

Impact of Adoption Adaptation Climate Change on Household Food Security and Incomes in Ferlo Semi-arid Area, Northern Senegal.

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Abstract

Pastoral communities in Ferlo semi-arid zone are faced with several climate change related threats to their food security and well being. To deal with the climate-change related threats, many adaptation strategies have been promoted widely for adoption by livestock owners in the Ferlo. This study aims to evaluate the impact of adoption adaptation strategies on household food security and income. Data come from a random sampling of 339 households in 32 villages. To estimate the causal effect of adoption of climate change adaptation strategies on household food security and income, the study used the instrumental variable method. It estimated the Local Average Treatment Effect (LATE) parameter of Imbens and Angrist (1994), which measures the mean impact on the subpopulation whose adoption was induced by the instrument (awareness of at least one adaptation strategy). The treatment variable is adoption of at least one adaptation strategy and outcome variables are household food score consumption and income. The results reveal that on average 56% of household head are aware of at least one adaptation strategy and 94% among those who are aware have adopted at least one adaptation strategy. Furthermore, result showed that adoption of at least one adaptation strategy have a positive and significant impact on food security and income. It increased the average household food score consumption by 8.64 and income by \$1, 213. In addition, household size, herd size and literacy of the household head are other factors that influence food security and income. The political implication scaling up adaptation climate change strategies can be a sustainable solution for fighting against food insecurity and poverty in sahelian zone.

Keywords : Adaptation, climate change, impact, food security, income, Ferlo, Senegal.

1. Introduction

Climate change is recognised as one of the big threat in the world (FAO, 2018 ; UNDESA, 2017 ; UNISDR, 2015). Sub-saharan Africa countries are the most vulnerable due to the lack of financials resource to support adaptation strategies (World Bank, 2018 ; Hallegatte *et al.*, 2017). Like in many arid et semi-arid areas of Sub-saharan african countries pastoral communities in semi-arid Ferlo area of northern Senegal are faced with several climate change threats related to thier food security and well being (Sarr, 2012). Due to they depend on agriculture and livestock production for thier livelihoods, pastoral communities are highly vulnerable to climate change (Di Falco, 2014 ; IPCC, 2014). According to CSE (2010), the main negative climate change effects in semi-arid area of Ferlo are recurrent episodes of drought, desertification, high temperature, water scarcity, etc. In addition to climate change effects, many other factors, such as the rapid increase in human population, declines in cropland fertility and increase in livestock populations have resulted in growing pressure on the natural resources, over-exploitation and degradation in this area (Hilhorst, 2008). Therefore, adaptation climate change are much needed by contributing to the reduction of negative climate change effects (Dickie *et al.*, 2014). In this sense, Government of Senegal have implemented National Adaptation Plan as policy option to reduce the impact of climate change at national level

(MEDD, 2015), as suggested by the COP 21 of Paris Agreement. At local level, many adaptation climate strategies have been widely promoted by many projects. In semi-arid of Ferlo area, PRODAM Project (Agriculture Development Project of Matam) have supported pastoral communities to develop autonomous adaptation to climate change by promoting community based natural resource management for wide adoption. According to Pailler et al. (2015), Riehl et al. (2015) management of natural resource as adaptation option is indispensable for sustainable development and socioeconomic well-being for local communities. In semi-arid Ferlo area, the most important community management of natural resource promoted as adaptation strategy are : prohibition of bush fire, prohibition of tree cutting, restoration of degraded land and forest through land use rotation (livestock and crops), zero grazing, tree planting, etc. Despite the importance of adaptation strategies, there have been limited studies evaluating the adoption of climate change adaptation strategies and their impact in semi-arid area focusing on livestock production. The few existing studies are related on impact of agriculture production adaptation strategies (e.g : Amare and Simane, 2018 ; Ali and Erenstein, 2017 ; Gebrehiwot et Anne Van Der, 2015). To fullfy the existing gap in the empirical literature, this study aims to evaluate the impact of adoption adaptation climate change strategies on food security and income of households pastoral communities in semi-aride Ferlo area in northern Senegal.

