Social Policy and Adaptation to Extreme Weather: Evidence from South Africa

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Introduction

- Adaptation has been recognised as an inevitable margin of response to extreme weather events and climate change;
  - Even if countries were to reduce emissions significantly in the coming decades, global warming is underway, and societies would need to adapt to the climate change that is already taking place (Diffenbaugh 2023).
- Adaptation responses are even more pertinent for developing countries.
  - Developing countries are known to be particularly vulnerable to climate change (Tol 2018, Diffenbaugh et al. 2019).
  - They lack resources, and often the institutional capacity, to withstand the negative effects of climate change.
- Adaptation can take several forms, and it can be either **public** (large-scale infrastructure, healthcare and education improvements, etc.) or **private**.

Private adaptation

- Adaptation in terms of agricultural production in response to extreme weather events includes more efficient use of water, better irrigation, planting more resilient crops, etc. (Hornbeck and Keskin 2014, Fishman 2018, Olmstead and Rhode 2018).
- Studies have dealt with the role of interventions in addressing negative shocks ex-post (through cash transfers, saving groups, etc.) (Karlan et al. 2017, Adhvaryu et al., 2018) and ex-ante (through insurance uptake, income diversification, capital and skills upgrading, etc.) (Karlan et al. 2014, Macours et al., 2022).
- Gap in literature: role of policies targeting access to and use of services (such as electricity or water) on private adaptation to extreme weather events (UNDP 2013, Murphy and Corbyn 2013).

Droughts in South Africa

- South Africa is highly vulnerable to droughts, and their frequency and intensity is expected to increase with climate change (van der Walt and Fitchett, 2021, Fitchett, 2021, Sousa et al., 2018).
- In recent years, a large part of the South African population has been affected by droughts.
- Access to (and judicious use of) amenities such as electricity and water may help South African households cope with droughts:
  - Examples: investment in durables such as fridges, borehole pumps, irrigation systems, etc.

This Study

- I evaluate the impact of a specific program meant to support low-income households, **the Indigent Program**, in facilitating access to and use of electricity and water in South Africa.
  - The Indigent Program (provides a certain amount of grid-based electricity (usually 50 KwH per household per month) and water (at least 6 kL per household per month) to low-income households either for free, or at heavily subsidised rates.
- Theoretically, the Indigent Program may:
  - incentivise households lacking access to a grid-based electricity or a water connection to acquire them (**extensive margin**).
  - compel households having existing connections to use them more intensively (**intensive margin**).
  - relax budget constraints for households, enabling them to spend on other things.

Research Objectives and Contributions

- Research Objectives
  - I evaluate the overall impact of eligibility for the Indigent Program in stimulating electricity as well as water access and use for rural South African households.
  - I analyze whether (and how) program eligibility influenced adaptation by drought-affected households.
- Contributions to the literature
  - Evaluating the impact of the Indigent Program.
  - Evaluating the role of development policy supporting amenity use in fostering ex-post adaptation behavior.

Indigent Program in South Africa

- Program eligibility based on monthly household income.
- Each municipality has its own income-based threshold to determine the indigent status of households, and have the freedom to decide how much to subsidise them.
  - Electricity provision of the program only valid for households connected to some electricity system (on-grid or solar home system)
  - Free water provision had been previously extended to all households by most municipalities.
- Any consumption above 50 KwH or 6kL per month charged using a block-tariff rate.

Data

- National Income Dynamics Study (NIDS) panel dataset (2008, 2010, 2012, 2014, 2017).
- The sample for this study is focused on non-urban households.
- I use the self-calibrating Palmer Drought Severity Index as the measure of drought (Climatic Research Unit (CRU) TS 4.05 database):
  - The index ranges from -4 (extreme drought) to 4 (extremely wet conditions).
- I use a binary indicator variable for drought incidence, denoting whether the scPDSI is less than the median value for the data sample, -2.48 (which denotes moderate to severe drought).

