Crop Diversity as a Strategy for Adaptation to Climate Change: Insights from Uganda Panel Data.

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Motivation

Bridging the limited knowledge on how farmers are responding to the effects of climatic shocks and how they have adjusted their farming practices to cope with the climate change.

Background

- Many consequences of climate change such as droughts, heat waves, floods and increases in storms intensify risks at economical, environmental and social level in agriculture-based economies existing in Sub-Saharan Africa (SSA).
- People depending on farming activities will require a **variety of adaptation strategies** to mitigate the negative impacts of climate change effects and to maintain the livelihoods of farming families (Phiri and Saka, 2008; Bezabih et al., 2010 ;Gao and Mills, 2017).

Country Overview

- **Uganda** is a landlocked country in Sub-Saharan Africa; it has some of the most fertile land in East Africa and it deeply relies on agricultural sector (USAID 2012).
- Ugandas **climate varies regionally**, with tropical rainforests in the south and drier savannah woodlands and semi-desert vegetation in the north.It almost everywhere presents **two rainy seasons**.
- Due to **climate change**, Uganda has recently experienced an increase in the frequency and intensity of droughts and floods.

Research Question

- To what extent farmers use crop and income diversification as self-protection measures against climatic and idiosyncratic shocks?

Conceptual Framework

The sustainable rural livelihood framework (SRL): analysis of the strategic choices made by a farmer i to manage his welfare level W_i, t at a specific time t (Ellis, 2000).

- Adapting SRL framework by considering a rural HH as a decision-making unit whose reaction to exogenous climatic and market shocks is correlated with a vector of idiosyncratic characteristics and the past, long or short term experience with such shocks (Mertz et al., 2009).
- SRL combined with a simplified **non-separable household** (NSH) model (Wouterse Taylor, 2008; De Janvry et al., 1991) and the **permanent income theory** (Gao and Mills, 2018) to investigate the timing and the impact of diversification on the rural welfare, conditional to weather and market shocks.
- HHs welfare is represented as a random outcome function of income and crop diversification ($D^{income}_{i,t}$ and $D^{crop}_{i,t}$), set up to minimise the income gap from a permanent income level ($W_{i,t} - \overline{W}$), according to the HHs endowment $K_{i,t}$:

$$\begin{cases} \mathrm{D}^{income}_{i,t} = f(S^C_{i,t-\tau}; S^M_{i,t-\tau}; S^C_{i,t}; S^M_{i,t}; K_{i,t}; v) \\ \mathrm{D}^{crop}_{i,t} = f(S^C_{i,t-\tau}; S^M_{i,t-\tau}; S^C_{i,t}; S^M_{i,t}; K_{i,t}; u). \end{cases} \tag{1}$$

- $S^C_{i,t-\tau}$ and $S^M_{i,t-\tau}$ = relative frequency of past climatic and market shocks experienced by farmer i over a time span $t - \tau$ (impact on decision to adapt ex-ante).
- $S^C_{i,t}$ and $S^M_{i,t}$ = contemporaneous shocks (cause the implementation of ex-post coping strategies that should impact also on welfare outcome in reducing vulnerability).
- v and u are unobserved time variant and invariant drivers of income and crop diversification.
- z unobserved time variant and invariant characteristics that impact on the income gap.

Descriptive statistics

DATA: longitudinal data of Ugandan rural households from **World-Bank Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA)** for the years 2009-10, 2010-11, 2011-12.

Global Land Data Assimilation System (GLDAS) (version 2.0 and 2.1): global gridded reanalysis dataset made publicly available by NASA's climate division (Rodell et al., 2004a). Indicators used:temperatures maximum, mean and daily, rainfall, **SPEI, SPI, CDD, WSDI, HDD, CWD**

Transition tables

Number of crops				
2009	Mean	SD	Min	Max
	4.88	2.04	1.00	17.00
2010	5.09	1.97	1.00	16.00
2011	4.58	1.85	1.00	16.00

Transition	From 2009 to 2010	From 2010 to 2011
HHs' percentage with the same number of crops	21.89	21.61
HHs' percentage which increase the number of crops	43.36	27.48
HHs' percentage which decrease the number of crops	34.76	50.91

Figure: **Crops transition table** .

