Crop and income diversity as adaptation strategies to cope with climatic shocks: insights from Uganda panel data.

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Climate change in rural economies

Weather shocks intensify risks at economical, environmental and social level in agriculture-based economies in Sub-Saharan Africa (SSA).

* Rural households will require a variety of adaptation strategies to mitigate the negative impacts and to maintain their livelihoods (Ellis, 2000).
* Specific adaptation strategies: changing the timing of planting, use of heat and drought- resistant varieties, practicing conservation techniques, fertilizer use, irrigation and diversification to non-farm activities (Phiri and Saka, 2008; Bezabih et al., 2010; Gao and Mills, 2017) .
* Agriculture technologies adoption needs a **multivariate model**, as a single technology has proven to be ineffective without interrelated technologies and complementary practices (Kassie et al., 2013; Teklewold et al., 2013)

- Environmental factors can influence crop portfolios. Farmers are forced to change agricultural practices and find **crops and varieties better adapted** to new weather dynamics (Meldrum et al., 2017).
- Still, there is limited knowledge on **how farmers are responding** to the effects of a changing weather pattern and **how they adjust their farming practices** to cope with that.
- Aim: exploring to what extent farmers use diversification as a self-protection measure against weather shocks.
- Country choice: Uganda, a challenging environment for agriculture due to the frequency and severity of extreme climate events.

Country overview

Uganda has recently experienced an increase in the frequency and intensity of droughts and floods.

- 80% of Uganda population lives in rural areas.
- Most of the country receives rains twice a year, providing for two major harvests in July/August and December (UBOS, 2016).
- Agricultural sector accounts for 20% of GDP, it is mainly rainfed and employs 70% of the labour force (USAID, 2012).
- Multiple impacts of climatic shocks on Uganda (increase in average maximum and minimum temperatures, variability in rainfall, regular severe droughts, receding and falling water levels, increasing incidences of malaria).

Contribution

This study attempts to further the present field-specific research by:

* Broadening the knowledge on how farmers are responding to the effects of a changing climate and how they have adjusted their farming practices to cope with the changes in climate;
* Applying a recently-developed empirical strategy [Kassie et al, 2018; Bourguignon et al, 2007];
* Implementing the research on four waves (most commonly implemented on shorter panels -2 or 3 waves).

- **To what extent do farmers use crop and income diversity as a self-protection measure against climatic shocks?**
- **What is the value-added gained by a household through diversifying income and agricultural practices ?**

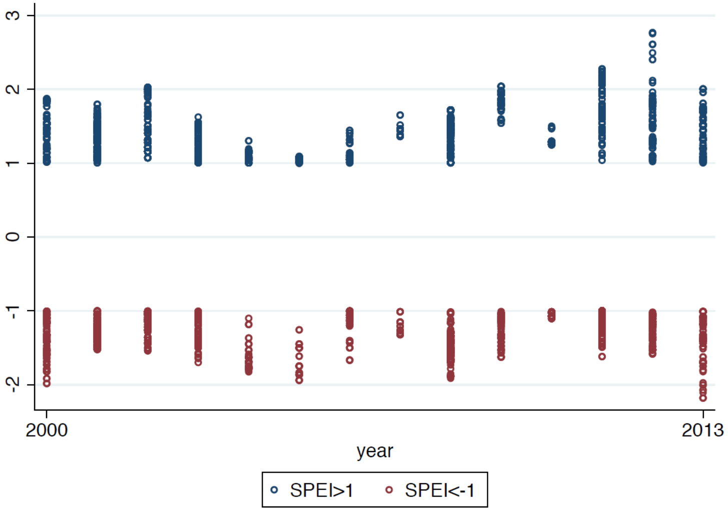
Data

Agricultural and socio-demographic data are collected from:
Longitudinal data of Ugandan rural households from World-Bank Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) for the years 2009-14.

Climate data and climatic-shocks indicators main source is:
Global Land Data Assimilation System (GLDAS) (Version 2.0 and 2.1): global gridded reanalysis dataset by NASA (Rodell et al., 2004a). Time series 1948-2017.