Methodology- I

- I first use a parametric reduced-form regression discontinuity design (RDD) approach for the program evaluation.
- I restrict the sample to the years 2014 and 2017 (which were drought years), and include districts with an income threshold of 1601 Rand (87 USD).

$$A_{i,j,t} = \alpha_0 + \alpha_1 Z_{i,t} + \alpha_2 f(I_{i,t}) + \alpha_3 Z_{i,t} f(I_{i,t}) + \alpha_4 X_{i,t} + \lambda_j + \nu_{j,t} + \mu_{i,j,t} \quad (1)$$

- Use bandwidth of 1000 Rand (51 USD) and a flexible functional form.
- Controls include gender, age, and education of the HH head, district fixed effects, whether the HH received rental income or owned their home, family size, sum of nighttime lights (district-level) and district-specific time trends.

Summary Statistics-I

Table: Summary Statistics (Band-width = 1000 Rand)

Explanatory Variables	Mean	Standard Deviation	Minimum	Maximum	Observations
HH eligible for the Indigent Program	0.539	0.499	0	1	1,876
Palmer Drought Severity Index	-2.653	0.898	-3.992	-0.030	1,876
Drought indicator (PDSI $<$ median)	0.666	0.472	0	1	1,876
Monthly household income (Rand, deflated)	1,749.58	501.06	592.12	2,807.10	1,876
Household size	4.053	2.430	1	18	1,876
HH head : female	0.738	0.440	0	1	1,876
HH head : age	50.964	17.786	12	99	1,875
HH head: at least primary school	0.722	0.448	0	1	1,867
HH member owns home	0.809	0.393	0	1	1,875
Someone in HH received rental income last month	0.014	0.119	0	1	1,874
Whether HH lives in a brick house	0.602	0.490	0	1	1,876
Sum of nighttime lights	15.752	21.452	0	63	1,876
Dependent Variables	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Observations**
Access to grid-based electricity	0.793	0.406	0	1	1,876
HH spent on electricity last month	0.750	0.433	0	1	1,873
Access to off-site/communal piped water as main water source	0.326	0.469	0	1	1,876
Access to on-site piped water as main water source	0.088	0.284	0	1	1,876
Access to on-site borehole as main water source	0.034	0.180	0	1	1,876
HH spent on water last month	0.019	0.137	0	1	1,874

Results

Table: Reduced-Form Parametric RDD Results

Sample	Overall Sample	Drought-affected Sub-sample	Drought-unaffected Sub-sample
Access to electricity	0.057	0.006	0.164***
	(0.035)	(0.044)	(0.058)
Observations	1,863	1,244	619
Spent on electricity	0.026	-0.046	0.174***
	(0.036)	(0.044)	(0.061)
Observations	1,860	1,244	616
Use of borehole as main water source	0.030*	0.040**	0.015
	(0.016)	(0.019)	(0.028)
Observations	1,863	1,244	619
Use of communal piped water	-0.009	-0.063	0.084
	(0.038)	(0.047)	(0.068)
Observations	1,863	1,244	619
Use of on-site piped water	-0.016	-0.052	0.053
	(0.026)	(0.032)	(0.044)
Observations	1,863	1,244	619
Spent on water	-0.007	-0.015	0.010
	(0.012)	(0.013)	(0.027)
Observations	1,861	1,244	617

Borehole Adoption

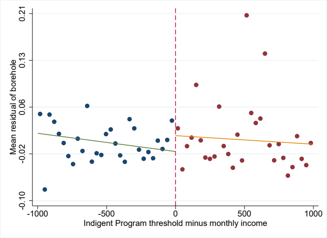


Figure: Overall sample

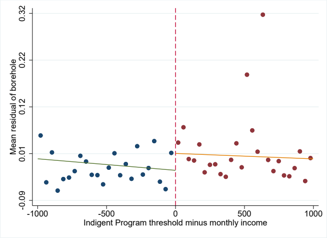


Figure: Drought-affected

Results

Table: Reduced-Form Results: Borehole Type

Sample	Overall Sample	Drought-affected Sub-sample	Drought-unaffected Sub-sample
Use of communal borehole as main water source	0.028**	0.034*	0.019
	(0.014)	(0.019)	(0.019)
Observations	1,863	1,244	619
Use of on-site borehole as main water source	0.002	0.006	-0.004
	(0.008)	(0.004)	(0.022)
Observations	1,863	1,244	619

