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## INTRODUCTION

Weather disturbances because of climate change exacerbate annual fluctuations in food availability and can increase price volatility, with its negative effects on agricultural production. Weather shocks result in food price shocks and price shocks, in turn, affect agricultural supply. In this context, the objective of this study is to analyze the interdependent effects of weather disturbances, evolution and price instability on the supply of the main food crops (corn, sorghum, millet, rice, yam, cassava, bean and groundnut) in Togo over the period 1988-2016

## MATERIAL AND METHODS

### Theoretical framework

The basic model is that of Nerlove (1958). Using a stochastic production function (Just and Pope, 1979):

$$Q_{it} = f(X_{it}, \varphi) + h_{it}(X_{it}, \emptyset) + \varepsilon_{it} \quad (1)$$

Estimated variance (Haile et al., 2017):

$$Q_{it} = f(X_{it}, \varphi) + \mu_{it}; E(\mu_{it}) = 0; E(\mu_{it}\mu_{is}) = 0, \text{ with } i \neq s; Q_{it} = E(\mu_{it}^2) = \exp[W'_{it}\emptyset] \quad (2)$$

### Empirical framework

Estimated log-linear supply model (Haile et al., 2017):

$$Q_{cit} = \alpha_c + \beta_c PR_{cit} + \tau_c CL_{cit} + \varphi_c X_{cit} + \vartheta_c T_{cit} + \eta_{ci} + \mu_{cit}(3)$$

The squared waste logarithm (Just and Pope., 1978) ( $\ln[\hat{\mu}_{cit}^2]$ ) of equation (3) is used as a measure of supply variance:

$$VQ_{cit} = \alpha'_c + B'_c W_{cit} + \vartheta'_c T_{cit} + \eta'_{ci} + \varepsilon_{cit} \quad (4)$$

The equation (3) is estimated with two stage least squares (2SLS) method. Equation (4) is estimated using ordinary least squares method because the residues are already purged of fixed effects. Interannual price volatility is measured as a standard deviation of the logarithmic changes of annual prices with respect to a five-years average (Santeramo and Lamonaca, 2019):

$$\sigma_t^{t,i} = \sqrt{(\Delta P_t^{t,i} - \Delta_5 P_t^{t,i})^2} \quad (5)$$

## RESULTS

**Table 1: Determinants of food supply (dependent variable: log (production)) FEIV**

Variables	Maize	Sorghum	Millet	Rice	Yam	Cassava	Bean	Groundnut
Own crop price	0.279***(0.121)	0.361*** (0.140)	-0.859*** (0.236)	0.855*** (0.319)	-0.760*** (0.154)	-0.126(0.116)	1.157*** (0.293)	-0.041(0.162)
Own price volatility	-0.077***(0.035)	-0.032(0.039)	-0.079***(0.040)	0.071*(0.041)	-0.036(0.038)	0.052*** (0.020)	-0.013(0.049)	-0.049***(0.023)
Acreage		0.906*** (0.042)	0.546*** (0.107)	0.698*** (0.075)	0.744*** (0.061)	0.717*** (0.085)		0.779*** (0.049)
Min. temp. RS					4.495*** (1.235)	-6.298** (2.686)		
Temp. threshold RS	-0.232***(0.097)		0.523*** (0.127)					
Max. temp. SP	7.597*** (2.421)	3.229(2.399)		-6.749** (3.012)				
Rainfall RS		0.030*** (0.011)	0.117*** (0.041)		0.034** (0.0134)	-0.004** (0.001)		0.004** (0.001)
Rainfall days RS	-0.056***(0.027)			0.674*** (0.250)				
Rainfall Anomaly RS		-0.649*** (0.240)	-1.254*** (0.356)		-0.511** (0.211)		-0.271*** (0.068)	
Rainfall SP		-0.026*** (0.010)	-0.037*** (0.013)				-0.022*** (0.007)	-0.003** (0.001)
Rainfall anomaly SP		0.737** (0.292)		0.284* (0.165)		-0.400** (0.178)	0.579** (0.274)	
Insolation RS	-3.205*** (1.146)		0.039*** (0.012)	-2.580* (1.514)	-3.343*** (1.017)			-0.184** (0.084)
Wind speed RS					1.311*** (0.445)		-2.215** (1.078)	
Max. humidity RS		-0.051** (0.024)		-1.393*** (0.527)		-3.293*** (1.072)	-1.839** (0.786)	
Max. humidity SP					-0.241*** (0.072)	-2.088*** (0.710)		
Mean SP humidity	0.066*** (0.017)		4.296*** (0.807)		0.294*** (0.080)			0.575*** (0.179)
Trend	0.101*** (0.016)	0.039*** (0.015)	-0.083*** (0.026)	0.149*** (0.023)	0.004(0.004)	0.005(0.007)	0.113*** (0.009)	
(Min. temp. RS) <sup>2</sup>					-0.105*** (0.028)			-0.061** (0.028)
(Max. temp. SP) <sup>2</sup>	-0.123*** (0.039)	-0.063* (0.038)		0.101** (0.050)				
(Wind speed RS) <sup>2</sup>					-0.297*** (0.111)		0.625** (0.276)	
(Max. humidity RS) <sup>2</sup>						0.017*** (0.005)	0.010** (0.004)	
(Max. humidity SP) <sup>2</sup>					0.002*** (0.0005)	0.013*** (0.004)		
N	135	135	54	108	135	108	135	135
R-squared	0.766	0.850	0.726	0.809	0.734	0.843	0.701	0.796
Anderson canon. corr. LM statistic	74.014	51.737	38.475	41.117	28.987	50.035	92.654	68.447
Sargan statistic	33.897	22.882	29.427	27.201	22.507	29.273	60.838	42.456
Number of regions	5	5	2	4	5	4	5	5