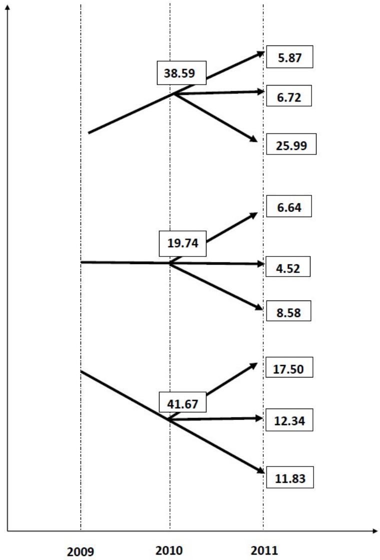
* Spatial resolution: $0.25^\circ \times 0.25^\circ$.
* Variables available at yearly, monthly, weekly, daily and sub-daily resolution.
* SPI and SPEI are drought indicators computed using temperature and precipitation. Usually computed on 6, 12 or 24 time scales.

Climate variability



Figur: *Uganda SPEI time series from 2000 to 2013*

Conditional crop transition table



Theoretical framework

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

- Consider a rural household 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) allows investigation of the timing and the impact of diversification on the rural welfare, conditional to weather and market shocks.

Theoretical framework

- **Households' welfare**: random outcome function of income and crop diversification ($D^{income}_{i,t}$ and $D^{crop}_{i,t}$), set up to minimize the income gap from a permanent income level ($W_{i,t} - \overline{W}$), according to the households' endowment $K_{i,t}$:

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

$$(W_{i,t} - \overline{W}) = f[(D^{income}_{i,t}, D^{crop}_{i,t}); S^C_{i,t}; S^M_{i,t}; K_{i,t}; z] \quad (2)$$

* $S^C_{i,t-\tau}$ 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.
* v and u are unobserved time variant and invariant drivers of income and crop diversification.
* z = unobserved time variant and invariant characteristics impacting on the income gap.

Estimation strategy

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

Estimation strategy

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

$$Prob(j|H_{i,t}; S^C_{i,t-\tau}; S^M_{i,t-\tau}; M_i) = \frac{exp(\alpha_j + H_{i,t}\beta_j + S^C_{i,t-\tau}\gamma_j + S^M_{i,t-\tau}\delta_j + M_i\Gamma^j)}{\sum_{k \neq j} exp(\alpha_k + H_{i,t}\beta_k + S^C_{i,t-\tau}\gamma_k + S^M_{i,t-\tau}\delta_k + M_i\Gamma^k)} \quad (3)$$

$$\text{for all } j = 0, 1, 2, 3, 4, 5$$

* $H_{i,t}$ = matrix containing the asset endowments $K_{i,t}$ and other observable characteristics at the HHs' level
* $S^C_{i,t-\tau}$ = past observed climatic shocks at HH's level;
* $S^M_{i,t-\tau}$ = past observed market shocks at HH's level;
* M_i = Mundlak devices representing time-constant unobserved heterogeneity terms;
* $\beta_j, \gamma_j, \delta_j, \Gamma^j$ = unknown parameters to be estimated.

Estimation strategy

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

$$\begin{cases} W_{i,t}^{0} = \alpha_{i,t}^{0} + H_{i,t}^{0}\Phi^{0} + M_{i}\Gamma^{0} + \hat{\lambda}_{i}^{0}\Omega^{0} + (\hat{\lambda}_{i}^{0}T)\zeta^{0} + \epsilon_{i,t}^{0} \\ \vdots \\ W_{i,t}^{5} = \alpha_{i,t}^{5} + H_{i,t}^{5}\Phi^{0} + M_{i}\Gamma^{5} + \hat{\lambda}_{i}^{5}\Omega^{5} + (\hat{\lambda}_{i}^{5}T)\zeta^{5} + \epsilon_{i,t}^{5}. \end{cases} \quad (4)$$

* λ_i = Inverse Mills Ratios (IMR), estimated from the first-step multinomial logit using the Durbin and McFadden formula (Bourguignon et al., 2007);
* Ω^{j} = covariance between error terms of diversification and outcome equations;
* $\epsilon_{i,t}^{j}$ = normally distributed errors.

Estimation strategy

- Through the MESR it is possible to assess the **average treatment effects on treated (ATT)** of the adoption of a diversification practice with respect to the other diversification levels - the difference of welfare between the actual adoption choice and a counterfactual scenario of adoption choice. The actual expected outcomes are:

$$\begin{cases} \mathrm{E}[\mathrm{W}^1_{i,t}|j=1] = \alpha^1_{i,t} + H^1_{i,t}\Phi^1 + M_i\Gamma^1 + \hat{\lambda}^1_i\Omega^1 + (\hat{\lambda}^1_i T)\zeta^1 \\ \vdots \\ \mathrm{E}[\mathrm{W}^5_{i,t}|j=5] = \alpha^5_{i,t} + H^5_{i,t}\Phi^5 + M_i\Gamma^5 + \hat{\lambda}^5_i\Omega^5 + (\hat{\lambda}^5_i T)\zeta^5. \end{cases} \quad (5)$$

