Adoption and impact of climate-smart innovation on household productivity, food and nutritional security in Benin: A Case study of Drought tolerant maize (DTM) varieties

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Plan

- Introduction
- Objectives of the study
- Data and methods
- Results and discussion
- Conclusion
- Recommandations and scope for next step

Introduction

- With the existence of very critical areas where hunger is rife, the food security status in the world is very worrying

(FAO and PAM, 2009).

- Indeed, over 39 countries surveyed in 2006 with high level of food insecurity in the world 25 of them come from Africa.

- Undertaking of micronutrient in consumption food than the required is one of the largest health and socio-economic issues.

Horton et al., (2009)

- But the treatment of which is underestimated. Rising food prices have serious consequences for inflation and the well-being of people around the world and especially in developing countries.

(Golay, 2010)

Introduction

- West Africa is identified as one of the most vulnerable regions to climate change

(Atchikpa et al., 2018; 2017; Yegbemey et al., 2014).

- Benin, like other Sub-Saharan countries, is vulnerable to climate change.

- Climate risks mainly identified on the territory of the Republic of Benin are drought, floods, sea level rise and coastal erosion.

(Tidjani and Akponikpè, 2012).

Introduction

- In Benin, 1.1 million people were food insecure in 2013, coming from 11% of households with less than 1% severe food insecurity and 11% moderate food insecurity.

AGVSA, (2014)

- In recent years studies have shown the primal role of innovation in Africa agricultural development in this context of climate change.

(Tambo and Wünscher, 2017; Wiggins, 2014)

- Indeed, it is commonly accepted that climate-smart innovations are crucial to meeting the challenges of adaptation to climate change to ensure food security and increase farmer’s income

(Campbell et al., 2014; Fieldsend, 2013; Long et al., 2016; Zongo et al., 2015)

Introduction

- Dissemination or promotion seven varieties of Drought Tolerant Maize in Benin like in 12 others countries (DTMA, 2009).

- But thing surprising despite of these multiple efforts only 20 percent in Benin, 30 percent in Mali and 27 per cent in Mozambique of farmers adopted the promoted varieties (CIMMYT-IITA, 2015).

- In the context of Benin, understanding the main determinants of DTM varieties adoption, in addition to the expected returns from adoption, in order to design policies that could address the supply side constraints in West Africa is consequently important.

Introduction

In addition:

- Generally empirical data on adoption of rates, on productivity and outcome indicators related to well-being are few in the literature, but there is practically no studies on the adoption of DTM varieties and better on their impact in Benin.

- Contradiction in some impact assessment study of adoption of innovations. (Omilola, 2009; Schneider and Gugerty, 2011; Suri, 2011)

- Also, it is difficult to observe the impact of innovation since the benefits are spread over several years and are distributed among several producers.

- The adoption of technology may favour some people to the detriment of others

Objectives of the study

The paper examine the adoption DTM varieties as climate-smart innovations and evaluate it impact of on food security and nutritional status of maize farming households in Benin.

- Bring out the **probable impacts of adoption of DT maize varieties at the household level in Benin this paper offers a comprehensive ex-post assessment.**

- Empirically contributes to the current adoption literature by examining the food security and nutritional status effects using a rigorous approach accounting for both unobserved and observed variables of heterogeneity between non-adopters and adopters

Data and methods

Municipalities	Number of villages	Villages	Size of sample
Kétou	5	Adaplamè, Kpankou, Akpambahou, Achoubi, Idigny.	54
Savè	10	Djaloumo, Ayedjoko, Gobé, Achakpa, Alafia, Ouoghi G, Djabata, Oké owo, Gogoro, Diho 1.	104
Bembèrèkè	8	Guessou-Nord, Gando, Pèdarou, Gam-Oues, Wodora, INA 1, Wanrarou, Warakéru.	87
Kandi	9	Padé, Tui, Sinanwon, Donwari, Pèdè, Sonsoro, Heboumey, Angaradébou, Kassakou.	94
Malanville	8	SakawanT, Tomboutu, Boiffo, Degue D, Guené, Garou T, Galliel, Monkassa	84
Tanguiéta	8	Finta , Sonta, Sépounga, Yarika, Mamoussa, Tchatingou, Douani, Kouayoti	95
Total	48	-	518

Data and methods

Data collected:

- socio-economic and demographic characteristics
- perceptions of drought and the climate-smart innovations practices developed to reduce the effects of climate change;
- quantities of inputs and outputs;
- household consumption expenditure
- perception of household food security; Knowledge Aptitudes and Practices in Food, Nutrition and Maternal and Child Health (Breastfeeding of the Child, Minimum Acceptable Diet, Eating Habits, household's Dietary Diversity)
- others information’s on the village and production systems
- Anthropometric data on children under 5 years old, as well as mortality data on all household members

Technic for data collection:

- Investigations through structured and semi-structured interviews
- Group discussions and participant observations

Data and methods: Conceptual framework

- Economic theory predicts that faced with a problem of choice, the rational economic agent opts for the option that maximizes its utility (McFadden, 1975, Gourieroux, 1989).

- The utility is a measure of the welfare or satisfaction obtained by obtaining a good, service or money (Mosnier, 2009).

- The economic principle of rationality and especially the maximization of utility assumption form the basis for the analysis of choice (Bouatay and Mhenni, 2014; Wooldridge, 2003).

- Although it is generally economical, this rationality can be ecological or sociocultural (Rasmussen and Reenberg, 2012).

Data and methods: Conceptual framework

$$\boldsymbol{Y_{JA} = X_j\beta_A + \varepsilon_{jA}} \quad \boldsymbol{and} \quad \boldsymbol{Y_{JN} = X_j\beta_N + \varepsilon_{jN}}$$

- Where the factor prices, as well as farm and household characteristics, are represented by X_j, ε_{jA} and ε_{jN} are iids; β_A and β_N are vectors of parameters.
- Farm households will generally choose the technology if the profit derived by doing so are higher than those obtained by not using the technology, that is, $Y_{JA} > Y_{JN}$.
- Therefore, a farmer adopts technology only if the perceived profit is positive. Although the preferences of the farmer, such as perceived profit of adoption are unknown to the researcher, the characteristics of the farmer and the attributes of the technology are observed during the survey period.
- Thus, the profit derived from innovation or technology adoption can be represented by a latent variable L_j^* , which is not observed but can be expressed as a function of the observed attributes and characteristics denoted as Z in the latent variable model as follows:

Data and methods: Conceptual framework

$$\boldsymbol{L_j^* = Z_{yj}^* + \mu_j \quad [L = 1, \qquad if \quad L_j^* > 0]}$$

- where L_j is a binary variable that equals 1 for farmers that adopt the technology and zero for farmers that do not adopt, with γ representing a vector of the parameter to be estimated.

- The error term μj with mean zero and variance δ_μ^2 captured measurement errors and factors unobserved to the researcher but known to the farmer. Variables in Z include factors affecting the adoption decision, such as farm-level, institutionnal variables and household characteristics.

- Therefore, the equation is also known as the selection equation.

- The probability of technology or innovation adoption can then be expressed as:

Data and methods: Empirical framework

$$\boldsymbol{Regime\ 1 \quad (Adopters) \qquad Y_{JA} = X_j\beta_A + \varepsilon_{jA}} \quad \textbf{If} \quad \textbf{L}_{\textbf{j}} = \textbf{1}$$

$$\boldsymbol{Regime\ 0 \quad (Non - Adopters) \qquad Y_{JN} = X_j\beta_N + \varepsilon_{jN}} \quad \textbf{If} \quad \textbf{L}_{\textbf{j}} = \textbf{0}$$

- Where Y_{JA} and Y_{JN} represent the outcome indicators for adopters (maize yield economic performances and welfare indicators) and for non-adopters respectively in regime 1 and 0;

- ε_{jA} and ε_{jN} represent the error term of the outcome variable respectively in regime 1 and 0

- The variables X capture represents a vector of the exogenous variables thought to influence the outcome function like the farm inputs and characteristics socio-economic/demographics with all other variables.

- While β_A and β_N are parameters to be estimated, however, selection bias may occur if unobservable factors affecting the error terms in the section equation and the outcome equations thus, resulting in a correlation between the two error terms such that $\text{corr}(\varepsilon, \mu) = \rho$ different to 0

Data and methods: Empirical framework

- According to Lee, (1982) and Rees and Maddala, (1985), in order to account for selection bias that may arise from observable and unobservable in farm and non-farm characteristics of the households on one other hand and estimate impact of DTM varieties adoption on the outcomes of interest on the other hand, the Endogenous Switching Regression (ESR) model approach is employed.

