Poverty and Exposure to Climate Change in sub-Saharan Africa

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and
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List of abbreviatons and acronyms

CEPR	Centre for Economic Policy Research
CMIP6	Coupled Model Intercomparison Project Phase 6
GCMs	General Circulation Models
IPCC	Intergovernmental Panel on Climate Change
LSMS	Living Standards Measurement Study
SSPs	Shared Socioeconomic Pathways
UNU	United Nations University
WIDER	World Institute for Development Economics Research
SID	Society for International Development

Abstract

This study provides a framework for examining the effects of climate change on poverty in sub-Saharan Africa. It presents and combines the most recent data on poverty and climate projections at the subnational level, and finds that, i) current levels of poverty and current climate are not correlated in any meaningful way, ii) poorer districts are exposed to larger projected increases in temperatures and precipitation than richer areas when looking at within-country variation. While this exposure will likely amplify the effects of climate change on poverty, overall vulnerability to climate change decreases through poverty reduction.

Key words: *Poverty; Climate change; CMIP6; Sub-Saharan Africa.*

JEL classification codes: *Q54; O55; R11.*

1. Introduction

In development debates around climate change, it is common to state that '*The effects of climate change fall disproportionately on the poor*'. However, there are many unknowns and implicit assumptions in a statement like this. For example, what is meant by climate change? Moreover, what definition of poverty is referred to? Are the mentioned effects geophysical or socioeconomic?

This framework study aims to help fill, in part, the knowledge gaps inherent in the introductory statement. We ask: "If the most recent climate projections for the year 2050 (i.e., the hazards) were realized tomorrow, what would the exposure of the poor populations be, compared to the overall population?" Answering this question is a first step in providing guidance on where to focus attention when analysing the effects of climate change on poverty.

We argue that poverty's exposure to climate change is firstly related to geography: poverty distributes unevenly across regions and districts, and so do current climate, future climate, and projected changes in climate. By disaggregating to the lowest common denominator, in this case 516 subnational administrative divisions, it is possible to clarify the extent to which areas that are likely to be more exposed to certain aspects of climate change are in general also poorer. Comparing changes in mean temperature and rainfall across geographical areas will obviously only tell part of the story. As noted by, for example, Hallegatte and Rozenberg (2017), a large portion of the effects of climate change arises because of poverty; or stated differently, because poor people are often more vulnerable to climate change.

As such, the purpose of the present study is twofold. We provide an overview of poverty's exposure to different current and future climates across sub-Saharan Africa, and wish to inspire other research to take on the task of estimating how projected climate change will likely affect poverty levels in the future, taking into account hazards, exposure, and vulnerability.

2. Review of existing studies

A wealth of studies has explored the links between welfare and climate change. Among the more influential, Dell et al. (2012) documented the long-run impacts of temperature shocks on economic growth. Higher temperatures reduce growth rates, especially in poor countries through mechanisms including agricultural productivity and political stability.

Taking a bottom-up perspective, Hallegatte and Rozenberg (2017) aggregated 92 representative household surveys to analyse the question taking into account distributional factors within countries. Under the assumptions of two different Shared Socioeconomic Pathways (SSPs), climate change's impacts on poverty were simulated through five channels: i) agricultural productivity, ii) food prices, iii) natural disasters, iv) labour productivity, and v) health. They found that climate change is expected to have a larger impact on poverty than on aggregate economies, and that lifting people out of poverty as soon as possible would reduce the future impacts of climate change on poverty.

Diverging strands of the literature study these channels separately and in-depth. For example, in a review paper, Hallegatte et al. (2020) conclude that poor people are disproportionately affected by natural hazards and disasters. This is mostly due to high vulnerability/low resilience, but often the poor are also more exposed, the authors claim. Again, the policy recommendation is that poverty reduction is the safest way to reduce vulnerability to natural hazards and, in turn, the impacts of climate change.

Finally, climate change may affect poverty through the risk of conflict. Many studies find that higher temperatures are directly associated with an increase in the probability of conflict in an African context (Burke et al., 2015; Eberle et al., 2020). Whether the mechanism is mainly physiological or driven by a drought-income link remains contested. Harari and La Ferrara (2018) found evidence that at least parts of the association can be accounted for through agriculture.