- The counterfactual outcomes are obtained by plugging into the previous set of equations the coefficients obtained from the estimation of W without diversification (j = 0)
- The ATT will be given by:

$$E[W^j_{i,t}|j=J] - E[W^0_{i,t}|j=J] \quad (6)$$

First step - Multinomial logit

First stage - Diversification, SPEI<-1.3

	1C-0I	2C-0I	0C-1I	1C-1I	2C-1I
Climatic past shocks	7.953**	9.653***	-0.921	5.554*	8.741***
	(3.220)	(3.240)	(4.668)	(3.261)	(3.262)
SPEI<-1	-0.081	-0.153	-0.355**	-0.131	-0.068
	(0.127)	(0.134)	(0.171)	(0.129)	(0.139)
SPEI>1	-0.011	0.007	0.024	-0.090	-0.009
	(0.135)	(0.137)	(0.199)	(0.138)	(0.140)
Yearly average temperature	-4.831	-10.038	25.213	0.258	3.019
	(22.638)	(24.124)	(28.127)	(22.837)	(25.110)

Eq. include hhd size, avg education, female hhd head, hhd head age, wealth, cellphone, distance from nearest market, maize and beans dummies.
Mundlak correction and dummy years included.
All the variables in logarithms.
Standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Second step - Pooled OLS

Consumption (log)

	0C-0I	1C-0I	2C-0I	0C-1I	1C-1I	2C-1I
SPEI<-1	-0.219**	-0.094**	-0.020	-0.144	-0.062**	0.006
	(0.105)	(0.037)	(0.044)	(0.163)	(0.029)	(0.042)
SPEI>1	0.119	0.037	-0.014	0.176	0.011	-0.046*
	(0.150)	(0.040)	(0.022)	(0.198)	(0.033)	(0.028)
Average annual temperature	-35.734	-10.722*	2.453	73.791	10.478	0.403
	(37.534)	(5.931)	(3.678)	(148.015)	(9.789)	(5.337)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Bootstraped SE in parenthesis, nreps(500).
Mundlak correction and dummy years included.
IMRs from the first stage multinomial logit are included.

Total income (log)

	0C-0I	1C-0I	2C-0I	0C-1I	1C-1I	2C-1I
SPEI<-1	-0.480**	-0.090*	-0.096	-0.080	0.006	-0.089*
	(0.196)	(0.056)	(0.075)	(0.217)	(0.041)	(0.054)
SPEI>1	-0.182	0.033	-0.059*	0.087	0.030	-0.065*
	(0.213)	(0.038)	(0.032)	(0.230)	(0.045)	(0.038)
Average annual temperature	-2.925	-6.999	11.711**	6.843	15.693*	-18.654
	(49.214)	(10.139)	(5.555)	(190.004)	(8.510)	(12.582)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Bootstraped SE in parenthesis, nreps(500).
Mundlak correction and dummy years included.
IMRs from the first stage multinomial logit are included.

Average Treatment Effects on the Treated

	(1) Diversification	(2) No diversification	ATE	se	(%)
Consumption (Ug Sh.)					
1C-0I	288514	252693	35821***	(11125)	14.2
2C-0I	320456	281135	39321***	(7921)	14
0C-1I	501089	448534	52555***	(7184)	11.7
1C-1I	463175	403854	59321***	(8012)	14.7
2C-1I	567440	505119	62321***	(9251)	12.3

*** $p < 0.01$

	(1) Diversification	(2) No diversification	ATE	se	(%)
Total Income (Ug Sh.)					
1C-0I	1342964	1188901	154063***	(31064)	11.5
2C-0I	1519102	1299024	220078***	(19521)	14.5
0C-1I	2266574	1925654	340920***	(55761)	15
1C-1I	2761460	2298987	462473***	(80451)	16.7
2C-1I	2156204	1859775	296429***	(108999)	13.7

*** $p < 0.01$

Preliminary remarks

- Households who experienced past climatic shocks are more likely to diversify;
- Contemporaneous shocks (droughts) negatively affect consumption and income;
- Crop and income diversification strategies when used jointly might increase consumption and total income.

Further developments

* Adding the fourth wave (2013/2014);
* Sensitivity analysis through access to credit information;
* Computing farmer's risk indicator as the (negative) distance of their actual income from the permanent income.