- The outcome equations and the error terms of the selection, in the ESR model, are supposed having a trivariate normal distribution, with zero mean and non-singular covariance matrix stated as:

$$\boldsymbol{cov(\mu_i, \varepsilon_1, \varepsilon_2) = \begin{bmatrix} \sigma_A^2 & \sigma_{AN} & \sigma_{A\mu} \\ \sigma_{AN} & \sigma_N^2 & \sigma_{N\mu} \\ \sigma_{A\mu} & \sigma_{N\mu} & \sigma^2 \end{bmatrix}}$$

Where $\sigma_A^2 = var(\varepsilon_1)$; $\sigma_N^2 = var\ (\varepsilon_2)$; $\sigma^2 = var\ (\mu_i)$; $\sigma_{AN} = cov\ (\varepsilon_1; \varepsilon_2)$; $\sigma_{A\mu} = cov\ (\varepsilon_1; \mu_i)$ and $\sigma_{N\mu} = cov\ (\varepsilon_2; \mu_i)$. σ^2 is stand for the variance of the error term in the selection equation and σ_A^2, σ_N^2 represent the variance of the error terms in the outcome equations

Data and methods: Empirical framework

Expected values of the truncated error Kotz, (1970):

$$E(\varepsilon_{jA}/L_i = 0) = E(\varepsilon_{jA}/\mu_i > -Z'_{yj}) = \sigma_{A\mu}\left[\frac{\varphi(Z'_{yj} / \sigma}{\phi(Z'_{yj} / \sigma}\right] = \sigma_{A\mu}\lambda_1$$

$$E(\varepsilon_{jN}/L_i = 0) = E(\varepsilon_{jN}/\mu_i > -Z'_{yj}) = \sigma_{N\mu}\left[\frac{\varphi(Z'_{yj}/\sigma}{1-\phi(Z'_{yj}/\sigma}\right] = \sigma_{N\mu}\lambda_2$$

Where and are the probability density and cumulative distribution functions of the standard normal distribution respectively.

The ratio of and represented by λ1 and λ2 in equations is referred to as the Inverse Mills Ratio (IMR) which denotes selection bias terms. Equations in (1) can then be written as follow:

$$\textbf{Adopters}: \quad Y_{JA} = Z\beta_{JA} + \sigma_{A\mu}\lambda_1 + \varepsilon_{jA}$$

$$\textbf{Non Adopters}: \quad Y_{JN} = Z\beta_{JN} + \sigma_{N\mu}\lambda_2 + \varepsilon_{jN}$$

Data and methods: Empirical framework

- Indeed, this two-step procedure may generate heteroskedastic residuals that cannot be used to derive consistent standard errors without unwieldy some adjustments (Rees and Maddala, 1985).

- So, in the present study, we employ the single stage Full-Information Maximum Likelihood (FIML) method following Lokshin and Sajaia, (2004, 2018).

- The FIML method fits the outcomes equations and the selection simultaneously in order to get consistent standard errors.

- Thus, λ1 and λ2 in equations (16) are homoscedastic.

$$\ln L_i = \sum_{i=1}^{N} \left\{ \begin{array}{c} L_i w_i \left[\ln F \left(\frac{Z_{\gamma j} + \rho_{1\mu}(Y_{jA} - X_j \beta_A \ / \ \gamma_j)}{\sqrt{1-\rho_{A\mu}^2}} \right) - \ln \left(f \ (Y_{jA} - X_j \ \beta_A / \gamma_j \right) \right] \\ +(1-L_i) w_i \left[\frac{\ln(1 - F(Z_{\gamma i} + \rho_{2\mu}(Y_{jN} - X_j \beta_N \ / \ \gamma_j)}{\sqrt{1-\rho_{N\mu}^2}}) - \ln \left(f(Y_{jN} - X_j \ \beta_N / \gamma_j \right) \right] \end{array} \right\} \qquad (17)$$

Data and methods: Empirical framework

$$\textbf{Adopters}: \quad E(Y_{JA}|L_i = 1) = Z\beta_{JA} + \sigma_{A\mu}\lambda_1 \tag{18}$$

$$\textbf{Non Adopters}: \quad E(Y_{JN}|L_i = 1) = Z\beta_{JN} + \sigma_{N\mu}\lambda_1$$