2. Materials et methods.

2.1. Study zone

This study was conducted in the semi-arid Ferlo area in northern Senegal. Ferlo is one of the most wide agroecology zone of Senegal. It covers 1/3 of national territory (Fall, 2006) but have less than 10% of the population (ANSD, 2013). The natural vegetation consists of dry grassland with scattered trees and bushes. The herbaceous layer comprises a mix of grasses, leguminous species and other plants. While both annual and perennial species occur in the Ferlo, annual species strongly dominate the herbaceous layer (Hein et al., 2008). Soils are mainly of aeolian origin and are predominantly sandy, with variable but generally small amounts of loam and clay (CSE, 2010). Annual rainfall varies between around 120 and 450 mm, with an average of 291 mm. The rainy season lasts only 3 months, from July to September (Sarr, 2012). With an average population density of around twenty wix people per square kilometer, the total rural population of the Ferlo can be estimated at around 2,086,000 people (ANSD, 2013). Livestock keeping is the main economic activity in the Ferlo and the principal animals kept are cattle (zebu), sheep and goats. According to Mieke (1997) the average livestock densities in the Ferlo are in the order of 0.15–0.20 Tropical Livestock Units per hectare.

Transhumance remains the most common production system among the Fulani (Adriansen and Nielsen, 2002). Families spend the wet season in the Ferlo, with the herds feeding on the green pastures and water being provided by ponds. During the dry season ponds dry out, but water is still provided by the boreholes. Feed resources strongly decline during the dry season, and many of the pastoralists migrate southwards to the more humid Sudan zone, where fallow lands and crop residues provide food for the animals and where more perennial water resources are available (Hein et al., 2008 ; Adriansen and Nielsen 2002). However, since the early 1990s, there has been an expansion of agricultural activities in the Sudan zone, which increasingly limits the possibility for pastoralists to migrate south in the dry season (Guerin et al., 1993 ; Adriansen 2006).



Figure 1: Ferlo zone (CSE, 2012)

2.2. Sampling procedure and data

We use a multi-stage stratified random sampling procedure to select villages and household. In the first stage villages was stratified into villages where the climate change adaptation strategies were promoted and controlled villages where no promotion activity took place. Thirty two villages was randomly selected including sixteen villages adaptation and non adaptation villages for each. Both adaptation villages and no adaptation villages are randomly selected in semi-arid Ferlo within a radius of 50 kilometers to maximise similarity with respect to soil, climate, and infrastructures, economic activities and others factors. During the second stage of sampling, a list of all households in the selected villages was obtained through key informant interviews. Eleven households were randomly selected from each village for a total sample size of 339. The data were collected using village and household questionnaires. Four enumerators with at least ten years experiences have been trained and used to conduct the survey. We used focus group discussions and household survey to collect qualitative and quantitative data, respectively. Data from the focus group were used to complement the information obtained through a household survey in order to have a better understanding of causes of food insecurity, poverty and the causal influence of different adaptation strategies on food security and income. There were 32 focus-group discussions held in all villages of the sample. The focus groups were composed of village cheif, household head, women, young and elders. Quantitative data were collected using household survey comprised the same sets of questions. The dataset consisted of food security variables (total grain produced, total grain purchased, total grain obtained through aid, total crop used for seed, type of food consumed, number of days for which each food consumed during a period of one week, etc.); adaptation options (different rules of management natural resource, livestock pratices, livelihood diversification strategies) ; asset ownership (landholding, livestock ownership); social capital (local institutions/organizations households are membership); and human capital and access to financial capital. The survey also covered data on several factors including households' demographic and socioeconomic characteristics (age, education, gender, and family size), etc.

