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Farm-level adaptation to climate and environmental changes: a triple hurdle model of coping strategies

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Abstract

This paper applies a triple hurdle decision making model in order to understand adaptation decisions by using farm level data from the 2011 National survey on household life conditions and agriculture in Niger, a landlocked country of the Sahel. In fact, farms decision making process is often taken sequentially and the model used in this paper takes into account the sequences and the diversity of the different adaptation decisions. The results show that the farmers adoption decision-making process and the different coping mechanisms depend on their characteristics and exposition to environmental and climatic problems. Health, age, available labor, and past climatic and environmental damages are crucial determining factors in explaining the decision, the choice, and the intensity of adaptation. These results can help to better understand the adoption decision making process in order to assist farmers, especially those who are the most vulnerable to environmental and ecological problems resulting from climate change.

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1. Introduction

The climate change issues resurged at the front of the international debate with the recent organization of the 21st Conference of Parties (COP 21) that gave it a prominent place in the development agenda. While governments are trying to find adequate solutions to deal with the causes and therefore minimize the long term impacts, farms at the micro-level are adopting autonomously their own strategies to cope with the changing environment that might deeply affect their productivity. In fact, it appears that adaptation[1] is more needed in the developing countries, while in the developed countries, it is more about reducing greenhouse gas emissions and targeting zero carbon growth. Climate and environmental changes seem to be more severe in zones like the Sahel and continue to make the rural households highly vulnerable to extreme poverty, especially those who depend on agriculture. Using farm level data from the 2011 National survey on household life conditions and Agriculture in Niger, my study identifies the determinants of the different strategies set by the climate-vulnerable farms. There is a gap to understand the drivers of adaptation strategies, especially in countries like Niger where populations are exacerbated by climate change and variability. Thus, it is important to look at the location specific determinants of adaptation strategies at the farm level.

I model strategies used by the farmers who are more and more subject to environmental and ecological problems resulting from climate change. This paper contributes significantly to the literature. At the methodological level, the adopted framework takes into account the simultaneity of the multiple strategies undertaken at the farm level in response to these climate effects. There is no single adaptation strategy, but a variety of adaptation strategies set in order to improve resilience to climate. Understanding what drives the adaptation decision-making at the micro level will help governments to undertake policy action against climate change and climate variability by strengthening livelihood resilience.

[1] Climate change adaptation is defined as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities (Intergovernmental Panel on Climate Change - IPCC, 2001).

Farm decision making is often taken sequentially and the proposed model seeks to take into account the sequences of the different decisions. Additionally, the different decisions about adopting a particular coping strategy are not taken randomly and independently.

At the first stage, farmers decide to react to climate change or not depending on the prevailing climatic conditions in their location, the level of land degradation and other adverse shocks like locust invasion. Once the decision taken, the next stage is to adopt a specific coping scheme. Ultimately, they set their minds to the extent they would like to develop the adopted strategies. Farmers can use different types of adaptation strategies, and some of them might be more reactive or more anticipatory than the others. Among the large set of adoption responses that might exist, I focus on the perennial crop plantation, the reactive adaptation to land damage and migration that are very frequent. The process is implemented through a triple hurdle model of decision making to take into account endogeneity and simultaneity.

In the context of the fragile environment and the vulnerability to climate shocks, the perennial crops can be a sustainable alternative to annual crops that are more water and inputs demanding and less suitable in the presence of aridity and other environmental problems. The mixture of perennial and annual crops can lead to a more resilient agricultural system with the reduction of the dependency on precipitation. At the same time, the adoption of tolerant varieties of perennial crops can also diversify the food supply in the country, ensure a periodic and more stable income for farmers, and make households less vulnerable to market fluctuations for some products. The combination of perennial crop and annually planted crop can reduce vulnerability to climate shocks by generating substantial income benefits because of the additional marketing possibilities for non-food products (firewood and fodder) and the tighter constraint on inputs. At the ecological level, perennial crop contributes more in reducing greenhouse gas and contribute to mitigate erosion. Farmers might also react directly to land degradation by setting strategies to restore, maintain, or enhance the soil quality. The migration of a household member, through remittances sent back to home is another diversification of income source that can make individuals less subject to agricultural income variability and climate change impacts.