Afterwards estimating the model's parameters, the conditional expectations or expected outcomes and the Average treatment effect on treated households (ATT) are computed as follows:

$$ATT = E(Y_{jA}|L_i = 1) - E(Y_{JN}|L_i = 1) \tag{19}$$

$$ATT = E(Y_{JA} - Y_{JN}L_i = 1) = Z_j(\beta_A - \beta_N) + (\sigma_{A\mu} - \sigma_{N\mu})\lambda_1$$

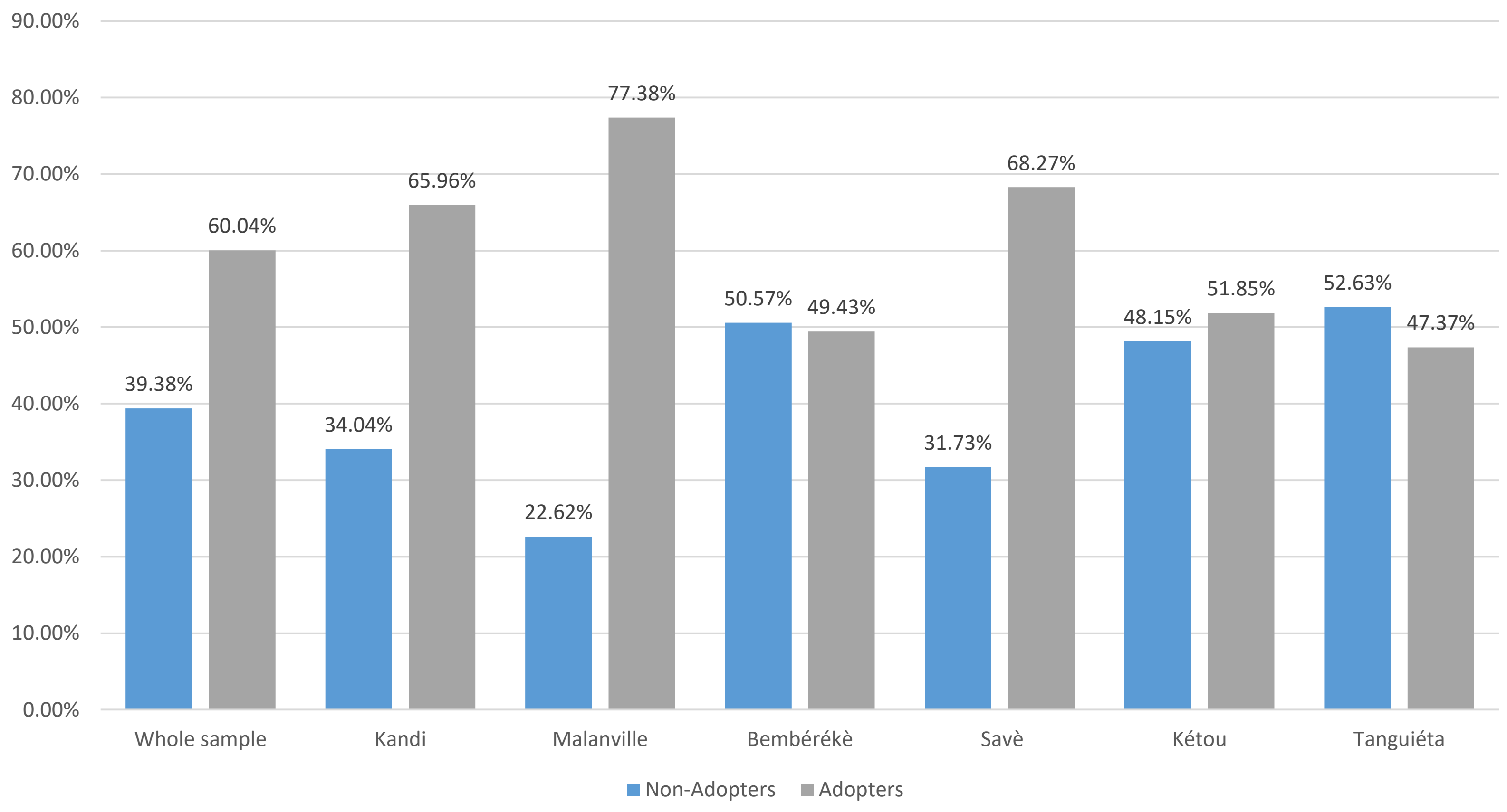
Results and Discussion

Table: Socio-economic characteristics of the respondents

Variable	Name and description	Mean in the full sample (n=518)	Mean in the adopters' group (n=314)	Mean in non-adopters' group (n=204)
Age	age of head of household (in years)	48,64	48,78	48,44
household size	Number of the people living together in the same house and eating from one pot.	11,19	11,31	11
Total of land cultivated size	total area planted (in ha)	8,16	7,83	8,67
Gender	sex of the head of household (0 = Woman, 1= Man)	1,93	1,93	1,92
Education	number of years of the head of household on the benches (years)	4.02	4,38	3.47
Religion	religion (1 = Christianity, 2 = Islam, 3 = Traditional religion (Animism), 4 = Other (No need to specify)	1,69	1,70	1,67
Wife	Number of wives of the household	1,46	1,45	1,48
Farm income	Household farm income in Euro	2231.681	2520.163	1787.645
Land ownership	If the household is the owner of this maize producing land (1 = yes and 0 = no)	0.9324324	0.964	0.8823529
Level of formal education	The highest level of school attended by the head of household (0= No formal education,1= Primary education,2= Secondary education,3= University education)	0,66	0,71	0,57
Informal education	If the head of household attend Informal education (0 = Non-formal education, 1 = Qur'anic education, 2 = Literacy, 3 = Other)	0,57	0,60	0,52
Side activity	If the head household has a secondary activity (0 = No, 1 = Yes)	0,36	0,31	0,44
Experience in agriculture	Number of the year the head of the household started to farm in general (in years)	24.22	24.14	24.35
Migration	If the head of household migrated for agricultural purposes (0 = No, 1 = Yes)	0,05	0,04	0,05
Experience of growing maize	Number of the year the head of household started to cultivate maize in his farm (in years)	22,67	22,83	22,42
Maize size	average total area planted in all for your maize crop (in ha)	4,16	3,87	4,62

Results and Discussion

Figure : Adoption rate of DTM varieties by the municipality



Results and Discussion

Table : Descriptive statistics of the food security indicators outcome used

