Climate Instability and Agricultural Productivity in Africa: Cross-Country Evidence

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Abstract

This paper analyzes the impact of rainfall instability on crop yield in Sub-Saharan Africa. Using a large panel of African countries over a sufficiently long period and relying on a very large dataset assembled for the agricultural sector in Africa, the paper tests whether agricultural research and development, and modern infrastructure provide such dampening effects in a context of rising climate instability and stagnating farm productivity in Africa. The results demonstrate a key and robust effect of greater investments in agricultural science and technology in dampening the effect on the link between rainfall instability on crop yield volatility in Sub-Saharan Africa. Effort should therefore be on boosting the availability of researchers specialized in agricultural science and technology and on agricultural infrastructure such as irrigation to help farmers cope better with the increased risks stemming from global warming.

Keywords: *Rainfall; Crop yield; Instability; Innovation; Infrastructure*

JEL classification codes : *Q54 ; Q16 ; O13*

1. Introduction

A key driver of poverty reduction in Africa is agricultural sector growth. Christiaensen et al. (2011) show that agriculture is significantly more effective in reducing poverty among the poorest of the poor. Despite its importance, agriculture is being challenged in Africa on several fronts. Productivity is very low, reflecting a conjunction of factors ranging from the large prevalence of smallholders (more than 60% of the population of Sub-Saharan Africa is smallholder farmers), traditional and manual approach of smallholder farmers, lack of infrastructure, limited innovation, financial constraints, and the instability of the weather.

This paper focuses on this latter challenge, the adverse effect of climate instability on the African agricultural sector. Increasing climate variability and extremes have been identified as one of the key drivers behind the recent rise in global hunger and a leading cause of severe food crises (FAO, 2018). The impact of climate change on Africa is likely to be severe (Barrios et al., 2008) due to the high agricultural dependence and the limited capacity to adapt (Collier et al., 2008). Natural disasters and extreme weather events are making it more difficult to grow crops, raise animals and earn a living, and rural areas across Africa are feeling the effects most acutely. The excessive variability of rainfall in Sub-Saharan Africa is also negatively associated with an elevated risk aversion and lower agricultural investments by farmers (di Falco, 2014).

According to statistics provided by the Food and Agriculture Organization (FAO), since 1990, cereal yields have increased by 164% in Brazil, 81% in Uruguay, and by 43% in Malaysia, while average African cereal yields grew by less than 40%. As a result, Africa's yields are only 56% of the international average. Africa currently holds the highest prevalence of the world's undernourished people and the continent will double in population to hold an estimated 2.5 billion of the world's nearly 10 billion people by 2050. An erratic climate will therefore disproportionally affect small-scale farmers who rely on consistent yields to earn a living. Climate change is expected to increase food prices, reduce food availability, and reduce the incomes and food production of smallholder farmers.

African farmers are increasingly susceptible to climate change-induced fluctuations in rainfall and temperature, with major African staple crops expected to have 8-22% lower yields by 2050. Only 6% of the continent's farmland is irrigated. In contrast, it is 37% in Asia, according to FAO estimates.

Together with small islands and developing states (SIDS), African countries are assessed as very vulnerable to climate risks. The (physical) index of vulnerability to climate shocks computed by the FERDI captures two types of risks related to climate change: the risks of an increase in the intensity of recurrent shocks (in temperature, rainfall, and storms), and the long-term risks of progressive shocks (such as flooding due to higher sea level, or desertification).[4] Of the 15 most vulnerable Least Developing Countries (LDCs) in the world, 12 are in Africa (all in Sub-Saharan Africa). Sudan, Mauritania, Niger, Chad, and Eritrea are the most vulnerable in both the LDCs group and the African countries group.