Empirical Strategy

Panel Multinomial Endogenous Switching regression (PMES) model (Murtazashvili and Wooldridge, 2016). A 2-steps approach.

In a **first step** a multinomial logit model is estimated on a categorical selection equation representing all the combinations of different levels of crop and income diversification:

- $D^{income}_{i,t}$ is categorized as **0** if the farmer relies only on on-farm income; **1** if she/he relies on additional income sources.
- $D^{crop}_{i,t}$ assumes three values: : **0** for no crop diversification, **1** for low crop diversification and **2** for high crop
- $D^{j}_{i,t}$ is the multinomial treatment variable built by allowing for all the potential combinations of $D^{income}_{i,t}$ and $D^{crop}_{i,t}$ ($D^{j}_{i,t}$= 0,1,2,3,4,5)

Probability that a farmer i adopts a diversification mix level j :

$$Prob(\mathrm{j}|H_{i,t}; S^C_{i,t-\tau}; S^M_{i,t-\tau}; \mu_i) = \frac{exp(\alpha_j + H_{i,t}\beta_j + S^C_{ea,t-\tau}\gamma_j + S^M_{ea,t-\tau}\delta_j + \bar{h}_i\Gamma^j)}{\sum_{k \neq j} exp(\alpha_k + H_{i,t}\beta_k + S^C_{ea,t-\tau}\gamma_k + S^M_{ea,t-\tau}\delta_k + \bar{h}_i\Gamma^k)}. \tag{2}$$

$H_{i,t}$ is a matrix containing the asset endowments $K_{i,t}$ at the HHs' level;$S^C_{ea,t-\tau}$ and $S^M_{ea,t-\tau}$ represent the past observed shocks at enumeration area level

In the second step, welfare outcome equations$W^j_{i,t}$ are estimated separately through an OLS and controlling for the endogeneity of the diversification level adopted. The 6 regimes result as follows:

$$\begin{cases} \mathrm{W}^0_{i,t} = \alpha^0_{i,t} + H^0_{i,t}\Phi^0 + \bar{h}_i\Gamma^0 + \hat{\lambda}_i\Omega^0 + {}^\wedge lambda^0_i\Psi^0 + \epsilon^0_{i,t} \\ \vdots \\ \mathrm{W}^5_{i,t} = \alpha^5_{i,t} + H^5_{i,t}\Phi^0 + \bar{h}_i\Gamma^5 + \hat{\lambda}_i\Omega^5 + \hat{\lambda}^5_i\Psi^5 + \epsilon^5_{i,t}. \end{cases} \tag{3}$$

λ^5_i is the IMRs estimated that is also interacted with time dummies to control for time trend which could drive selection probability;$\Omega^j$and Ψ^j represent the covariance between selection and outcome equations, $\epsilon^j_{i,t}$ normal distributed errors.

Through PMES it is possible to assess the **average treatment effects (ATE)** of the adoption of a diversification practice with respect to the other diversification. It is given by the difference of welfare between the actual adoption choice and a counterfactual.

The **ATE** is thus the welfare outcome that adopters would have if they decided to not adopt any level of income and crop diversification and is equal to:

$$E[W^j_{i,t}|j = J] - E[W^0_{i,t}|j = J] \tag{4}$$

Preliminary Results

$$Model1 : ln(ci_{it}) = \alpha + \mathbf{X}\beta_1 + \beta_2 Sh_i t + \mathbf{H}\beta_3\mathbf{H}\beta_{3\mathbf{H}\beta_{3\mathbf{H}\beta_3 +}}$$

$$Model2 : ln(toti_{it}) = \alpha + \mathbf{X}\beta_1 + \beta_2 Sh_i t + \mathbf{H}\ \beta_3\mathbf{H}\ \beta_{3\mathbf{H}}\ \beta_{3\mathbf{H}\ \beta_3 +}$$

$$Model3 : ln(fi_{it}) = \alpha + \mathbf{X}\beta_1 + \beta_2 Sh_i t + \mathbf{H}\beta_3\mathbf{H}\beta_{3\mathbf{H}\beta_{3\mathbf{H}\beta_3 +}}$$