2.1. Impact estimation method.

The main challenge underlying impact evaluation is the problem of identifying and estimate rigorously the causal effect while controlling bias. For instance, let d refers to the treatment status for a given farmer $d_1 = treated$ and $d_0 = untreated$. For this, every farmer has two potential or counterfactual outcomes, denoted as y_1 for a particular household when $d_1 = 1$, and y_0 otherwise. The causal effect treatment for household i is the difference between its two potential outcomes ($y_{1i} - y_{0i}$). An identification problem arises from the fact that the two potential outcomes cannot be observed simultaneously for any particular household. In reality, we can only observe $y = dy_1 + (1 - d)y_0$. Since we only observe one of the potential outcomes, we cannot measure the treatment effect ($y_{1i} - y_{0i}$) directly. In contexte of adoption, if the adaptation strategies were randomly assigned to farmers, someone could assess the impact of their adoption on households' food security by estimating the Average treatment effect (ATE) ($y_1 - y_0$) by comparing total food consumption scores between adopters and non-adopters. This is based on the assumption that the output levels of the adapters before their adoption can reasonably be approximated by the output level of nonadapters during data collection. However, adaptation options are rarely randomly assigned (Amare and Simane, 2018). Instead, adoption usually occurs through self-selection of farmers or, sometimes, through program placement (Di Falco, 2014). In the presence of self-selection or program placement, the above procedure may result in a biased estimation of the impacts of adaptation strategies since the treated group (the adapters) are less likely to be statistically equivalent to the comparison group (the non-adapters) in a nonrandomized setting (Heckamn and Vytlacil, 2007). In the literature several methods have been designed to address the problem of selection bias. To estimate adaptation strategies on households food security and income most of the studies founded in the literature have adopted the *Propensity Score Matching (PSM)* method (e.g : Riehl et al., 2015 ; Ali and Erenstein, 2017 ; Gebrehiwot et Anne Van Der, 2015). The PSM technique pairs the treatment (adapters) and control (non-adapters) groups based on the similarity of observable characteristics (Ali and Abdulai, 2010). It is based on the conditional independence assumption and the common support condition. But one of the limitation of PSM is it is difficult to know if all relevant factors are included in the estimation model of PSM (Pailler et al., 2015). Further PSM does not account for the unobservable variables, rather, it assumes that selection is based on « observable variables ». Or, in the case of autonomous adaptation, the endogenous decision of adoption a given adaptation strategies by a farmer is the ex-ante subjective valuation by individuals of the anticipated welfare impact which explains the change in their behavior. This fact gives rise to what is called (unobserved) essential heterogeneity in the literature (e.g. Heckman, 2010 ; Heckman et al., 2006 ; Maddision, 2007 ; Kurukulasuriya and Mendelsohn, 2008b ; Di Falco and Veronesi, 2013). The presence of essential heterogeneity rules out the “selection on observables” assumption, which justifies PSM as a strategy for the identification of the average treatment effect (ATE) and the average treatment effect on the treated (ATT) of adaptation climate change on food security and income.

In this study we account for the endogeneity of the adaptation decision and we take “selection on unobservables” to be the natural assumption to make and to use instruments to identify the Local Average Treatment effect (LATE) parameter of Imbens and Angrist (1994), which measures the mean impact on the subpopulation induced to change their behavior by the selected instruments. This is the “Quasi-experimental (instrumental variables)” identification strategy. More precisely, we use the Local Instrumental Variable (LIV) approach (Heckman and Vytlacil, 2007b) to identify LATE. Further we use the Locale Average Response Function (LATE) method of Abadie (2003) to estimate the LATE parameter, whene the population distribution of receipt of the instrument is not random. The study use awareness of at least one adaptation strategy as an instrument to induce the exogenous change in adoption. Past studies

on impact adoption found awareness to be a natural instrument (Di Falco et al., 2013 ; Dibba et al., 2012). The treatment variable is adoption of at least one climate change adaptation strategies. Thus, outcome variables are household food score consumption and incomes. Let d_z represent potential adoption outcomes given a binary instrument z taking the value 1 when a farmer is aware of at least one adaptation strategy and 0 otherwise. Hence, $d_1 = 1$ and $d_0 = 0$ means a particular household will adopt at least adaptation strategy if is exposed, but would not adopt otherwise. In this case, the observed adoption outcome is given by $d = zd_1 + (1 - z)d_0$. Since it is not possible to adopt at least one adaptation strategy without being aware of it, then $0 d_0 = 0$ for all households and then observed adoption outcome can be simplified as $d = zd_1$. Potential adoption in the subpopulation of exposed households is given by $d_1 = 1$ and that of actual adopters is given by $d = 1$. With the potential treatment indicators $d_1 = 1$ and $d_0 = 1$, a population is divided into four groups based on their status of compliance (Imbens & Angrist, 1994): *compliers* (those with $d_1 = 1$ and $d_0 = 1$), *always takers* (those with $d_1 = d_0 = 1$), *never takers* (those with $d_1 = d_0 = 0$) and *defiers* (those with $d_1 = 0$ et $d_0 = 1$). Imbens et Angrist (1994) have given a causal interpretation only to the subpopulation of compliers and used the WALD estimator to estimate the LATE parameter by using a random instrument z , treatment status variable d and the observed outcome variable y :

$$E(y_1 - y_0 | d_1 = 1) = \frac{E(y|z = 1) - E(y|z = 0)}{E(d|z = 1) - E(d|z = 0)} \quad (4)$$

However, in case of adaptation to climate change, the population distribution of receipt of the instrument is rarely random. Therefore, we use the LARF estimator of Abadie (2003) in the situations where there is no random instrument. The model is given by the equation below :

$$f(x, 1) - f(x, 0) = E(y_1 - y_0 | x, d_1 = 1) \quad (5)$$

$$E(g(y, d, x) | d_1 = 1) = \frac{1}{P(d_1 = 1)} E(k \cdot g(y, d, x)) \quad (6)$$

where $k = 1 - \frac{z}{p(z=1|x)}(1 - d)$ is a weight function used to identify the sub-population of potential adopters.