**Table 2: Determinants of variance of food supply (dependent variable: log (production variance))**

Variables	Maize	Sorghum	Millet	Rice	Yam	Cassava	Bean	Groundnut
Own crop price	-0.494*** (0.069)	-0.715*** (0.014)	1.013*** (0.251)	-1.634*** (0.092)	1.331*** (0.066)	0.251*** (2.82e-08)	-1.836*** (0.195)	0.081*** (2.89e-08)
Own price volatility	0.152*** (0.016)	0.062*** (0.003)	0.143*** (0.044)	-0.139*** (0.011)	0.068*** (0.013)	-0.104*** (4.98e-09)	0.035(0.027)	0.098*** (4.20e-09)
Mean temp. SP	11.86*** (1.418)	3.941*** (0.321)	-0.682*** (0.151)	-6.310*** (1.587)				
Rainfall RS		-0.063*** (0.001)	-0.145*** (0.050)	-1.049*** (0.101)				
Rainfall days RS					-0.068*** (0.018)	-0.115*** (9.74e-09)		0.517*** (3.42e-08)
Rainfall SP		0.056*** (0.001)	0.028* (0.015)	-0.002*** (0.0004)				
Insolation RS	6.205*** (0.736)		-0.061*** (0.015)	5.419*** (0.638)	6.037*** (0.739)	3.535*** (3.22e-07)	0.439*** (0.106)	0.369*** (1.99e-08)
Max. humidity RS	-3.416*** (0.469)	0.106*** (0.003)		2.559*** (0.219)				
Mean RS humidity					-1.376*** (0.349)	-6.166*** (3.22e-07)		-0.079*** (4.46e-09)
Max. humidity SP					0.415*** (0.050)	4.176*** (2.32e-07)	-4.860*** (0.820)	0.107*** (6.71e-09)
Mean SP humidity					-0.494*** (0.056)	-7.590*** (4.19e-07)	6.854*** (1.091)	-1.149*** (4.43e-08)
Trend	-0.207*** (0.012)	-0.079*** (0.002)	0.147*** (0.034)	-0.278*** (0.010)	-0.002(0.002)	-0.009*** (2.20e-09)	-0.190*** (0.008)	
(Mean temp. RS) <sup>2</sup>	-0.146** (0.061)	0.031*** (0.009)	0.013(0.007)	0.110*** (0.031)			0.185*** (0.048)	0.120*** (1.35e-08)
(Mean SP humidity) <sup>2</sup>					0.005*** (0.0007)	0.056*** (2.96e-09)	-0.046*** (0.007)	0.008*** (3.06e-10)
Supply	1.841*** (0.080)	1.993*** (0.011)	1.563*** (0.157)	1.929*** (0.042)	1.779*** (0.070)	2.000*** (3.12e-08)	1.890*** (0.094)	2.000*** (2.10e-08)
Acreage	0.033(0.091)	-1.804*** (0.011)	-0.714*** (0.146)	-1.349*** (0.043)	-1.314*** (0.067)	-1.433*** (3.53e-08)	-0.127(0.113)	-1.557*** (2.02e-08)
Kara	1.436*** (0.102)	0.800*** (0.018)		0.916*** (0.080)	1.603*** (0.162)	0.838*** (4.95e-08)	14.07*** (3.830)	-0.417*** (3.90e-08)
Maritime	-0.926*** (0.200)	0.838*** (0.118)			1.394*** (0.330)	-1.523*** (1.28e-07)	14.66*** (3.833)	0.793*** (7.27e-08)
Plateaux	-1.297*** (0.160)	-0.419*** (0.064)		0.638*** (0.133)	1.141*** (0.229)	-0.947*** (7.95e-08)	13.22*** (3.801)	0.770*** (5.92e-08)
Savanes	0.405*** (0.104)	1.016*** (0.038)	-4.044*** (0.658)	-2.301*** (0.111)	1.847*** (0.176)		11.19*** (3.831)	-0.697*** (5.04e-08)
Constante	79.91*** (25.26)	13.84*** (4.96)	-58.04(34.40)	-231.7*** (17.36)	71.39*** (13.31)	-30.20*** (1.50e-05)	-16.75(45.61)	36.27*** (7.63e-06)
N	135	135	54	108	135	108	135	135
R-squared	0.924	0.997	0.807	0.964	0.887	1.000	0.906	1.000

Notes: Asterisks \*, \*\* and \*\*\* represent the meaning levels of 10%, 5% and 1%. Coefficient (Standard Error). RS: rainy season. SP: sowing period. Excluded instruments: Ending stocks and stocks variations (regional and national); net import; weather variables; food production index and offset real exchange rate index. All IVs are lagged.

## CONCLUSION

Climate change has varied effects on the food crops studied. However, the negative effects outweigh the positive ones. Extreme weather shocks during the rainy season and the sowing period have adverse effects on the supply of food crops. In addition, climate change is exacerbating food product price volatility. This food products prices volatility has a negative effect on food crop production, indicating that food producers are risk averse. While price volatility plays a deterrent role, price developments encourage production. The effects of climate change on food supply vary across agroecological regions. It is found that, on average, the variation in food supply in the Sudanese climate regions (Savanes and Kara) and in the Guinean climate regions (Plateaux and Maritime) is greater than the variation in the Region with a Sudan-Guinean climate (Central). Extreme weather events therefore exacerbate annual fluctuations in food availability and further increase price volatility, with its negative effects on food supply and its fluctuation. Through the linear trend, it is also noted that improvements in agricultural technology and practices have stimulated food production and reduced its interannual fluctuations.

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