3. Analytical framework

Generally, the effects of natural phenomena like climate changes are functions of hazard, exposure, and vulnerability. While a hazard can be a natural phenomenon like high temperatures or lack of rainfall, exposure reveals whether human or physical capital (or activity) is located where the hazard occurs, and vulnerability is the degree to which a hazard affects the exposed.

Climate change impacts thus depend on all components of the function, and all components are variable. Hazards are unpredictable, and although often taken as exogenous in economic studies, the whole debate about climate change mitigation revolves around affecting potential future hazards through the control of greenhouse gas emissions. Exposure can vary due to population changes, migration, and protective measures. Vulnerability is the most volatile component, and the one with most potential for reducing the impacts of climate change. For a given hazard and exposure level, households can be highly affected by climate change—or not at all—following small changes in, for example, savings or insurance coverage.

This study investigates the exposure of poverty to potential future climate change. Assuming the distribution of poverty rates across sub-Saharan Africa remains more-or-less stable, the aim is to assess whether the hazards will occur disproportionately where the poor and vulnerable are located.

4. Data and estimation strategy

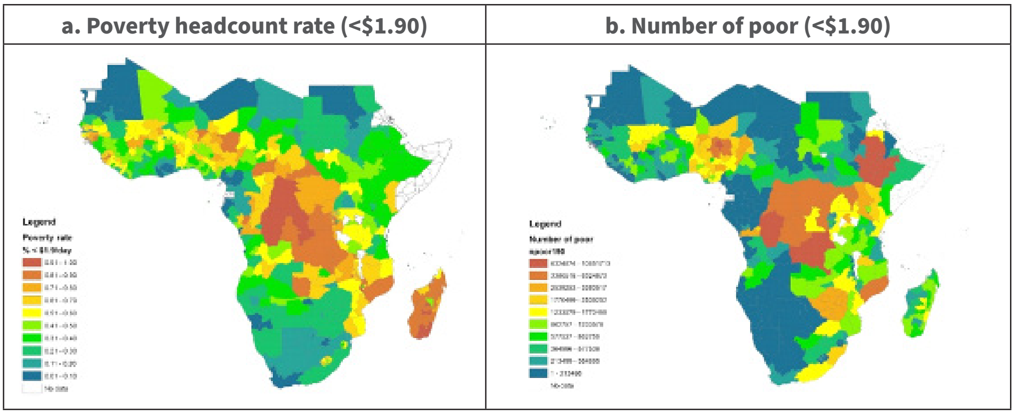
At the core, this study combines existing sources of data on the geographical distribution of poverty with data on climate and projected climate change within sub-Saharan Africa. Accordingly, our unit of analysis is the lowest common denominator between data on, respectively, poverty and climate; namely, either first or second level administrative units—often known as regions and districts. There are two main reasons why this level of analysis is meaningful: firstly, it provides a helicopter perspective of the distribution of poverty in SSA—but with significantly more data points and variation than classical cross-country analyses. Secondly, the geographical sizes of these units correspond well with the spatial resolution of the gridded climate projection data with which it is combined. Had the units been much smaller, many would not even contain a single climate projection pixel, while larger units would imply a loss of information.

Poverty

Since the introduction of the international one-dollar-a-day poverty line (World Bank, 1990; Ravallion, 2018), the World Bank and others have been using this metric to compare achievements in poverty reduction across countries. Aggregate figures using the updated $1.90, $3.3, and $5.5 purchasing power parity poverty lines are available through PovcalNet. National statistical offices and/or the World Bank typically estimate subnational poverty rates following each new round of representative national household surveys. This study employs a database of the most recent subnational poverty figures similar to the one used by Beegle and Christiaensen (2019). It consists of household level poverty estimates from national LSMS-style surveys aggregated to first (53%) or second level administrative units for comparisons within and between countries. The survey years in the database range from 2005 to 2015 with 82% of data points based on estimates from 2009 or later.

Figure 1 shows the distribution of the poverty headcount rate and the number of poor people distributed across our 516 subnational administrative units. Our analysis makes use of both numbers, although we mainly focus on poverty rates.

Figure 1: Units of observation and distribution of poverty



Source: Beegle and Christiaensen (2019).