Municipal/Communal Boreholes

- What kind of costs are incurred for communal/municipal boreholes?
  - Drilling and installation costs, costs for equipment (such as pipes, tanks, taps etc.)
  - Payments to pump operators (labor costs) and other maintenance costs
  - Depending on the type of borehole pump used, either fuel costs (diesel or petrol) or electricity costs- these are usually shared by households.
- Increased communal borehole use by eligible households thus may reflect drought-affected households using 'loosened budget constraints' from the program to incur some of these expenses.
  - Given that there is no water fee for groundwater use, and electricity costs for communal boreholes cannot be covered by individual metered connections, households may have used their savings from the program on fuel/ electricity expenses, or on other borehole-related expenditures.

Methodology-II

- How does using boreholes influence socioeconomic outcomes for eligible households in drought-affected areas?
- I estimate an event-study model following the methodology of Sun and Abraham (2021):

$$Y_{i,t} = \alpha + \sum_{k=-4}^{4} \beta_k \mathbf{1}_{(k=t)} D_i + \gamma X_{i,t} + \eta_i + \mu_t + \epsilon_{i,t} \quad (2)$$

- $Y_{i,t}$ denotes various socioeconomic outcomes for household 'i' in period 't'.
- Control group is the set of households that never used boreholes as the main water source.
- Model estimated using data for five years (2008, 2010, 2012, 2014 and 2017) with clustered standard errors.
- Sun and Abraham (2021) estimator yields the weighted average of treatment effects for each cohort (by year of borehole adoption) and each relative time after or before adoption.

Effect of Borehole Adoption: Consumption Expenditure

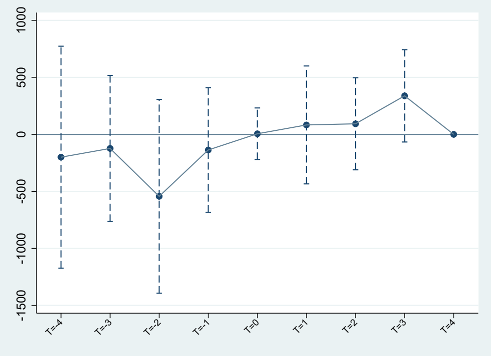


Figure: Effect of Borehole Adoption on Consumption Expenditure for Eligible Households in Drought-Affected Areas (N=740)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 1.62 (p-value = 0.8055).

Effect of Borehole Adoption: Expenditure on Energy (Including Diesel)

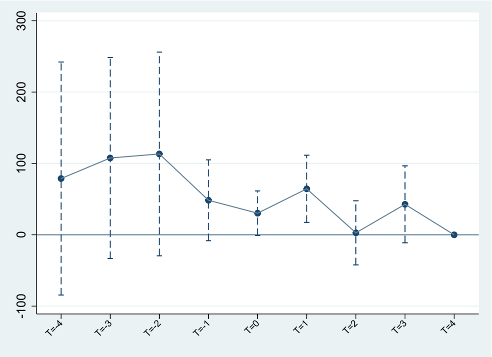


Figure: Effect of Borehole Adoption on Expenditure on Energy (inc. Diesel) for Eligible Households in Drought-Affected Areas (N= 277)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 6.32 (p-value = 0.1767).