Panel data results

VARIABLES	Model (1)	Model (2)	Model (3)
Household characteristics and Market			
Number of people in the hh	-0.00261	0.00160*	0.000661
	-0.633	1.844	0.131
HH Distance in (KMs) to Nearest Population Center with +20,000	0.000780	-0.000445	-0.0118***
	0.313	-1.050	-2.855
HH Distance in (KMs) to Nearest Market	-0.00476	-0.000256	0.0117**
	-1.585	-0.420	2.186
Land characteristics			
Area planted in hectares	0.0421***	0.00407**	0.0119
	4.864	2.024	0.943
Irrigation as water source(1=yes)	0.0824**	-0.00779	-0.159***
	2.167	-0.762	-2.836
Have you any problem with erosion?(1=yes)	-0.00467	-0.00428	0.0220
	-0.294	-1.004	0.940
Use of intercropping (1=yes)	0.0140	0.00414	0.0187
	0.995	0.956	0.744
Shannon Index	0.0264*	-0.00289	0.0107
	1.946	-0.556	0.454
Inputs			
Labor use (adult days)	0.0742***	-0.00125	0.00176
	7.973	-0.419	0.127
Organic fertilisers (1=yes)	-0.000473	0.00634	-0.0211
	-0.0221	1.338	-0.768
Chemical fertilisers (1=yes)	0.0178	0.00150	0.0185
	0.610	0.182	0.499
Total livestock in TLU	-0.000217	-0.000148	-0.000717
	-0.905	-1.061	-1.507
Extension services and shocks			
Agricultural shocks (1=yes)	-0.0216	0.00396	0.115***
	-0.707	0.567	3.130
Market shocks (1=yes)	0.0602**	0.0146	0.0134
	2.002	1.583	0.290
Health shocks (1=yes)	-0.00660	0.00626*	0.0806***
	-0.413	1.763	3.463
Advice & information (1=yes)	0.00930	0.00112	-0.00763
	0.735	0.352	-0.389
Year			
2010	0.0535***	0.00201	-0.255***
	3.863	0.553	-10.77
2011	0.225***	0.00887*	-0.246***
	13.14	1.880	-8.433

Figure: agricultural and social variables

VARIABLES	(1)	(2)	(3)
Climatic factors			
Total annual Precipitation (mm)	-0.0168	0.0183***	-0.00693
	-0.797	2.649	-0.188
Square of Total annual Precipitation (mm)	0.00125	-0.000794***	-0.000249
	1.516	-3.008	-0.167
Rainfall (mm) in wettest quarter within Jan-Dec	0.0687**	-0.0113	0.0414
	2.085	-1.189	0.732
Square of Rainfall (mm) in wettest quarter within Jan-Dec	-0.00934***	0.00111	-0.00415
	-3.017	1.268	-0.761
Precipitation variance	12.60***	3.039***	7.321
Constant	13.49***	17.24***	0.348
	94.35	404.5	1.298
Observations	4,277	4,277	4,278
R-squared	0.192	0.015	0.167
Number of hhid	1,430	1,430	1,430
rho	0.470	0.441	0.533
Hausman Test - chi2(20)	232.66	192.09	140.17
Prob>chi2	0.00	0.00	0.00

Figure: climatic variables

Conclusions

- Crop diversification strategies might increase crop income;
- Irrigation affects positively total annual income;
- Total annual precipitations and rainfall in wettest quarter have a nonlinear relationship with income: the path is positive only up to a certain threshold, after which the effect is negative;
- Precipitation variance positively impacts the income. The result apparently controintuitive does not take into account interaction with temperature variables.

Work in progress

- Expanding panel to four waves;
- Making use of a model taking endogeneity into account (PMES);
- Including access to credit and overall market constraint factors;
- Improving the study by using more sophisticated climatic indicators (GLDAS).

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