Climate

Our source of detailed data on current climate and projected future climate is worldclim.org. This database contains the most recent estimates based on the sixth round of the Coupled Model Intercomparison Project Phase 6 (CMIP6) framework, as recommended by Navarro-Racines et al. (2020) as well as Hsiang and Kopp (2018).

At the time of writing, nine different General Circulation Models (GCMs) are available that all use the assumptions of CMIP6, which will also be the basis of the Intergovernmental Panel on Climate Change (IPCC) sixth assessment report, planned for publication in 2022. The climate projections used here are a simple average of the nine GCMs.

The climate change projections we use are for the period 2041-2060. We refer to this as 2050 interchangeably. While this period is far enough into the future to entail measurable climate changes, it is also close enough to be relevant for today's policy makers, who are concerned about the impact of climate on poverty.

In terms of spatial resolution, the data sets are downscaled to rather detailed pixel levels (much smaller units than the subnational administrative divisions for which we have poverty data). Here, a resolution of 10 arc-minutes is chosen, corresponding to pixels of around 16km at the equator.

A key aspect of CMIP6 is the introduction of five so-called Shared Socioeconomic Pathways (SSPs). These scenarios reflect different trends in global development that, in turn, lead to different challenges with respect to mitigation and adaptation. In this study, we concentrate on SSP2, also called "middle-of-road", because it assumes medium challenges to both mitigation and adaptation.

All climate models contain a set of variables. For climate modelling, monthly mean, minimum, and maximum of temperatures and rainfall are typically the most relevant. Here, however, we focus on annual averages, for a broader set of variables.

In particular, we use current and future values for the following bioclimatic variables: annual mean temperature, annual precipitation, mean diurnal range (mean of monthly (max temp - min temp)), precipitation in wettest month (growing season), and precipitation seasonality (CV). Figure 2 shows the spatial distribution of current climate as well as projected climate change until 2050, all at the subnational level.

Figure 2: Geographical distribution of current climate and projected climate for subnational units