The reinforcing challenge of climate change means that there is need to increase the use of climate-smart agriculture (CSA)—agriculture centred on efficient input use, climate change resilience, and greenhouse gas emission reduction. This requires substantial investments in several areas, including on innovation. Embracing digitalization for agriculture, and seizing the potential of drones or farm machinery will not only modernize the sector, increase its attractiveness to young people, but also provide a key input to strengthening the sector's resilience to rising climate instability.[5] For example, drones, satellite imaging, remote sensors and mobile applications are recognized now as powerful instruments to prevent transboundary pests and diseases.[6] Digital innovations also help to provide meteorological and climate data to family farmers and enhance early warning and disaster risk reduction models. Technology and mobile phones are increasingly adopted in the rest of the world as a way to not only reach farmers, including in the form of climate-informed digital advisories, but also as a mechanism for data collection and analysis on soil conditions, fertilizer application, and climate change.[7]

Agricultural technology has already seen impressive uptake in the UK, US and Australia, where many growers now deploy a sophisticated range of drones, satellite data, soil sensors and internet-of-things-enabled devices. However, as the UN notes, technology has caught on more slowly in the developing world. But things are starting to improve. In Africa, a start-up scene is taking shape, which is developing technological innovation to help boost resilience and food production. Yet, obstacles such as shortage of capital, lower literacy rates in rural areas, lower internet and telephony penetration rates make the use of these digital tools challenging.[8]

Climate change also has impact on human health issues and obviously the capacity of people to work in the fields, with major implications for livelihoods based on non-mechanized farming. Globally, it is estimated that rural labour capacity fell by more than 5% between 2000 and 2016 (Watts et al., 2015). It is therefore clear that modernizing the practices via higher mechanization is clearly a way to adapt to climate change.

Obviously, innovation is more than technology and goes beyond apps, drones, or farm machinery. It also involves advisory services, market access via improved infrastructure, access to finance, and research and development (Africa needs crops that can deal with higher temperatures, flooding, and other risks). For example, solar-powered irrigation can clearly be a game changer in several areas, and so is soil testing or research to develop climate-resilient seeds, better energy supply including for cold storage, and transport infrastructure in rural areas.[9] Without access to finance on favourable terms, high-quality supplies such as improved seeds will remain out of reach to small-scale farmers. One option is to invest in databases (such as information on transaction histories) that could then be used to enable farmers to access loans.

This paper proposes a cross-country empirical examination of the policy levers to increase the resilience of the agricultural sector to climate instability in Africa. Using a large sample of African countries, the paper quantifies the contribution of various variables in dampening the sensitivity of agricultural productivity to climate shocks, approximated by the instability of rainfall from country-specific trends. The selection of these mitigating factors is dictated by the recent literature and the availability of data.

We specifically test whether the following variables act as dampening mechanisms in the agriculture-climate nexus in Africa: (i) innovation in the sector (measured by the agricultural R&D spending, the availability of researchers in agricultural science and technology); (ii) fundamental infrastructure (irrigation coverage, fertilizer use, mechanization).

We design a panel data model that allows to control for country-specific and time-invariant factors to isolate the effect of each of these above-mentioned variables in the relationship between agricultural productivity and climate instability. To our knowledge, this is the first study to provide such a comprehensive examination of what factors are key to mitigate the adverse effects of climate instability on agricultural productivity in Africa.

The rest of the paper is as follows. Section 2 presents a brief overview of the empirical literature on the effects of climate change on the agricultural sector in Africa and discusses some factors that dampen the adverse effects of climate shocks on agriculture. Section 3 presents the empirical design and the choice of data. Section 4 focuses on results. Section 5 discusses the results of the computed index of agricultural resilience to climate shocks while section 6 concludes on the key policy implications.

2. Review of existing studies

A recent comprehensive review of the latest key results from literature is done by Thornton et al. (2018). Changes in climate over the last 30 years have reduced global agricultural production in the range of 1–5% per decade globally, with particularly negative effects for tropical cereal crops such as maize and rice (Porter et al., 2014). The evidence is mounting that even at low (+2°C) levels of warming, agricultural productivity is likely to decline across the globe but particularly across tropical areas (Challinor et al., 2014). Temperature shifts are likely to change the distribution and productivity of major cash crops such as coffee and cocoa in some tropical regions (Schroth et al., 2016).

A recent study (Deutsch et al., 2018) shows that for the three most important grain crops - wheat, rice, and maize - yields lost to insects will increase by 10% to 25% per degree Celsius of warming, hitting hardest in the temperate zone. It is estimated that with a 2°C rise in temperature, insect pests could destroy maize - Africa's most essential food crop - by as much as 30% more than they do today, according to USAID (2014). These higher temperatures reduce the amount of water available for crops by drying out air and soils, leading to an increase in pest and disease, stress in livestock production and reduced labour productivity. With 4°C of warming, crop seasons in most of Sub-Saharan Africa could shrink by 20% or more (Thornton et al., 2011).

