living environment and the living conditions of populations. By participating in the fight against water-borne diseases and reducing health expenses, EcoSan technology contributes to increasing the capabilities of rural households in terms of expanding the functionalities of each household.

It would be appropriate for public authorities to implement ECOSAN programs in several rural areas in order to contribute to improving the living conditions of the most disadvantaged, that is to say, increasing the capabilities of the poor in order to reduce poverty. prevalence of diseases linked to water and lack of hygiene, which results in a reduction in health spending.

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Conflicts of Interest

The authors have no conflicts of interest to declare.

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