2. Background

Niger is one of the world least developed nation[2] and is located in the Sahel zone with a large fraction of its surface covered by the Sahara desert. Due to its geographical location, the agricultural and pastoralism systems face to many climatic and environmental shocks. This might severely impact on population welfare as it is estimated that 80 % of the population live in rural areas and heavily rely on small-scale family farming mainly based on rain-fed agriculture. The Nigerian economy relies on the primary sector with around 45% of contribution to the Gross Domestic Product (GDP). However, agricultural growth is constrained by the unfavorable climate conditions, especially prolonged droughts. Niger is often subject to many climatic and environmental damages like droughts, floods, temporal and spatial variability of rainfall, sandstorm, soil degradation, temperature increases, desertification, and locust invasion that tends to destroy farm annual harvests or negatively affect their productivity and food security. The risk increases over time and raises the need for farmers to develop climate change adaptation strategies.

In this context of climate change impacts, farmers set many and diverse adaptation strategies in order to reduce the negative impacts of climate and environmental changes, and improve farm welfare, food security and resilience. Conscious of the fact that climate and environmental condition are affecting productivity and food security in the country, the government has established a National Action Programme for Adaptation (NAPA) in 2006. This plan seeks to integrate climate change in the national budget and to reinforce existing institutional and technical capacities (PNUD, 2014).

Many conceptual and empirical studies have been conducted in order to identify the different climate change adaptation methods and explain their determinants. In Eastern and Southern Africa, Eriksen et al. (2008) identify strategies like diversification, livestock herding in Namibia and Botswana, and ecological diversification[3] in Mozambique. Using household level data in South-Africa, Thomas et al. (2007) have categorized four groups of climate change responses: changes in farming practices, the use of the spatial and temporal diversity of the landscape, livelihoods commercialization and diversification, and social networks.

For Brooks (2003) household autonomous adaptation depends on factors such as health and education, access to information, financial and natural resources, existence of social networks, and

[2] 186th in the 2013 Human Development Index, UNDP
[3] Cultivating plots in high or low ground depending on the amount of rainfall.

presence or absence of conflict. Many researchers have recognized the role of migration through remittances as an adaptation strategy to climate change (Davies, 1993; Agrawal and Perrin, 2009; Tacoli, 2011). Other studies have found that diversification of income through mechanisms like mixed livestock-farming system can also be a coping mechanism and help households to escape poverty in the context of increasing changing climate (Kristjanson et al., 2004; Thornton et al., 2006).

3. Methodology and data

3.1. Triple hurdle model of farm-level adaptation strategies

I estimate the following empirical model to analyze the determinants of the choice of adaptation strategies and the intensity of the use of the different types C. Adaptation decision and choice of the adaptation methods might depend on farmer characteristics, preferences and the environmental risk that might threaten their location. The model is specified below.

$$D_{id} = \varphi(V_{id}) + \varepsilon_i$$

$$S_{c_{id}} = \psi_c(H_{id}) + \mu_{c_i} \text{ if } D_i = 1, \ c = 1, \ldots C=3$$

$$I_{c_{id}} = \Gamma_c(X_{id}) + \upsilon_{c_i} \text{ if } S_{c_i} = 1$$

Where D_{id} is a binary variable and equals to 1 if the farm household i living in the location d decides to use an adaptation strategy. V_{id} is a set of variable capturing the environmental status of the location d of the household i. $S_{c_{id}}$ represents C different variables equaling to 1 if the household i living in location d adopts the strategy c. These variables show how adaptation strategies are set.

I focus on the development of perennial cropping system, protection of land and migration among the C strategies. $I_{c_{id}}$ is a continuous variables and represents the extent the household i living in location d is adopting the strategy $c. H_{id}$ and X_{id} are household level socioeconomic and environmental variables.

I conducted a preliminary data analysis to explore the correlates the different variables related to adaptation strategies by using statistical tests and simple bivariate statistics (see Brinda et al. 2014 for example). In addition, I used the knowledge gained in the literature to specify the model.

The model is estimated using a conditional mixed process estimator procedure developed by Roodman (2007) which estimates a multi-equation system where the dependent variable of each equation may have a different format. Based on the three adaptation strategies described earlier, the model estimates simultaneously the seven equations presented above and is based on a nested structure by using Full Information Maximum Likelihood (FIML) and allowing for possible correlation between residuals of the equations.

3.2. Data

The study is based on the 2011 National survey on household life conditions and Agriculture in Niger. This survey covers around 4000 households, including farm and non-farm households. The data collection was done in two steps with a first round during the cultivation and the preparation of cultivation areas from mid-July to mid-September 2011, and the second round during the harvesting period in November and December 2011. The survey was based on three questionnaires: the household questionnaire that collected information on socioeconomic characteristics of households, the agricultural questionnaire to get data on farming activities, and the community questionnaire that provided information on the available infrastructures at district level.