Effect of Borehole Adoption: Expenditure on Electricity

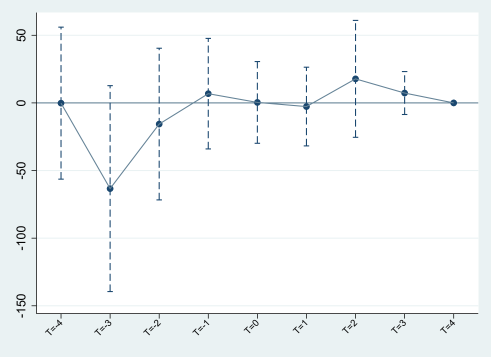


Figure: Effect of Borehole Adoption on Expenditure on Electricity for Eligible Households in Drought-Affected Areas (N= 769)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 3.30 (p-value = 0.5097).

Effect of Borehole Adoption: Employment

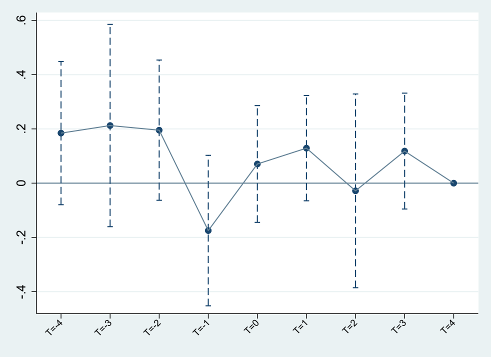


Figure: Effect of Borehole Adoption on Employment for Eligible Households in Drought-Affected Areas (N=783)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 6.63 (p-value = 0.1571).

Effect of Borehole Adoption: Life Satisfaction

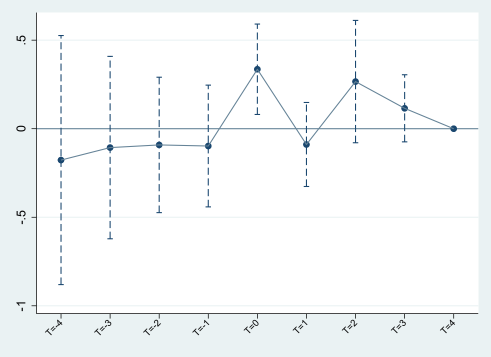


Figure: Effect of Borehole Adoption on the likelihood of the household head being 'satisfied with life' (N= 702)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 0.58 (p-value = 0.9656).

Robustness Checks and Placebo Checks

- The main RDD-based results on borehole adoption are robust to:
  - Alternative functional forms for the parametric RDD model (omitting the interaction between the running variable and the treatment indicator, quadratic polynomial, dropping covariates).
  - Use of a non-parametric RDD methodology (Carill et al. 2023 methodology for subgroup analysis).
  - Using groundwater level as a measure of drought.
  - Using weighted average of scPDSI over five closest grid-points to the district centroid to construct the drought variable.
  - Using only one year of data (from 2017, the year of a severe drought).
- The RDD results on borehole adoption do not hold on using
  - Varying income cut-offs.
  - Estimating RDD models individually for other years except 2014 and 2017 (when drought conditions were weaker).

Conclusion-I

- The Indigent Program may have facilitated adaptation, to the extent that eligible households were more likely to use a borehole (especially communal borehole) as their main water source.
  - These effects were small, but salient for drought-affected households.
  - Effects of program eligibility on other measures of electricity and water use were largely insignificant for drought-affected households.
- Event-study results suggest short-term positive effects of borehole adoption on expenditure on other sources of energy such as diesel, as well as on life satisfaction, but no significant employment and consumption expenditure effects for eligible households in drought-affected areas.
  - Households likely used their loosened budget constraints for other costs related to borehole pump use (e.g., costs of diesel for generators and borehole pumps, etc.).

Conclusion-II

- However, the gains from the program in terms of adaptation behaviour were limited:
  - Households may not have even been aware of the program, and may not have registered for it.
  - Small benefits offered within the program (average South African household consumes 9.4 KwH of electricity per day, or about 282 KwH per month).
  - Take-aways: adaptation/development programs need to:
    - Take into account differences between drought-affected and -unaffected households, particularly in terms of the magnitude of assistance needed.
    - Raise awareness about the policy.
    - Provide incentives to minimise overuse of scarce resources.

Thank you!