Rojas-Downing et al. (2017) review the vast literature on the impact of climate change on livestock. They conclude that livestock production will be limited by climate variability as animal water consumption is expected to increase by a factor of three, demand for agricultural lands increase due to need for 70% growth in production, and food security concern since about one-third of the global cereal harvest is used for livestock feed. The authors argue that crop and animal diversification are the most promising adaption measures, including improvements to animal feeding and genetics.

Molua et al. (2010) examined how long-term profitability of 4,000 farms vary with local climate, such as temperature and precipitation in four African countries Burkina Faso, Egypt, Kenya and South Africa. The findings suggest that climate affects agricultural returns in the four countries.

Schlenker and Lobell (2010) use a panel data for several African countries and show that by mid-century, rising temperatures would lead to aggregate agricultural production changes in SSA of −22, −17, −17, −18, and −8% for maize, sorghum, millet, groundnut, and cassava, respectively. Kurukulasuriya et al. (2006) and Kurukulasuriya and Mendelsohn (2008) use data from a survey of more than 9,000 farmers across 11 African countries through a cross-sectional approach to show that the rising temperatures lead to a significant fall in revenue from dryland crops and livestock, whereas revenue rises for irrigated crops.

Calzadilla et al. (2013) show that agricultural productivity achieves better outcomes than an expansion of irrigated area in adapting to climate change, with a 25% increase in crop yields almost completely offsetting the impact of climate change on child malnutrition in Sub-Saharan Africa. Dillon (2011) uses micro data for Mali to show that small-scale irrigation has a larger effect on agricultural production and agricultural income than large-scale irrigation, but large-scale irrigation has a larger effect on consumption per capita.

An interesting paper by Alene and Coulibaly (2009) investigates the effect of agricultural research on productivity growth and poverty reduction in Sub-Saharan Africa. The results show that agricultural research contributes significantly to productivity growth, with an aggregate rate of return of 55% while it currently reduces the number of poor people by 2.3 million or 0.8% annually. However, these impacts are not large enough to more than offset the poverty-increasing effects of population growth and environmental degradation, the potential impact of agricultural research are far greater. Doubling research investments in Sub-Saharan Africa would reduce poverty by 9% annually. However, this would not be realized without more efficient extension, credit, and input supply systems.

Past research has pointed to rural finance as a key enabler of technology change (Feder and Umali, 1993). In the face of growing climate risks, well-designed index insurance embedded in comprehensive agriculture risk management approaches need to be in place. There has been progress: some 650,000 farmers in Africa now have access to insurance (Hazell and Hess, 2017), but that is still very limited coverage given more than 40 million smallholdings in Sub-Saharan Africa alone (Lowder et al., 2016). In addition to insurance, extension of credit to farmers to adopt climate-resilient technologies and practices will also be key.

The positive impact of credit use on climate-smart agriculture adoption has been confirmed in studies of highland crops in Ethiopia (Pender and Gebremedhin, 2008), fisheries systems in Nigeria (Arimi, 2014) and soil conservation in Malawi (Marenya et al., 2014), high-yielding maize varieties in Tanzania (Arslan et al., 2016) and in Benin (Yegbemey et al., 2014). There are also studies focusing on the key role of indemnity-based or index-based insurance mechanisms in improving the incentives of farmers to adopt climate-smart agricultural practices (Brick and Visser, 2015).

3. Analytical framework and data

This paper examines the contribution of innovation, infrastructure, and finance in dampening the sensitivity of the instability of agricultural productivity to climate instability in Sub-Saharan Africa. The following specification is proposed:

$$a_{it} = (\theta_1 + \theta_2 Z_{it-5})\, Shock_{it} + \theta_3 Z_{it-5} + X_{it}^{'} \beta + u_{i.} + \gamma_t + \epsilon_{it} \qquad [1]$$

where a denotes the rolling standard deviation of the residuals of growth rate of crop yield derived from a stochastic and quadratic trend observed in a country *i*, over a period of 5 years *t*. Country fixed-effects $u_{i.}$ in the model control for all time-invariant or very slow-moving factors that drive agricultural productivity growth or its instability. These could be geographical factors (land ruggedness, country's latitude, and quality of governance). Time fixed effects are controlled for to account for common shocks to countries at each given year. These, for example, are related to fluctuations in commodity prices (such as oil prices).