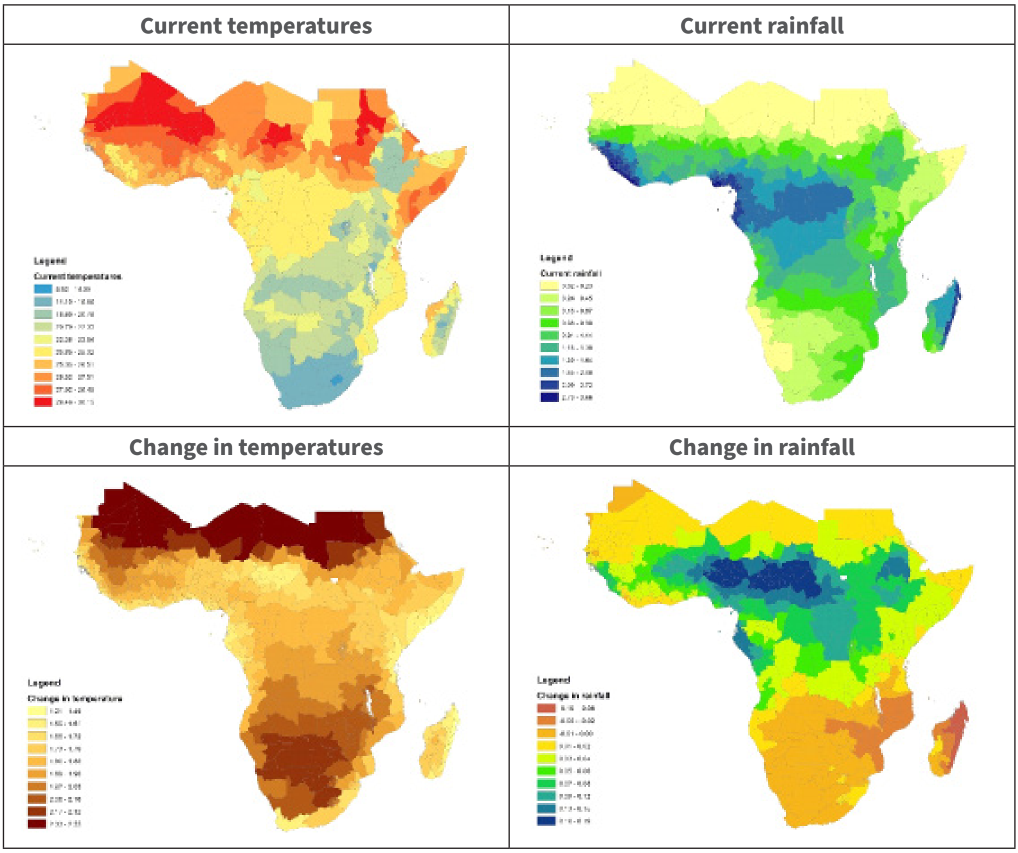


Table 1 indicates that large variations in poverty, climate, and climate change are typical across sub-Saharan Africa, while Figure 1 shows the spatial distribution of poverty.

Table 1: Mean and range of key variables

	Obs	Mean	Min	Max
Population	532	1,557,415	5,186	30,100,000
Poverty rate ($1.90)	543	0.442	0.000	0.977
Poverty rate ($3.20)	543	0.676	0.004	0.997
Poverty rate ($5.50)	543	0.841	0.037	1.000
Number of poor ($1.90)	543	756,950	0	10,700,000
Number of poor ($3.20)	543	1,227,933	48	25,000,000
Number of poor ($5.50)	543	1,571,360	536	32,500,000
Current annual mean temperature	558	23.932	8.922	30.147
Future annual mean temperature	558	25.788	10.908	32.223
Change in annual mean temperature	558	1.856	1.208	2.552
Current annual precipitation	558	1102	20	3663
Future annual precipitation	558	1142	22	3720
Change in annual precipitation	558	40	-99	192
Current mean diurnal range	558	11.740	4.621	17.489
Future mean diurnal range	558	11.664	4.453	17.780
Change in mean diurnal range	558	-0.076	-0.790	0.438
Current precipitation in wettest month	558	227	10	1102
Future precipitation in wettest month	558	242	11	1193
Change in precipitation in wettest month	558	16	-31	92
Current precipitation seasonality (CV)	558	93	27	172
Future precipitation seasonality (CV)	558	95	28	178
Change in precipitation seasonality (CV)	558	2	-5	16

Estimation model

In order to test the relationship between current climate and poverty, we rely on the following simple model:

$$(1) \quad Poverty_i = temp_i + pcp_i + diur_i + pcp(wet)_i + pcp(CV)_i + \lambda + \varepsilon_i$$

Where, *Poverty* in unit *i* is measured either as the headcount rate or the number of poor at $1.90 per person per day, *temp* is the average annual temperature, *pcp* is the average annual precipitation, *diur* is the mean diurnal range, *pcp(wet)* is the average precipitation in the wettest month, *pcp(CV)* is the coefficient of variation of precipitation, λ is a vector of country fixed effects, and ε_i is a random error term.

When analysing the relation between poverty and climate change, a similar model is used, where, all right-hand-side climate variables are replaced by the projected change between current values and projected values for the year 2050.

It is important to note that, most concerns about comparability of poverty measures across countries are alleviated in the specifications where country fixed effects are included, as all level differences in poverty between countries are cancelled out. This is so for both potential concerns about the use of international poverty lines and differences in survey years that could affect between-country comparisons in a period of general poverty reduction.

5. Results and discussion

This section analyses the relationships between poverty and current, future, and changes in climate for 516 subnational units across sub-Saharan Africa. Each part of the analysis considers poverty headcount rates, number of poor people, temperatures, rainfall, and the full set of bioclimatic variables described above. Importantly, we do each regression cross-sectionally for the whole region, as well as with country fixed effects to isolate within-country correlations.

Figure 3 and Table 2 show the relationships between current climate and poverty across the 516 subnational entities. For both average annual temperatures and rainfall, there seems to be a significant unconditional correlation with poverty rates: Poorer districts are slightly cooler and wetter than the average. However, visual inspection of Figure 3 reveals that this relationship is heterogeneous and weak. Furthermore, controlling for country fixed effects diminishes the significance levels of the correlations. A variable that does seem to correlate strongly with poverty rates when controlling for country fixed effects is mean diurnal range, i.e., the average monthly temperature range. So districts with more variation in temperatures (e.g., between night and day) also tend to be poorer, both in terms of the share and number of poor.