4. Results and Discussion

Table 1 presents the results of the triple hurdle model for farm-decision making process. The first column shows the determinants of farms' intention to react to climate and environmental changes. Farm decision to react depends on how the environment he is living is affected by climate and environmental shocks. Farms in locations that had past climate and environmental damage experiences are more likely to decide to set adaptation mechanism in response to this exposition whether anticipatory or adaptively. The results in column (1) show that those living in the locations that tend to have poorer rainy season are those making the decision to react. However, the model reveals that there are other kinds of previous shocks that discourage farms to react within the set of the presented adoption methods. In fact, the occurrence of post-harvest diseases in the recent past might negatively influence the farmer to use methods like tree cultivation, restoration of land degradation or migration as these might be out of scope and almost irrelevant in such situations.

As explained earlier, those taking the decision might use different traditional coping strategies. Columns (2) to (4) respectively show the determinants of the decisions to opt for perennial crops, maintain or restore land ecosystem, and send a family member who is expected to send back earnings to the family. Columns (5) to (7) explain the determinants of the farm adoption level for the different strategies.

Columns (2) show that the occurrence of floods increases the probability to opt for perennial crops because these are less vulnerable. The results also show that farmers might opt to home tree cultivation if they face to inaccessibility of their village due to the impracticability of the roads. In fact, perennial crops grow with less fertilizer and equipment, generally only available at the market. This could also be an option to avoid time losses due to the potential inaccessibility of agricultural land devoted to crop planted annually.

The results also show that the probability to grow perennials increases with the deterioration of the household health stock since perennial crops compared to annually cultivated crop are frequently used in small-scale operations and might demand lesser physical force.

Column (3) shows that the probability to use protection systems against erosion increases with the frequency of floods and strong wind blowing. The potential ravages of rain motivate farmer to build these protection systems and measures against the risk of eventual floods, erosion and submersion of land. Contrary to perennial crops, the use of the land protection system decreases with the deterioration of farmer household health stock. The availability of family labor also increases the probability to adopt land protection and restoration systems and activities, but it decreases with the age of family members. Households headed by women tend to use less land protection systems. Column (4) presents the determinants of the decision to adopt a migration strategy. The results show those rural farm households take more the decision to send a family member than urban agricultural households. Households with low health stock and those living in locations with enough rain are less motivated to adopt the migration strategy. The results in columns (5) to (7) show that the intensity of adoption decreases with age for perennial crops and land protection systems, while it increases for migration. Ultimately, households with more plots adopt less intensively perennials and are less engaged in fighting land degradation and caring about sustainability.

Table 1: Triple hurdle model of adaptation decisions

VARIABLES	(1) Adaptation (1/0)	(2) Perennial system decision (1/0)	(3) Erosion system decision (1/0)	(4) Migration decision (1/0)	(5) # of perennial cops	(6) # of systems against erosion	(7) # of migrants outside the area
D_Insect Attack	0.0846	-0.263	-0.343	2.006*			
	(0.140)	(0.420)	(0.309)	(1.117)			
D_Disease_harv	-0.388***	-0.191	0.487**	0.104			
	(0.115)	(0.431)	(0.246)	(1.463)			
D_Rainfull	-0.172***	0.555**	0.264**	-1.003**			
	(0.0567)	(0.233)	(0.122)	(0.419)			
D_agri_orientation	-0.345	0.582	-1.167***	0.380			
	(0.216)	(0.818)	(0.303)	(0.779)			
# Week Impracticable roads	-0.0290	0.519*	0.0136	-0.247			
	(0.127)	(0.311)	(0.291)	(0.359)			
D_electricity	0.363**	0.140	-0.662*	1.250			
	(0.168)	(0.511)	(0.370)	(1.306)			
D_Transp	0.00344	-0.00309	0.000682	0.00450			
	(0.00254)	(0.00612)	(0.00460)	(0.00711)			
D_wind		-0.839	2.115***	-0.211			
		(0.712)	(0.525)	(1.088)			
D_road	-0.312**						
	(0.144)						
D_extension			-1.095**				
			(0.440)				
D_phone					0.0651		0.354
					(0.434)		(0.496)
D_Market		0.439	-0.122	-0.572	1.209		
		(0.432)	(0.305)	(0.922)	(0.819)		
Floods		0.997**	1.900***	-3.552***			
		(0.484)	(0.327)	(0.888)			
Rural		-0.874	-0.406	7.036***	-0.936	0.241	0.462**
		(0.783)	(0.582)	(2.118)	(1.160)	(0.357)	(0.230)
Household Health Stock		0.191***	-0.151**	-0.291**	0.109	-0.000623	-0.00583
		(0.0738)	(0.0771)	(0.142)	(0.122)	(0.0421)	(0.0313)
HH_literacy		-0.259	-0.0795	-0.718	0.148	-0.000125	-0.0893
		(0.274)	(0.209)	(0.897)	(0.522)	(0.138)	(0.0906)
Average Age		-0.00359	-0.0391**	0.00526	-0.0273*	-0.0143**	0.0181***
		(0.0172)	(0.0171)	(0.0233)	(0.0158)	(0.00587)	(0.00475)
Labor		0.00757	0.0982***	0.00193	0.0204	-0.0701**	0.0621***
		(0.0519)	(0.0338)	(0.123)	(0.0537)	(0.0356)	(0.0172)
Land (10^{-05}, scale for the coefficients for land)		1.06*	-73.8	-1.14	-2.16***	45.9	-10.4
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HH_Sex			-0.586*	1.181		-0.386	0.0753
			(0.330)	(0.871)		(0.274)	(0.118)
# plots					-0.120*	-0.0560**	0.0352
					(0.0678)	(0.0260)	(0.0230)
Constant	0.645*	-3.775***	-0.0481	3.512**	3.336**	3.154***	0.641
	(0.391)	(1.110)	(0.905)	(1.709)	(1.696)	(0.333)	(0.573)