- Agricultural productivity is measured by the level of crop yield (crop production per hectare harvested). Data are from the FAO statistics.

- *Shock* is the climate instability variable derived by computing the 5-year rolling standard deviation of the rainfall residuals derived from country-specific stochastic and quadratic trends. Time series of average annual rainfall in millimeters are drawn from the World Bank's Climate Change and Knowledge Portal. Later in the paper, we also propose alternative measures of rainfall variability that exploit the information contained in monthly data to focus on the instability of the rainy seasons rather than the instability of the yearly average of rainfall volumes.

- The variable Z represents the set of conditional factors in the climate-agricultural productivity nexus. It enters the model with a four-year lag to account for the fact that variables such as innovation, infrastructure or access to finance take some time to have an impact on agricultural productivity. The set of variables is chosen to assess the impact of *proximal* factors that act immediately on resilience, such as agricultural innovation, irrigation, and infrastructure. We do not focus on *underlying factors such as financing (bank credit foreign aid for agriculture) as* they will act through these proximal factors.

- Innovation: We mobilize various proxies depending on data availability: Agricultural Science, Technology, and Innovation (ASTI) spending as a percentage of agricultural value added, the ASTI researchers per 100,000 farmers, and the consumption of fertilizers in agriculture in kg per hectare and in log. The former two variables are extracted from the FAO statistical database (FAO,2020) while the latter is drawn from the World Bank (2021) tables. We expect these variables approximating for the degree of agricultural innovation to reduce the sensitivity of agricultural productivity instability to climate instability in Africa. More precisely, we expect climate shocks to positively affect productivity instability (θ_1 to be positive) and this positive effect to be dampened by agricultural innovation (θ_2 to be negative).

- Irrigation: This will be measured by the log share of agricultural land that is irrigated. The variable is extracted from the World Bank (2021).

To ensure that the model is well specified, we also control for the lagged level of economic development proxied by the log of per capita GDP.

4. Empirical results, robustness, and discussion

Baseline estimates

We start by discussing the results obtained from running traditional fixed effect estimates. The model is estimated for the sample of Sub-Saharan African countries with annual data. The panel is strongly unbalanced due to gaps in the series of conditional variables aimed at dampening the effects of climate shocks to agricultural productivity.

The results are shown in Table 1. Due to the expected strong collinearity between the conditional variables Z, we run the estimations variable by variable. We are also obliged to run the regressions separately due to severe data constraints. Indeed, only a few countries in Sub-Saharan Africa have data on all the conditional variables Z for the same years. When taken individually, we end up with a much bigger sample than when we attempt to jointly examine the variables.

The results are as follows. First, innovation appears to be a key factor that dampens the effect of rainfall instability on agricultural productivity (columns 1 and 2). The interaction terms of climate instability and spending on agricultural science and technology and with the number of available ASTI researchers show a negative coefficient that is statistically distinguishable from zero. At the same time, the coefficient of the additive term of climate instability is as expected, strongly associated with the instability of crop yield. These results suggest that greater investment in agricultural science and technology makes a difference by dampening the sensitivity of crop productivity to climate instability.

Table 1: Impact of climate instability on crop yield instability in Sub-Saharan Africa: OLS with fixed effects estimates

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Volatility of crop yield					
Rainfall instability	0.197***	0.444***	0.408***	0.216*	-0.506**
	(3.681)	(4.429)	(2.816)	(1.925)	(-2.194)
Rainfall instability * (ASTI spending-to-value added, lagged)		-0.269***			
		(-4.119)			
Rainfall instability * (ASTI researchers ratio, lagged)			-0.115**		
			(-1.998)		
Rainfall instability * (Fertilizer use, lagged)				-0.0330	
				(-0.793)	
Rainfall instability * (Irrigation, lagged)					-0.0177
					(-0.702)
ASTI spending-to-value added, lagged		0.0440***			
		(3.767)			
ASTI researchers ratio, lagged			0.0486***		
			(3.284)		
Fertilizer use, lagged				0.00582	
				(1.116)	
Irrigation, lagged					-0.0276
					(-1.196)
Log of real GDP per capita, lagged	-0.008	-0.0379**	-0.0523***	-0.0737***	0.0661
	(-0.543)	(-2.117)	(-2.848)	(-3.079)	(1.030)
Constant	0.175	0.371***	0.423***	0.667***	-0.211
	(1.482)	(2.623)	(3.058)	(3.555)	(-0.395)
Fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	1,035	692	712	396	95
R-squared	0.0156	0.039	0.032	0.041	0.146
Number of countries	43	38	38	33	21