Variable	Definition	Mean	Std. Dev.	Min	Max
Household Per capita Food Expenditure	Household Per capita Food Expenditure	47701.3	72378.8	0.26667	1333333
Household Food Diversity Score	Number of food groups consumed within during the seven days preceding the survey by a household	2.65058	0.59941	1	3
Household food consumption scores	Sum of the weighting of each food group multiple by the number of days of consumption	2.57722	0.69317	1	3
Food insecurity severity experienced by households	Sum of the score of the nine questions on food insecurity experience	5.93243	3.81553	1	10

Table : Descriptive statistics of the nutritional indicators outcome used

Variable	Whole Study area	Non-Adopters	Adopters
Underweight or WAZ	-0.67	-0.74	-0.58
Stunting or HAZ	-1.07	-1.17	-0.97
Wasting or WHZ	-0.09	-0.08	-0.00

Results and Discussion

Tableau : Determinants of productivity
(Only significant variables are presented here)

	Maize productivity or yield		
VARIABLES	Non-Adopter	Adopter	Selection model
Age of head of household (in years	0.057* (0.032)	0.015 (0.037)	-0.052 (0.082)
Square of the Age of the household head	-0.001** (0.000)	-0.000 (0.000)	0.001 (0.001)
emigration for agricultural purposes	0.235 (0.215)	0.540* (0.297)	0.002 (0.659)
Experience of growing maize (years)	0.005 (0.010)	-0.029* (0.016)	-0.049* (0.029)
Ownership of the land on which maize is produced	0.289* (0.152)	-0.164 (0.330)	1.060** (0.472)
membership in an association or producer's cooperative	0.186 (0.115)	0.241* (0.134)	-0.509* (0.280)
Number of poultry holding	-0.000***(0.000)	-0.000 (0.000)	-0.000* (0.000)
Total of farm income	0.000** (0.000)	-0.000 (0.000)	0.000*** (0.000)
Number of wagon holding	0.175** (0.087)	0.061 (0.154)	-0.373 (0.278)
Maize farm size (ha)	0.027* (0.016)	-0.098*** (0.034)	0.008 (0.044)
Use of fertilizer(NPK)	0.317** (0.137)	-0.021 (0.209)	-0.744* (0.412)
Quantity of fertilizer used (kg)	0.000* (0.000)	0.000*** (0.000)	-0.000*** (0.000)
Total farm assets in the household	-0.033** (0.014)	0.039** (0.017)	-0.036 (0.030)
Distance from house to demonstration farm			-0.565*** (0.080)
Distance from house to farm inputs magazine.			0.099*** (0.017)
Constant	4.809*** (0.900)	7.727*** (1.081)	1.581 (2.254)
Wald chi2		121.07***	
Log likelihood		-720.009	
lns0, lns1	-0.501***(0.050)	0.008 (0.040)	
r0, r1	-0.246 (0.208)	-0.329 (0.218)	
σ_0, σ_1	0.605*** (0.030)	1.008 (0.040)	
ρ_0, ρ_1	-.241*** (0.196)	-.318 (0.195)	
LR test of indep. eqns.		3.79	