2.2. Calculation Food Consumption Score.

The different food items recorded in each household are grouped into six food groups : cereals and tubers, pulses, vegetables, fruits, meat and fish, and milk. Due to the lack of data on the remaining three food groups proposed by the WFP (2008), sugar, oil, and condiments are not considered. Each food group is given a weight based on the nutrient content of that particular food group. The frequencies of food consumption are determined by considering the number of days for which each food group has been consumed in a household during a period of one week. The following equation is used to generate the food consumption score :

$$SCA = \sum_{i=1}^n a_i X_i \quad (7)$$

where FCS = Food Consumption Score, n = total number of food groups, a_i = number of days for which each food group is consumed in a household during a period of one week, and x_i = weight of each food group.

2.3. Calculation household income

Direct measurement of income can be laborious and complex. In this study, we use a measure of household cash income: annual total income. To do this, we asked each household to list the different sources of income and for each source to estimate the annual income obtained by the household. This is a way to improve income data. To estimate total household income, the following equation was used:

$$Y_i = \sum y_{i,k} \quad (8),$$

where Y_i = global income for a given household $i=1, \dots, n$

$y_{i,k}$ = Annual income by source income.

3. Results and discussions

3.1. Descriptive analysis

3.1.1. Socio-demographic characteristics of households.

Table 1 presents descriptive statistics of key socio-demographic characteristics of households by adoption status. Results reveals that the average age of the head of household is 45 years. The average household size is 16 and is above the national average of 10. In the area, the heads of households are majority Fulani, married and male. This result reflects the reality of the country in general and the area in particular, which because of tradition, religion, the man is facto, the head of household. Only 4% of heads of households are in school. However, 37% of them are literate with a positive and significant statistical difference. In the area, 44% of households live in straw huts, 40% in concrete buildings and 15% others. On average, the herd size is 155 head and the area per household is 3.29ha. On average 55% of heads of households own a mobile phone.

Table 1 : Socio-demographic characteristics of household

Variables	Adopters	Non-adopters	Total	Difference test
Number observations	163	176	339	
Age (Ans)	48 (0.99)	43 (1.05)	45 (0.73)	5***
household size	17 (7.3)	16 (5.87)	16 (6.7)	0.9
Male (%)	96 (20)	94 (24)	95 (22)	1.58
Fulani (%)	99 (11)	91 (29)	95 (22)	8***
Married (%)	97 (18)	96 (18)	96 (18)	0.2
Education (%)	6 (24)	1 (11)	4 (19)	5*
Literacy (%)	66 (47)	6 (22)	37 (48)	60***
Strow box (%)	22 (42)	68 (46)	44 (49)	-45***
Concrete bulding (%)	54 (49)	25 (43)	40 (49)	29***
livestock size	103 (134)	199 (167)	150 (158)	-96***
Land area (ha)	3.98 (4.61)	2.55 (2.17)	3.29 (3.71)	1.43***

Note : Means are shown with robust standard errors in parenthesis : * $P<0.10$, ** $P<0.05$, and *** $P<0.01$.

3.1.2. Identification Identifying impact based on observed differences

Figure 1 seeks to measure the association between adoption adaptation strategies and household food security by comparing the proportion of households that fall under three different food security groups by adoption status. The results indicate that only 2% and 2.9% of households adopters at least one adaptation strategy respectively are severely food insecure. About 3% of non-adopters are moderately food security compared to 8.1% of adopters. Moreover, 95% of adopters are food secure compared to 85% of non-adopters. The difference in percentage between the two groups is statically different from zero at 1% significance level, which suggest that adoption adaptation strategy is positively correlated with household food security.

Nonetheless, this simple comparison of food security outcomes between households adopters and non-adopters does not have any causal interpretation of the impact adoption adaptation strategy on household food security. Besides adoption adaptation, there are several other factors that may explain the difference in the food security status between adopters and non-adopters. Such differences must be accounted for to identify causal effects of adoption adaptation on household food security.