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Second, we do not find any statistically significant dampening effect from other factors such as such as fertilizer and irrigation techniques, based on the sample at our disposal.

Alternative measures of rainfall instability

This paper has so far relied on a very specific functional form to measure the variability of rainfall, which was derived from the five-year standard deviations of the yearly residuals from country-specific stochastic and quadratic trends.

We now propose to check the robustness of the results using two alternative measures of rainfall variability that will exploit granular monthly observations. The first measure (*m*) is computed from the standard deviation over each period of 12 months of year-on-year changes in rainfall in each country. This is a measure of within-country within-year instability of rainfall changes. We posit that over a period of five years, the average of this measure will measure the climate uncertainty faced by farmers, and this could have important implications for crop productivity. In contrast, if the same pattern of rainfall was repeated every year, this measure of volatility would have been zero.

The second measure (*w*) is more elaborate. For each country and for each year, we identify the month during which the maximum rainfall (in mm) has been seen and we assign values from 1 to 12. We then extract the corresponding volume of rainfall for this particular month for each year and for each country. We further compute the standard deviation of these two series for each country over sub-periods of 5 years. They will represent an approximation of the uncertainty over the “good rainfall month”—this is standard deviation of the month of good rain—and a parallel uncertainty over the volume of rainfall. The combination of these two volatilities in a multiplicative expression is our proxy for climate instability.

The results are presented in Table 2 and Table 3. Regardless of the measure of rainfall instability that is used, we find that rainfall instability interaction with public spending on agricultural science and technology, and with the number of available ASTI researchers, show a statistically negative coefficient. At the same time, the coefficient of the additive term of rainfall instability remains strongly and positively associated with the instability of crop yield. These results suggest that greater investments in agricultural science, technology and innovation are strongly associated with a lower sensitivity of crop productivity to climate instability. The other potential dampening factors (irrigation or fertilizer use) do not appear to exhibit a statistically significant effect when interacted with rainfall instability.

Table 2: Impact of climate instability on crop yield instability in Sub-Saharan Africa: Alternative measure of rainfall variability (m)

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
Volatility of crop yield				
Rainfall instability	0.0701***	0.0414*	0.00702	0.0307
	(4.576)	(1.667)	(0.429)	(0.447)
Rainfall instability (*m*) * (ASTI spending-to-value added, lagged)	-0.0752***			
	(-6.179)			
Rainfall instability (*m*) * (ASTI researchers ratio, lagged)		-0.0243*		
		(-1.801)		
Rainfall instability (*m*) * (Fertilizer use, lagged)			0.00321	
			(0.595)	
Rainfall instability (*m*) * (Irrigation, lagged)				-0.00693
				(-0.418)
ASTI spending-to-value added, lagged	0.0857***			
	(5.837)			
ASTI researchers ratio, lagged		0.0674***		
		(3.254)		
Fertilizer use, lagged			-0.00106	
			(-0.178)	
Irrigation, lagged				-0.0231
				(-0.465)
Log of real GDP per capita, lagged	-0.0434**	-0.0588***	-0.0763***	0.0294
	(-2.474)	(-3.181)	(-3.149)	(0.413)
Constant	0.399***	0.458***	0.704***	-0.00654
	(2.863)	(3.288)	(3.747)	(-0.0119)
Fixed effects	Yes	Yes	Yes	Yes
Observations	692	712	396	95
R-squared	0.062	0.024	0.032	0.049
Number of countries	38	38	33	21

t-statistics in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Impact of climate instability on crop yield instability in Sub-Saharan Africa: Alternative measure of rainfall variability (w)