Appendix

Example: Borehole Adoption By Program Eligibility

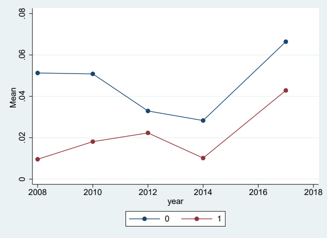


Figure: Drought-unaffected areas

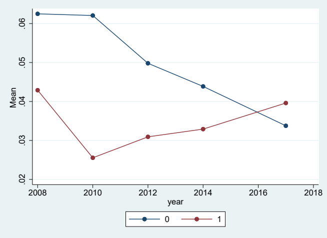
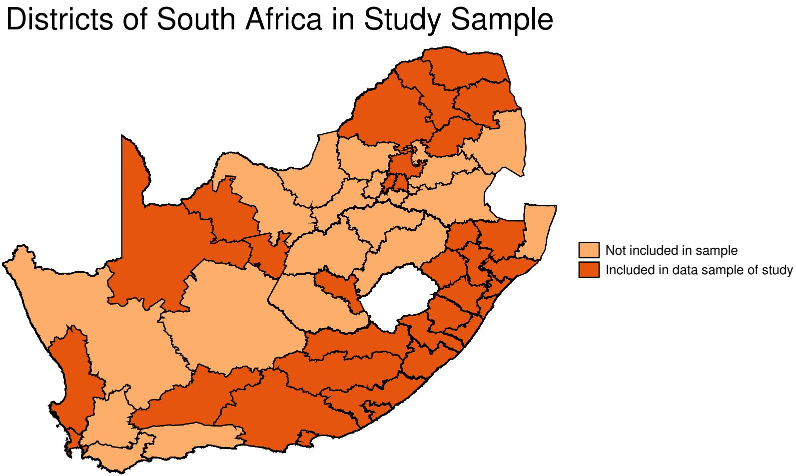


Figure: Drought-affected areas

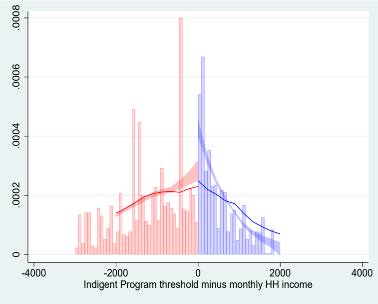
Data Sample: Districts



Assumptions of RDD- I

- Using the approach of local polynomial density estimators proposed in Cattaneo et al. (2020), the value of the T-statistic is 1.579, with a P-value of 0.114 on using a bandwidth of 1000 Rand.

Figure: Assumption 1: No Manipulation of the Running Variable (Using Cattaneo et al., 2020 Approach)



Assumptions of RDD-II

Table: Assumption 2: Covariate balance

Dependent Variables	Bandwidth = 1000
Whether HH owns home	-0.014
	(0.029)
Observations	1,863
Female HH head	-0.077**
	(0.037)
Observations	1,863
Educational attainment of HH head	-0.036
	(0.035)
Observations	1,863
Whether HH receives rental income	-0.012
	(0.014)
Observations	1,863
Whether HH lives in a brick house	-0.035
	(0.042)
Observations	1,863
Sum of nighttime lights (district-level)	0.114
	(0.081)
Observations	1,863
Household size	-0.172***
	(0.053)
Observations	1,863
Age of HH head	4.455***
	(1.276)
Observations	1,863

Impact of Borehole Use on Drought Indicators (Suggestive Evidence)

- What can we say about increased borehole adoption on the drought severity index and on groundwater levels?
- GWLS: groundwater level status, 0 denoting shallowest groundwater, 100 the deepest groundwater level.