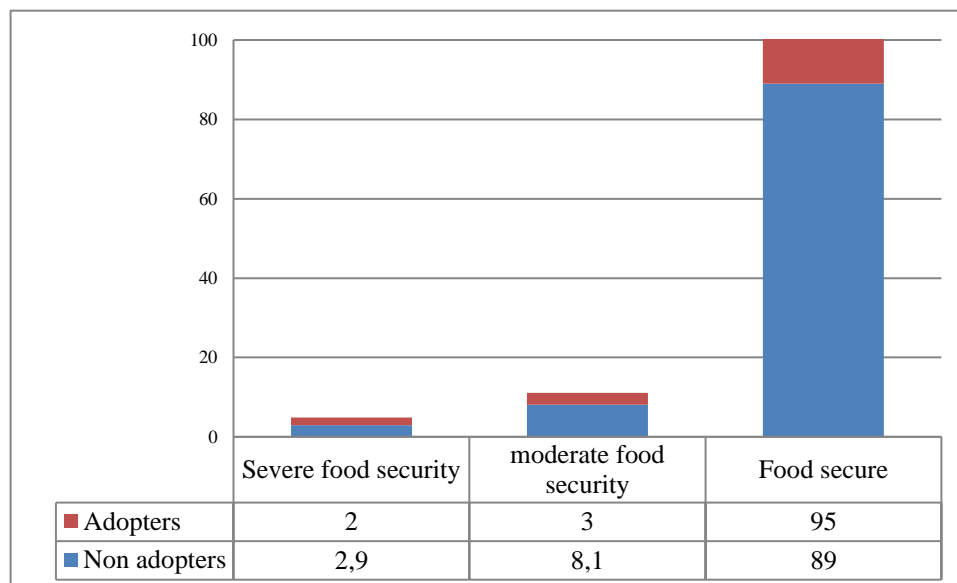


Figure 1 : Household food security by adoption status

Table 2 compares mean differences in food consumption score and the annual household income between adopters and non-adopters. The results show that adopters have an average food consumption score significantly higher than non-adopters. The mean difference in food consumption score is estimated to be 3.07, which is statistically different from zero at the 1% significance level. Moreover, the results reveal that adopters have a significantly higher annual income than non-adopters household. The mean difference is estimated to be 668.77 USD¹, which is statistically significant at 1% significance level. However, these results are merely descriptive and have no causal interpretation of the impact of adoption adaptation strategy on food security and income.

Table 2 : Identifying impacts using mean differences in outcome by adoption status

Caracteristics	Adopters	Non adopters	Total	Difference test
Numbers observations	159	180	339	
Average Food Consumption Score	76.65 (1.54)	73.58 (1.74)	75.21 (1.16)	3.07***
Average Annual Income (USD)	2 381.93 (210.24)	1 713.15 (143.19)	2 068.26 (131.35)	668.77****

Note: Means are shown with robust standard errors in parenthesis. *** $P < 0.01$ and **** $P < 0.001$.

¹ change 1 USD to Franc CFA (UEMOA) : 1 USD = 560,91068 XOF in june 30, 2018

3.2. Econometric analysis

3.2.1. Impact of adoption adaptation strategies on household food security.

Table 3 presents the estimates of the impact of adoption at least one adaptation strategy on household food consumption score. The LATE estimate based on Local Average Response Function (LARF) interacted with covariates shows that adoption of at least one adaptation strategy have a positive and significant impact on household food security. It increase the average household food consumption score by 8.48 with is statistically different from zero at the 0.1% significance level. The LATE estimates based on the Wald estimator have not shown any significant impact on household food security due to it is based on the assumption that the instrument variable (awareness of at least one adaptation strategy) is randomly distributed in the population, that is not exact in this case. The positive and significant impact implies that adoption of adaptation strategy has a causal influence on household food security status. This indicates that the return to investment in management natural resource (prohibition bush fire, tree cutting, restoration degraded land and forest) each does generate reliable results, especially in areas where climate change and variability adversely affects livestock production which is considered as the main livelihood option of the households. This reaffirms the narrative from the results of the focus-group discussions in which not adopting adaptation strategies undermines the prospect of food security. This is consistent with the secondary literature that shows a positive effect of adoption adaptation strategy on food security (Amare and Simane, 2018 ; Ali and Erenstein, 2017 ; Paillet et al., 2015 ; Magrini and Vigani, 2014).

Tableau 3 : Impact of adoption adaptation on food security with LATE

Caracteristics	Food Consumption Score
Number of observations	339
LATE estimate based on WALD estimator	3.36 (280)
LATE estimate based on LARF estimator with interaction	8.46 (0.0006) ****

Robust standard errors are shown in parenthesis. **** $P < 0.001$.