Results and Discussion

Tableau : Determinants of household Per capita Food consumption expenditure per year in (US Dollars)
(Only significant variables are presented here)

VARIABLES	household Per capita Food consumption expenditure per year in (US Dollars)		
	Non-adopter	Adopter	selection
Household's total assets amount	-0.00 (0.00)	0.00** (0.00)	-0.00 (0.00)
Gender	0.03 (0.16)	0.26** (0.11)	0.18 (0.33)
Access to agricultural credits	0.20* (0.11)	0.03 (0.05)	0.30 (0.19)
Awareness of climate change	-0.20 (0.15)	0.13*(0.07)	0.83*** (0.26)
Size of the household	-0.05*** (0.01)	-0.06*** (0.01)	0.04** (0.02)
Experience in agriculture	0.01** (0.01)	-0.00 (0.00)	-0.02 (0.01)
Quantity of maize consumed in the household	0.00*** (0.00)	0.00** (0.00)	0.00*** (0.00)
Holding of a bank account	0.28** (0.12)	0.25*** (0.06)	0.26 (0.21)
Amount of Own financial capital	0.00*** (0.00)	0.00*** (0.00)	0.00 (0.00)
Use fertilizers	0.28** (0.12)	0.19***(0.07)	-0.58** (0.24)
Total maize farm size	0.03*** (0.01)	0.00 (0.01)	-0.09*** (0.02)
Existence of Health centre	-0.20 (0.13)	-0.12* (0.07)	-0.01 (0.26)
The distance of home to Demonstration fields			-0.43*** (0.06)
The distance of home to Farm inputs shop			0.07*** (0.01)
Constant	11.08***(0.32)	11.85*** (0.21)	0.08 (0.74)
Wald chi2	143.83***		
Log-likelihood	-427.10008		
lns0, lns1	-0.636***,-0.878***		
r0, r1	0.004, 0.811**		
σ0, σ1	0.529, 0.415		
ρ0, ρ1	0.004, 0.670***		
LR test of indep. eqns.	**chi2(2) = 8.83 Prob > chi2 = 0.0121**		

Results and Discussion

Tableau : Determinants of Household food consumption score (HFCS)
(Only significant variables are presented here)

	Household food consumption score (HFCS)		
VARIABLES	Non-adopter	Adopter	select
Total Amount of the household assets	0.00*** (0.00)	0.00 (0.00)	-0.00 (0.00)
Age of household head	-0.03*** (0.18)	0.01(0.07)	0.01(0.20)
Awareness of climate change	-0.51** (0.23)	-0.19** (0.08)	0.83*** (0.26)
Participation in Migration	-0.40 (0.32)	0.29* (0.16)	-0.12 (0.44)
Household size	0.04* (0.02)	-0.00 (0.01)	0.05** (0.02)
Number of children dropped from school	-0.11*** (0.03)	-0.02** (0.01)	-0.04 (0.03)
Experience in agriculture	0.03*** (0.01)	-0.01* (0.00)	-0.02* (0.01)
Contact with extension services	0.50*** (0.16)	0.08 (0.07)	-0.38* (0.20)
Quantity of maize consumed in the household	-0.00*** (0.00)	-0.00 (0.00)	0.00** (0.00)
Holding of a bank account	-0.58*** (0.19)	-0.00 (0.07)	0.39* (0.21)
Amount of Own financial capital	-0.00*** (0.00)	-0.00 (0.00)	0.00 (0.00)
Possession of a side activity	0.32** (0.16)	0.01 (0.07)	-0.16 (0.19)
Existence of Health centre	0.34* (0.20)	0.10 (0.08)	0.01 (0.27)
Year of Education	0.03* (0.02)	0.00 (0.01)	0.03 (0.02)
Participation in an informal education	0.07 (0.08)	-0.10*** 0.04)	0.03 (0.11)
Awareness of DTM varieties	-0.05 (0.22)	0.15* (0.09)	0.78*** (0.24)
The distance of home to Demonstration fields			-0.47*** 0.05)
The distance of home to Farm inputs shop			0.08*** (0.01)
Constant	4.01*** (0.51)	3.84*** (0.26)	0.53 (0.74)
Wald chi2	92.52***		
Log-likelihood	-581.65748		
lns0, lns1	-0.151**,-0.690***		
r0, r1	-0.331**,0.147		
σ0, σ1	0.859, .501		
ρ0, ρ1	-0.319**,0.146		
LR test of indep. eqns.	chi2(2) = 4.37 Prob > chi2 = 0.1127		
Observations	**518**		