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
Volatility of crop yield				
Rainfall instability	0.0115**	0.00687	0.00210	-0.0107
	(2.014)	(1.054)	(0.276)	(-0.639)
Rainfall instability (*w*) * (ASTI spending-to-value added, lagged)	-0.0140***			
	(-4.309)			
Rainfall instability (*w*) * (ASTI researchers ratio, lagged)		-0.00389**		
		(-2.226)		
Rainfall instability (*w*) * (Fertilizer use, lagged)			0.000317	
			(0.119)	
Rainfall instability (*w*) * (Irrigation, lagged)				0.00241
				(0.750)
ASTI spending-to-value added, lagged	0.0106			
	(1.517)			
ASTI researchers ratio, lagged		0.0369***		
		(2.737)		
Fertilizer use, lagged			0.00172	
			(0.432)	
Irrigation, lagged				-0.0456*
				(-1.831)
Log of real GDP per capita, lagged	-0.0533***	-0.0640***	-0.0752***	0.0524
	(-2.958)	(-3.457)	(-3.068)	(0.765)
Constant	0.542***	0.558***	0.701***	-0.101
	(3.813)	(3.981)	(3.658)	(-0.181)
Fixed effects				
Observations	692	712	396	95
R-squared	0.046	0.031	0.029	0.055
Number of countries	38	38	33	21

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Dynamic panel data estimates

We now propose to estimate the models using dynamic panel data techniques. We resort to dynamic panel data as an alternative for two main reasons. First, agricultural productivity volatility could be strongly affected by their past values, requiring us to control for lagged levels of the dependent variable in the current fixed effects panel setting. Second, this is even more important in our current setting as we compute the instability of crop yield using a rolling standard deviation, which implies a mechanical autocorrelation embedded in the variable.

The presence of lagged dependent variables and the country-specific effects render traditional Ordinary Least Squares (OLS) estimator biased. Fixed effects (FE) estimators can eliminate the country-specific effect. However, the bias caused by the inclusion of lagged dependent variables remains (Nickell, 1981). Since the average number of observations across countries in our sample is likely to be small, the bias of the FE estimator may be non-negligible. To avoid these problems, we adopt the System-GMM estimator developed for dynamic panel data by Blundell and Bond (1998). Equations in levels and the equations in first differences are combined in a system and estimated with an extended System-GMM estimator, which allows for the use of lagged differences and lagged levels of the explanatory variables as instruments. In the framework, all the explanatory variables and the interaction term that includes the slow-moving variables Z, are treated as predetermined.

There are good reasons to treat climate shock variables as not strictly exogeneous in this framework. Agriculture is a major source of greenhouse gases, which contribute to the greenhouse effect and therefore climate change. At the same time, it is obvious that climate change is not a localized phenomenon solely explained by human agricultural activity in a given region. Put differently, climate hazards (rainfall and temperature instability) in a country *i* do not mostly originate from the sole activity generated in that country. This helps provide some degree of exogeneity to our climate shock variables in the model. Because the interaction terms Z also enters the equations with lags, we further reduce their endogeneity bias as well.

More specifically, the model takes the following form:

$$a_{it} = \rho a_{it-1} + (\theta_4 + \theta_5 Z_{it-5})\, Shock_{it} + \theta_6 Z_{it-5} + X_{it}^{'}\beta + u_{i.} + \gamma_t + \epsilon_{it} \quad [2]$$

Two specification tests check the validity of the instruments. The first is the standard Hansen test of over-identifying restrictions. The second test examines the hypothesis that there is no second-order serial correlation in the first-differenced residuals. Finally, the risk of overfitting the model by using too many internal instruments will be addressed by restricting the number of internal instruments to a very minimum (ideally to levels below the number of countries).

We now re-run the entire set of estimates with a dynamic specification as presented in equation 2 and the results are shown in Table 4 and using the baseline definition of rainfall shocks already used in Table 1. Importantly, the results in a GMM setup using the two alternative definitions of rainfall instability are broadly unchanged.

Once again, we do see a significant effect of greater investment in agricultural science and technology in dampening the effect of climate shocks onto crop yield productivity (columns 1 and 2 in all three tables). This was also the case for the naïve estimates performed earlier, using simple OLS fixed effects. In contrast, we do not find a dampening effect played by the other regressors.