The exponential LARF coefficient estimates of the determinants of food security with interaction are presented in Table 4. Besides adoption adaptation strategies, which influences household food security at the 0.1% significance level, a number of other coefficient estimates also significantly influence the food security status of household, such as the household size and livestock size. This indicates that the difference in food security estimates between adopters and non-adopters obtained in the descriptive analysis cannot be solely attributed to adoption of at least one adaptation strategy, thus confirming the heterogeneity of the impact of adoption adaptation strategies on household food security in the population.

Table 4 : Exponential LARF coefficient estimates for determinants of food security with interaction

Variables	Coefficients	Robust Standard Error	P-value
Adoption at least one adaptation strategy	8.76**	3.37	0.010
Age	-0.32	0.09	0.001
Household size	0.63**	0.19	0.001
Literacy	-8.17	3.07	0.008
Shop access	1.57	2.87	0.583
Livestock size	0.02*	0.008	0.009
Nombre obs.	298		
F (6, 291)	5.41		
Prob > F	0.000		
R2	0.10		
R2 ajusted	0.08		

Robust standard errors are shown in parenthesis. ** $P < 0.05$ and *** $P < 0.1$.

3.2.2. Impact of adoption adaptation strategies on households annual income.

Table 5 presents the estimates of the impact of adoption at least one adaptation strategy on household annual income. The LATE estimated by the Wald estimator is not statistically different from zero. As explained above in this case the assumption of the WALD estimator is not consistent. The LATE estimate based on the LARF estimate shows that adoption at least one adaptation strategy increases average household annual income by 1 082 USD with is statistically different from zero at the 0.1% significance level. The positive and significant impact implies that adoption of adaptation strategy has a causal influence on household income. This indicates that the return to investment in management natural resource (prohibition bush fire, tree cutting, restoration degraded land and forest) each does generate reliable results, especially in areas where climate change and variability adversely affects livestock production which is considered as the main livelihood option of the households. This reaffirms the narrative from the results of the focus-group discussions in which not adopting adaptation strategies undermines the prospect of income. This is consistent with the secondary literature that shows a positive effect of adoption adaptation strategy on income (Berhe et al., 2017 ; Ali and Erenstein, 2017 ; Riehl et al., 2015 ; Dibba et al., 2012 ; Fernandez et al., 2009).

Tableau 5 : Impact of adoption adaptation on household income with LATE.

Characteristics	household annual income (USD)
Number of observations	339
LATE estimate based on Wald estimator	710.13 (902.60)
LATE estimate based on LARF estimator with interaction	1 082.03 (0.0003004) ****

Robust standard errors are shown in parenthesis. **P<0.05 and **** P<0.001.

The exponential LARF coefficient estimates of the determinants of household annual income with interaction are presented in Table 6. Besides adoption adaptation strategies, which influences household annual income at the 5% significance level, a number of other coefficient estimates also significantly influence the annual income of household, such as the household size, literacy and livestock size. This indicates that the difference in household annual income estimates between adopters and non-adopters obtained in the descriptive analysis cannot be solely attributed to adoption adaptation, thus confirming the heterogeneity of the impact of adoption adaptation on household annual income in the population.

Table 6 : Exponential LARF coefficient estimates for determinants of income with interaction

Variables	Coefficients	Robust standard error	P-value
Adoption at least one adaptation strategy	542 946**	175 688	0.002
Age	1702	5185	0.743
Household size	66 059****	10 227	0.000
Literacy	416 011****	160 268	0.010
Shop access	183 250	149 770	0.222
Livestock size	2 741****	435	0.000
Nombre obs.	298		
F (6, 291)	24.67		
Prob > F	0.000		
R2	0.33		
R2 ajusted	0.32		

Robust standard errors are shown in parenthesis. **P<0.05 and **** P<0.001.

4. Conclusion.

This study finds that adoption climate change adaptation strategies has a significant positive impact on household food security and income. The analysis revealed also that the impact of adoption at least one adaptation strategy on food security, among adopting households, is greater for households that have a greater number of people and livestock. The analysis also revealed that the impact of adoption adaptation strategies on annual income, among adopting households, is greater for households that have a greater number of people and livestock and literacy of household head. The positive impact of adoption adaptation strategies on household food security and income indicates that natural resource management can contribute positively on food insecurity and poverty reduction in Semi-arid area. The positive impact of the adoption adaptation has a major political implication as it can encourage the Senegalese government to take direct intervention measures to ensure food security and fight against poverty of rural households that depend on natural resources to survive.

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