Observations	1,167	1,167	1,167	1,167	1,167	1,167	1,167

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 D_: district level variables

5. Conclusion

The purpose of this paper is to understand the determinants of farm-level adaptation strategies in Niger. The latter is affected by climate change and variability that more and more jeopardize household welfare, especially in case of lack or very low adaptive capacities. Farm adopts different adaptation strategies based on their characteristics and the environmental conditions prevailing in their locations. The results reveal different mechanisms that lead farmers to take the decision to react to climate and environmental damages, choose between available set of strategies, and ultimately determine the extent they use the different options. The results show that household labor, health status, average age, environmental exposition, and district level variables are determinant in explaining the adoption mechanism.

The results can help to better understand the adoption decision making process in order to better help the vulnerable farmers to be able to cope with the climate change and variability, and boost their income. To complement the autonomous adaptation at farm level, the Government can organize national projects on adaptation like technologies, management, and capacity building program based on traditional as well as modern coping strategies. This should take into account the heterogeneity in the adoption decision and mechanisms in order to achieve an optimal farm reaction and enhance food security.

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Appendix

Table A1: Descriptive Statistics

VARIABLE	MEAN	STD.	MIN	MAX
ADAPTATION (1/0)	0.5	0.5	0.0	1.0
PERENNIAL SYSTEM DECISION (1/0)	0.0	0.2	0.0	1.0
EROSION SYSTEM DECISION (1/0)	0.1	0.2	0.0	1.0
MIGRATION DECISION (1/0)	0.7	0.4	0.0	1.0
NBD_PERENIAL	0.1	0.4	0.0	8.0
NB_EROSION	0.1	0.6	0.0	3.5
MIGRATION_NB	1.5	1.3	0.0	6.0
D_INSECT ATTACK	0.7	0.4	0.0	1.0
D_DISEASE_HARV	0.5	0.5	0.0	1.0
D_RAINFULL	2.9	0.9	1.0	4.0
D_AGRI_ORIENTATION	0.9	0.3	0.0	1.0
# WEEK IMPRACTICABLE ROADS	0.2	0.4	0.0	1.0
D_ELECTRICITY	0.3	0.4	0.0	1.0
D_TRANSP	19.7	29.6	0.0	99.9
FLOODS	0.1	0.3	0.0	1.0
RURAL	0.9	0.3	0.0	1.0
HOUSEHOLD HEALTH STOCK	1.4	1.6	0.0	13.0
HH_LITERACY	0.5	0.5	0.0	1.0
HH_SEX	0.1	0.3	0.0	1.0
AVERAGE AGE	20.8	9.6	6.8	80.0

LABOR	5.1	2.9	0.0	26.0
D_PHONE	1.0	0.2	0.0	1.0
D_MARKET	0.1	0.3	0.0	1.0
LAND	19872.9	22774.8	0.0	400000.0
# PLOTS (NB)	3.0	2.0	0.0	18.0

Note: NB = number