Table: Effect of Average Borehole Adoption Rate (District-Level) on PDSI and Groundwater Levels

Mean DSI Value	(1)	(2)	(3)	(4)	(5)
Average Adoption Rate of Boreholes (District-level)	-0.503	0.617	0.664	1.863	2.074
	(2.064)	(2.314)	(2.203)	(2.647)	(2.395)
Observations	1513	1513	1513	1513	1513
GWLS	(1)	(2)	(3)	(4)	(5)
Average Adoption Rate of Boreholes (District-level)	-52.528**	-77.921**	-47.936**	-64.017**	-56.604*
	(23.465)	(29.683)	(22.309)	(26.227)	(28.386)
Observations	1283	1283	1283	1283	1283
District Fixed effects	No	Yes	No	Yes	Yes
Year fixed effects	No	No	Yes	Yes	Yes
Province-specific time trends	No	No	No	No	Yes
Covariates	Yes	Yes	Yes	Yes	Yes

FBE-I

- Districts decide income-based thresholds for households to qualify for the program.
- Eligibility is mostly based on income, but there are other requirements as well that vary across municipalities: applicants on behalf of a household must be at least 18 years old and South African citizens, the household should not own other fixed property than the one on which they reside (some municipalities require they must reside at the owned property), the applicant must be the owner of the property, etc.
- Households are required to submit, among other documents, certified copies of proof of income or a sworn affidavit if unemployed, as well as a copy of the applicant's identity document, as well as those of the spouse and all dependents.
- Households with prepaid meters can load extra electricity once the free allocation is finished, which is charged at regular rates. Those with post-paid meters will have the 50kWh amount discounted from their bill at the end of the month.

FBE-II

- The FBE program is administered at the municipality level: eligible households are identified by municipalities, and the list of possible FBE beneficiaries is submitted to Eskom/other electricity utilities.
- Beneficiaries can collect FBE vouchers on a monthly basis from Eskom vending outlets.
- FBE households who have prepaid meters can load extra electricity once the free allocation is finished, which is charged at regular rates. Those without prepaid meters will have the 50kWh amount discounted from their bill at the end of the month.

Results-I

Table: Reduced-Form Results: Other Outcome Variables

Sample	Overall Sample	Drought-affected Sub-sample	Drought-unaffected Sub-sample
Log of consumption expenditure	-0.024	-0.032	-0.014
	(0.041)	(0.043)	(0.092)
Observations	1,842	1,228	614
Log of expenditure on other energy (inc. diesel)	-0.113	-0.110	0.029
	(0.184)	(0.201)	(0.420)
Observations	691	493	198
Use electricity as the main energy source for cooking	0.009	-0.021	0.062
	(0.042)	(0.052)	(0.072)
Observations	1,863	1,244	619
Use electricity as the main energy source for lighting	0.025	-0.023	0.118**
	(0.032)	(0.041)	(0.051)
Observations	1,863	1,244	619
Use electricity as the main energy source for heating	0.003	-0.038	0.075
	(0.042)	(0.050)	(0.075)
Observations	1,861	1,242	619
Own a fridge	-0.004	-0.032	0.044
	(0.042)	(0.052)	(0.072)
Observations	1,863	1,244	619
Own an electric stove	0.001	-0.036	0.071
	(0.041)	(0.050)	(0.071)
Observations	1,863	1,244	619

Effect of Borehole Adoption: Probability of HH Growing Crops

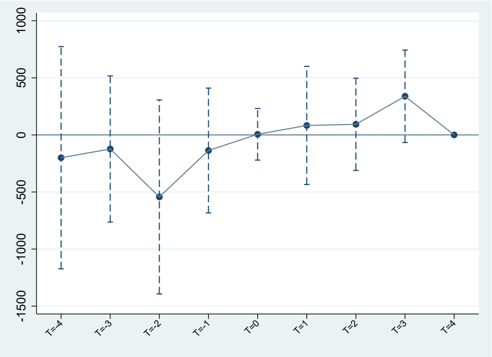


Figure: Effect of Borehole Adoption on Likelihood of Growing Crops for Eligible Households in Drought-Affected Areas (N= 740)

- F-statistic of pre-trends (testing whether all of the coefficients on the pre-event relative time indicators are jointly zero): 1.62 (p-value = 0.8055).