Results and Discussion

Tableau : Determinants of Household Food insecurity severity experienced (HFIES)
(Only significant variables are presented here)

VARIABLES	Household Food insecurity severity experienced (HFIES)		
	Non- adopter	Adopter	selection
Gender	-0.19 (0.40)	-0.61* (0.34)	0.11 (0.34)
Contact with extension services	-0.27 (0.25)	-0.33* (0.18)	-0.39** (0.20)
Possession of a side activity	0.37 (0.25)	0.30* (0.18)	-0.07 (0.19)
Year of Education	-0.7*** (0.03)	0.02 (0.02)	0.03 (0.02)
Participation in an informal education	0.32** (0.13)	0.03 (0.10)	0.02 (0.11)
Awareness of DTM varieties	-0.14 (0.35)	0.26 (0.23)	0.80*** (0.24)
The distance of home to Demonstration fields			-0.47*** (0.05)
The distance of home to Farm inputs shop			0.08*** (0.01)
Constant	2.15*** (0.80)	2.24*** (0.68)	0.28 (0.75)
Wald chi2		21.78	
Log-likelihood		-921.12135	
lns0, lns1		0.288***, 0.228***	
r0, r1		-0.397**, -0.186	
σ0, σ1		1.334, 1.256	
ρ0, ρ1		-0.377**, -0.184	
LR test of indep. eqns.	chi2(2) = 4.86 Prob > chi2 = 0.0879		
Observations		**518**	

Results and Discussion

Tableau : Determinant of Household Dietary Diversity Score (HDDS)
(Only significant variables are presented here)

	Household Dietary Diversity Score (HDDS)		
VARIABLES	Non- Adopter	Adopter	select
Gender	-0.10 (0.07)	-0.13** (0.06)	0.11 (0.31)
Access to agricultural credits	-0.01 (0.05)	-0.10*** (0.03)	0.31* (0.18)
Household size	-0.00 (0.01)	-0.01** (0.00)	0.03** (0.02)
Number of children under 5 years old	0.03 (0.02)	0.03** (0.02)	0.10 (0.09)
Experience in agriculture	0.00 (0.00)	0.01** (0.00)	-0.02** (0.01)
Contact with extension services	-0.03 (0.04)	0.11*** (0.03)	-0.38** (0.18)
Holding of a bank account	0.10* (0.05)	0.07** (0.03)	0.27 (0.19)
Use fertilizers	0.24*** (0.05)	0.06 (0.04)	-0.72*** (0.24)
Possession of a side activity	-0.05 (0.04)	-0.08** (0.03)	-0.14 (0.17)
Existence of Health centre	0.13** (0.06)	0.01 (0.04)	-0.31 (0.25)
Year of Education	0.01* (0.00)	0.00 (0.00)	0.04** (0.02)
Participation in an informal education	0.05** (0.02)	-0.03* (0.02)	0.03 (0.10)
Awareness of DTM varieties	0.12* (0.06)	-0.12*** (0.04)	0.68*** (0.21)
The distance of home to Demonstration fields			-0.3*** (0.09)
The distance of home to Farm inputs shop			0.07*** (0.01)
Constant	1.57*** (0.14)	2.16*** (0.12)	-0.00 (0.72)
Wald chi2	179.88***		
Log-likelihood	-96.468296		
lns0, lns1	-1.470***,-1.458***		
r0, r1	0.114, -1.425**		
σ0, σ1	0.229, .232		
ρ0, ρ1	0.113, - 0.890***		
LR test of indep. eqns.	chi2(2) = 3.91 Prob > chi2 = 0.1416		
Observations	**518**		