Figure 3: Unconditional correlations between poverty rates and mean temperatures (left) and precipitation (right)

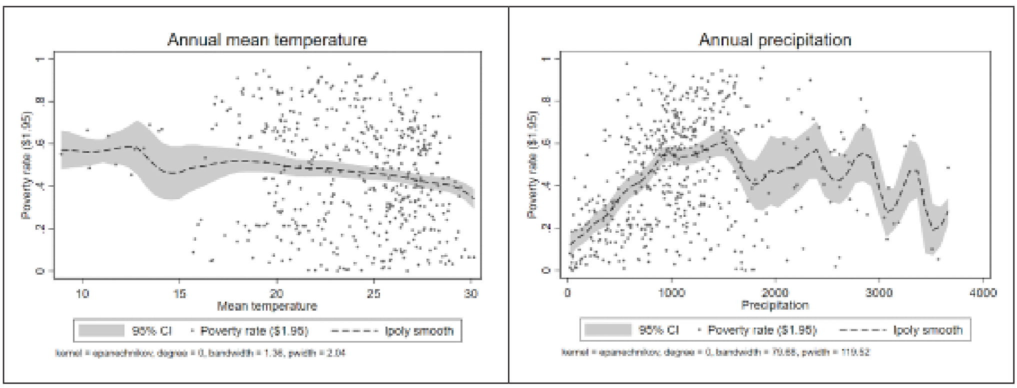


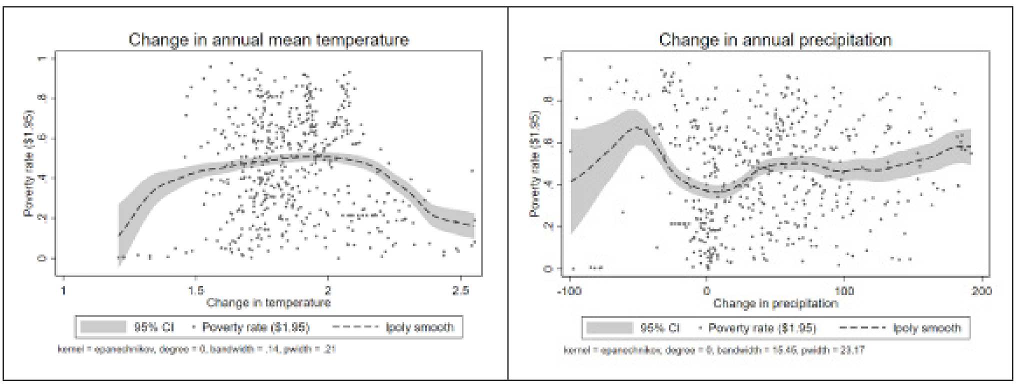
Table 2: Poverty and exposure to current climate

	Poverty rate				Number of poor			
	1	2	3	4	5	6	7	8
Annual mean temperature	-0.012***	0.000	-0.014***	0.005	0.010	-0.035	0.047	-0.034
Annual precipitation	0.090***	-0.058**	0.004	0.007	0.220	-0.073	-0.733	0.054
Mean diurnal range			0.007	0.041***			0.111**	0.123***
Precipitation in wettest month			0.534	0.182			4.484*	1.483
Precipitation seasonality (CV)			0.000	0.000			-0.017***	0.004
Country fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	516	516	516	516	516	516	516	516
r^2	0.083	0.676	0.098	0.711	0.008	0.769	0.039	0.781

Note: *, **, and *** represent statistical significance at 0.1, 0.05, and 0.001 level respectively.

Turning to climate change, Figure 4 and Table 3 contain the main results. Again, simple cross-sectional analyses of the relation between changes in either temperatures or rainfall and poverty rates do not reveal any meaningful patterns. In other words, there is no clear relationship between two key indicators of climate change and poverty when looking broadly across the continent.

Figure 4: Unconditional correlations between poverty rates and change in temperatures (left) and precipitation (right)



However, when focusing only on within-country variations, a clear correlation emerges, namely that poorer districts are projected to experience both higher temperatures and more rainfall in 2050. In fact, a 23 percentage points higher in poverty rate is associated with a 1 degree Celsius larger increase in temperatures, while 10cm extra rainfall in the wettest month in 2050 is associated with 27 percentage points higher in poverty rates today.