Table 4: Impact of climate instability on crop yield instability in Sub-Saharan Africa: Dynamic GMM estimates

Dependent variable:	**(1)**	**(2)**	**(3)**	**(4)**
Volatility of crop yield				
Rainfall instability	0.551***	0.481**	0.0836	-0.243
	(3.110)	(2.152)	(0.360)	(-1.011)
Rainfall instability * (ASTI spending-to-value added, lagged)	-0.398**			
	(-2.430)			
Rainfall instability * (ASTI researcher ratio, lagged)		-0.200**		
		(-2.116)		
Rainfall instability * (Fertilizer use, lagged)			0.0372	
			(0.303)	
Rainfall instability * (Irrigation, lagged)				-0.0354
				(-1.541)
ASTI spending-to-value added, lagged	0.0600***			
	(2.675)			
ASTI researcher ratio, lagged		0.0330**		
		(2.404)		
Fertilizer use, lagged			-0.000756	
			(-0.0666)	
Irrigation, lagged				0.00102
				(0.330)

continued next page

Table 4 Continued

Dependent variable:	**(1)**	**(2)**	**(3)**	**(4)**
Lagged volatility of crop yield	0.908***	0.868***	0.892***	0.422***
	(16.78)	(23.06)	(18.37)	(4.215)
Log of real GDP per capita, lagged	0.00399	-0.000976	0.00142	0.0619***
	(1.195)	(-0.119)	(0.493)	(2.848)
Constant	-0.0888**	-0.0507	-0.0153	-0.372**
	(-2.067)	(-0.826)	(-0.426)	(-2.531)
Observations	690	710	396	95
AR[2]: p-value	0.512	0.451	0.016	0.520
Hansen OID: p-value	0.285	0.451	0.546	0.602
No of instruments	21	21	21	21
Number of countries	38	38	33	21

z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Overall, the various specifications appear to confirm the key role played by agricultural innovation, as approximated by agricultural science and technology indicators.

5. Conclusion

This paper proposes a comprehensive empirical assessment of the various factors that help mitigate the adverse effects of climate instability on agricultural sector productivity in Africa. The paper makes an empirical contribution, exploiting the cross-country variation in the data. A significant effort to assemble reliable data specific to the agricultural sector in Africa is made throughout the paper.

The results from this paper unambiguously show that greater investments in agricultural science and technology, including to making available to farmers researchers in agriculture, are key to ensuring the resilience of crop yield to climate instability. Furthermore, the paper shows that availability of modern inputs such as irrigation and the use of fertilizer also significantly dampen the effect of climate variability on crop yield productivity.

These results provide key inputs to fine tune debate and policy priorities at the micro level. Strengthening the resilience of the agricultural sector to climate shocks is in itself a productivity-enhancing goal. Ensuring that farmers have access to knowledge including via available ASTI researchers would help boost their productivity but also make them more resilient to climate shocks.

Notes

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4. Each component is scaled between 0 (the least vulnerable) to 100 (the most vulnerable) using the min-max procedure.

5. The average age of a farm worker in Africa is about 60 years, while the continent has the world's youngest population—60% of its 1.2 billion people are under 25.

6. Africa farmers lose an estimated 49% of expected total crop yield per annum due to crop pests and disease—the highest in the world—according to the Centre for Agriculture and Biosciences International. This is likely to get worse as the impact of climate change worsens.

7. For example, digital communications and farmer-to-farmer education can provide critical weather information to help landowners make planting and harvesting decisions.

8. Telephony penetration rates vary wildly across Sub-Saharan Africa, which in 2017 had an overall rate of 44%, compared with a global average of 66%.

9. Globally, 20% of cropland is irrigated. In Africa, this figure is just 5%.

10. Other relatively exogeneous external instruments could have been used, such as climatic zones of Africa (arid and semi-arid areas of Sahel region, Kalahari and Namib deserts; tropical Savanna grasslands in Sub-Saharan Africa and Central Southern Africa; equatorial area in the Congo region and the East African highlands; temperate areas in the South Eastern tip of South Africa. These variables could not be used in our current setup as they are already fully absorbed by fixed effects.

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Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

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