Results and Discussion

Tableau : Determinant of body index
(Only significant variables are presented here)

VARIABLES	Children body index		
	Adopter	Non-Adopter	selection
Age of children in the household	-0.02(0.01)	-0.03***(0.01)	-0.02 (0.02)
Square of age of the household head	0.00(0.00)	0.00***(0.00)	-0.00(0.00)
Access to agricultural credits	0.29(0.23)	-0.90***(0.34)	-0.12(0.40)
Contact with extension services	0.11(0.27)	1.49***(0.36)	-0.75*(0.44)
Own financial capital	0.87**(0.38)	1.25***(0.36)	0.10(0.61)
Year of Education	-0.04(0.03)	0.10***(0.04)	0.04(0.05)
Total maize farm size	-0.02(0.02)	-0.14***(0.03)	0.01(0.04)
Participation in maize market	0.29(0.26)	0.73**(0.31)	-0.11(0.41)
Awareness of DTM varieties	-0.66*(0.36)	-1.11**(0.45)	0.14(0.56)
Awareness of climate change	0.61*(0.36)	2.40***(0.53)	0.97(0.62)
Existence of Health centre	0.33(0.31)	-1.42***(0.41)	-0.30(0.52)
Household completed secondary school	-0.04(0.41)	1.94***(0.58)	-0.69(0.77)
The distance of home to Demonstration fields			-0.60***(0.12)
The distance of home to Farm inputs shop			0.08***(0.03)
Constant	-0.71(0.61)	-2.47***(0.95)	2.78**(1.41)
Wald chi2	21.51*		
Log-likelihood	-189.86072		
lns0, lns1	-0.3200635**, -0.0232575		
r0, r1	0.6784223 , 0.4055517		
σ0, σ1	0.7261029* , 0.9770109*		
ρ0, ρ1	0.5904928** , 0.3846892		
LR test of indep. eqns.	chi2(1) = 4.26 Prob > chi2 = 0.0390		
Observations	122		

Results and Discussion

Tableau : Impact of DTM adoption on the food security in farming household in Benin
(Only significant variables are presented here)

Outcomes	Decision of Adoption of DTM varieties		ATT	ATT in %
	To adopt	To not adopt		
Maize productivity (grain yield of maize).	6.92	6.89	0.04	0.52
Household Per capita expenditure	5.22	4.63	0.58***	11.19
Household Food expenditure per capita	73.26	84.46	-11.2***	-15.29
Household Food Insecurity Access Scale	6.16	3.02	3.14	50.93
households Dietary Diversity score	2.78	2.46	0.32***	11.55
Household Food Diversity Score	2.68	2.51	0.16***	6.14
Children Body index	4.63	5.22	0.59***	12.74

Conclusion

- By conducting our study on the impact of Drought tolerant maize (DTM) varieties adoption on household productivity, food security and Nutritional status in Benin, we contribute to the existing literature on climate smart innovations.

- For this purpose, we have based our analysis on estimations of the Treatment Effect (ATT) method for adoption DTM varieties on productivity and household welfare indicators measured by total expenditure, consumption expenditure and food security and nutritional status.

- To control selection bias, we have applied econometric techniques on our data from a field survey of rural farm households in Benin

Conclusion

- Omitted the indicator of Household Food Insecurity Access Experience score, the significant contribution to all the other indicators of food security and household nutritional status in Benin of the adoption of DTM varieties,

- This suggested the need to undertake additional actions to ensure that the positive effects on productivity translate into an increase in the share of maize harvests reserved for consumption likely to undergo agri-food processing for better household nutrition in the area of our study.

- Thus, it would be beneficial that beyond the availability dimension of food security, in our study area that policies to reduce food insecurity also focus on nutritional security

Recommandations and scope for next step

- Even though our study has shown that poor rural farmers with limited resources through the adoption of DTM varieties that generate benefits on household welfare, the adoption of innovation being a dynamic process.

- Envision that future research involving panel data to study the long-term effects of innovations led by farmers.

- Finally, it would also be interesting to extend this research on the impact of DTM varieties on the children intake energy in the same study area also on the nutritional status on women in the same household in Benin using innovative technologies

Thank you for your attention!