Table 3: Poverty and exposure to climate change

	Poverty rate				Number of poor			
	1	2	3	4	5	6	7	8
Δ Annual mean temperature	-0.050	0.233***	-0.047	0.205***	0.387	0.176	1.065**	0.362
Δ Annual precipitation	0.311	1.933***	0.967	0.781	8.594***	6.458***	1.510	-1.422
Δ Mean diurnal range			0.273***	-0.026			-0.023	0.059
Δ Precipitation in wettest month			0.848	2.728*			31.579**	22.267**
Δ Precipitation seasonality (CV)			0.000	0.003			-0.202***	-0.066
Country fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	516	516	516	516	516	516	516	516
r^2	0.0594	0.7081	0.046	0.7173	0.0734	0.7768	0.1005	0.7816

Note: *, **, and *** represent statistical significance at 0.1, 0.05, and 0.001 level respectively.

The finding that today's poverty rates are associated with larger variations in temperature (diurnal range) as well as larger projected increases in both temperatures and rainfall, may be explained by an important omitted variable, namely distance to the coast. In an attempt to investigate this possibility, Table 4 shows the pairwise correlations between the main poverty and climatic variables included and the (log) distance in metres to the African coastline measured from the geographical centre point of each subnational division.

Table 4: Pairwise correlations between distance to coast and key variables of interest

	Log distance to coast
Poverty rate	0.35
Number of poor	0.49
Annual mean temperature	-0.13
Annual precipitation	-0.31
Mean diurnal range	0.50
Δ Annual mean temperature	0.60
Δ Annual precipitation	0.31

Note: All correlation coefficients are significant at 0.01-level.

Both poverty rates and the number of poor correlate positively with the distance to coast, meaning that the further inland a district is located, the poorer it is, on average. Secondly, inland districts are both cooler and drier than coastal districts. Mean diurnal range shows a strong positive correlation with the distance to coast, as do changes in temperatures, and to a lesser extent changes in precipitation.

A re-analysis of the regressions behind column 4 in Table 2 and Table 3 confirms that, if the log of distance to the coast is included, the only climatic variable that comes out statistically significant is precipitation in the wettest month for current climate and change in temperature for the climate change regression. However, change in temperature now has a negative sign, meaning that the inclusion of distance to coast as a control variable reverses the observed relationship between poverty rates and projected changes in temperatures.

Vulnerability

What do the exposure to higher temperature and more rainfall mean for the future poverty levels? As stated in the introduction, exposure to climate change is only one part of the equation when determining the impacts of climate change on poverty. While it is beyond the scope of this study to estimate the total effect of climate change on poverty in sub-Saharan Africa, it is possible to contribute to the ongoing debate by drawing on some insights from the literature and relating these to our findings.

Hallegatte and Rozenberg (2017) provide a thorough overview of the effects of climate change on poverty using a bottom-up approach combining 91 representative household surveys from across the world to analyse the distributional effects of a high-impact versus a low-impact scenario in 2030 under the assumptions of two different Shared Socioeconomic Pathways (SSP4 and SSP5). They argue that the effects of climate change on poverty work through five different channels: i) agricultural productivity, ii) food prices, iii) natural disasters, iv) labour productivity, and v) health.

Larger increases in temperatures in poor districts, therefore, likely add to the poverty figures in those districts due to lower productivity and lower agricultural productivity (producer side) and higher food prices (consumer side). The latter effects depend on precipitation as well—and especially whether the expected increase in rainfall leads to a net increase or decrease in aridity. One of the main health effects of climate change on poverty goes through malaria—a disease that seems to be more prevalent in warmer and wetter climates. The effects on poverty through natural disasters are more difficult to assess based on the present data set since it rests on an assumption of increasing frequencies in extreme events, something that is impossible to assess using yearly averages of climatic variables (see discussion in Hsiang and Kopp (2018)).

One of the main conclusions of the work of Hallegatte and Rozenberg (2017) is that, vulnerability to climate change is much higher among the poor than among the non-poor. Reducing poverty as much as possible, and as quickly as possible, should, therefore, be a highly effective strategy for alleviating the negative consequences of climate change. On the other side, climate change works as an obstacle for poverty reduction through a combination of exposure and vulnerability.

6. Conclusion

This study has presented a framework for analysing and discussing the extent to which climate change affects the poor disproportionately.

Firstly, it highlights the importance of distinguishing between hazard, exposure, and vulnerability.

Secondly, it is shown that climate change is expected to take place in a heterogeneous pattern across sub-Saharan Africa (using the most recent downscaled CMIP6 climate projections).

Thirdly, a data set of headcount rates from 516 subnational units (i.e., districts) reveals that, areas that are currently poorer are generally not more exposed to warmer, drier, or wetter conditions than richer areas. However, when controlling for country fixed effects, temperatures are expected to increase more in poorer than in richer districts, probably due to the fact that poorer districts and larger increases in temperatures are typically found inland, and increasingly so with the distance to the coast. Most places expected to see large temperature increases are also likely to receive more rainfall, but not in exactly the same pattern, and local conditions will determine whether this increase can offset the temperature increases thus avoiding an increase in aridity.

These findings highlight the importance of analysing the effects of climate change at the subnational level, since considerable variations in both projected climate changes and outcome variables are found within country limits, and ignoring the country level effects can blur the results.

As found in the literature, higher temperatures can, ceteris paribus, lead to more poverty through multiple channels, and this relationship will be exaggerated by a larger exposure to climate change in poor areas. However, poverty reduction is itself the strongest driver of climate change adaptation, so the effects of climate change on poverty likely depend more on development pathways than on exposure to changes in temperatures and rainfall.

Future work on poverty and climate change needs to be aware of the following: i) effects of climate change depend on levels of hazard, exposure, and vulnerability; ii) there is considerable spatial variation in climate change projections, between and within countries, and iii) climate change disproportionately affects the poor, both through exposure and vulnerability, but poverty reduction remains key for climate change adaptation.

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Appendix

Figure A1: Unconditional correlations between poverty rates and future temperatures (left) and precipitation (right)

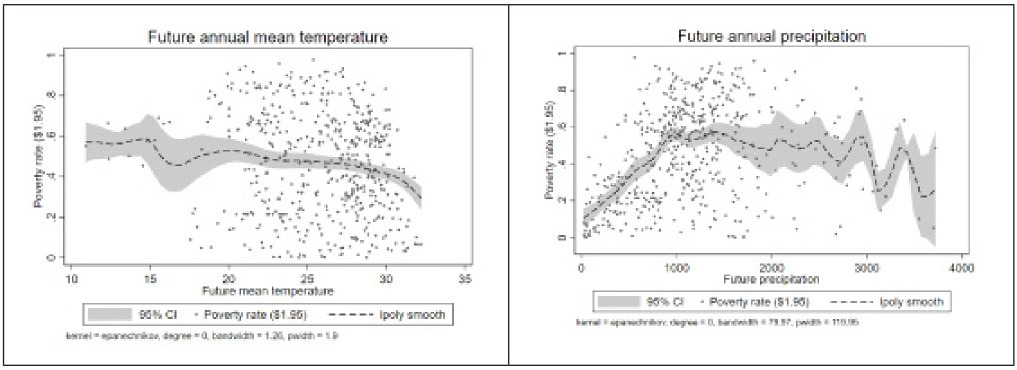

Table A1: Poverty and exposure to future climate

	Poverty rate				Number of poor			
	1	2	3	4	5	6	7	8
Annual mean temperature	-0.012***	0.001	-0.015***	0.005	0.009	-0.036	0.044	-0.036
Annual precipitation	0.091***	-0.046*	0.004	-0.018	0.271*	-0.036	-0.849	-0.049
Mean diurnal range			0.005	0.041***			0.092*	0.122***
Precipitation in wettest month			0.516	0.327			5.045**	1.942
Precipitation seasonality (CV)			0.000	0.000			-0.018***	0.003
Country fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	516	516	516	516	516	516	516	516
r^2	0.087	0.675	0.104	0.712	0.012	0.769	0.043	0.782

Note: *, **, and *** represent statistical significance at 0.1, 0.05, and 0.001 level respectively.

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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