Cost and benefits of climate change adaptation policies

Evidence from an RCT and extreme flooding in Pakistan

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Can communities in low- and middle income countries
be made more resilient to extreme weather shocks ?

Summary

- **Setting** : Areas with highest needs of humanitarian aid after having been heavily affected by recurring disasters in the past
- **Interventions** : Support for community-level recovery with focus on protection against high risk events, such as natural disasters
- **Identification** : Cluster-randomized assignment of preparedness interventions
- **Data** : 3-wave panel data collected (2015, 2016, 2017)
- **Main result** : Disaster preparedness improves resilience in the face of a large shock
- **Funding** : $399.997 by UK's Department for International Development through the International Initiative for Impact Evaluation (3ie)

Background

- **Extreme weather events** are becoming more common due to climate change
- **Damages** from gradual warming are projected to be very high (recurrent humanitarian disasters and estimated $2.97 trillion in losses to the global economy over the past two decades (UNDRR 2020))
- Events **disproportionately impact lower-income communities** that cannot take steps to insure against the risk or costs of these events (esp. South Asia)

Empirical Evidence

Causally Testing Preparedness and Responses to Extreme Weather Events

Empirical challenges

- **Selection into programs** : Probability of receiving aid is negatively correlated with wealth

- **Natural disasters are hard-to predict** : Data-collections and policy evaluations are hard to plan and implement

- Little evidence . . .

Impacts of Extreme (Weather) Events : Large and Growing Body of Empirical Evidence

↓ **Risk** : Reduced propensity to take risks up to nine years after the disaster (Cameron and Shah 2015) ; fewer and less riskier investments (Binswanger et al. 1993; Dercon and Krishnan 1996)

↑ **Poverty** : 47-57 % (Datt and Hoogeveen 2003)

↓ **Education** : Herding households less likely to complete mandatory education, both in the long and medium terms (Groppo and Kraehnert 2017) ; intergenerational transmission (Caruso and Miller 2015)

↑ **Borrowing** : Del Ninno et al. (2003)

Δ **Consumption** : Hunger [due to war] → larger fraction of income spent on food throughout life (Kesternich et al. 2015)

↑ **Mortality** : Exposure at birth to (weather-related) famine → boys and girls lose on average 4, respectively 2.5 years of life after age 50 (Lindeboom et al. 2010)

Less Evidence on Effective Measures for Preparedness to Disasters/ Climate Change/ Extreme Weather Events

- ▸ Dacy and Kunreuther (1969) "The Economics of Natural Disasters" : Importance of resource allocation for recovery activities - emergency disaster plans ; early warning systems
- ▸ Barreca et al. (2016) : In the US, air conditioners reduce the mortality risk associated with high temperatures during the twentieth century
- ▸ Luechinger and Raschky (2009) find that flood disasters lower life satisfaction in regions without mandatory insurance, yet in regions with mandatory flood insurance the effect on life satisfaction was unchanged
- ▸ Von Peter et al. (2012), cross-c., uninsured disaster-related losses lead to income declines whereas there is no negative effect for insured losses (see also Noy (2009))
- ▸ Access to finance can raise a country's resilience to natural hazards (see alsoNoy (2009) cross-c.)

Overall, quickly growing and relevant body of literature !

Research Relevance of THIS Study

- Careful **evidence** on an adaptation policy that is sorely **missing** in the climate change literature
- **Type of intervention** that is increasingly important - partly for reasons of feasibility
- Gap in **cost-effectiveness** analyses of interventions - in particular need to have empirical estimates for **Social Cost of Carbon** (SCC)

Important topic, especially of interest to development economists, environmental economists, donors, and policy-makers or -implementers

The Intervention

Natural Disaster

Preparedness, Response and Recovery Program

DFID's Multi-Year Humanitarian Programme in Pakistan (total 100 million Pound)

to support a decrease in needs among populations affected by natural disasters and conflict

Natural Disasters in Pakistan

Exposure

- Pakistan is among the most natural disaster-affected countries (floods, earthquakes, droughts, monsoons, cyclones, and landslides)

Consequences

- Natural disasters were followed by recurrent humanitarian disasters in the past years
  - Lack of safe water, poor sanitation ; flood-related diseases, such as diarrhea and malaria
  - Food shortage (fertile crop land submerged ; livestock killed, grain washed away) ; chronic malnutrition
  - Lack of shelter ; migration
  - Loss of employment opportunities

Local Context

Pakistan's flood-hit areas — *2011, Source: OCHA*

The 2010 Pakistan flood was the most devastating since 1950s. One fifth of the country was flooded, over 20 million people were affected, and over 1,700 people died (WHO 2010).

In 2011, within only two months, floods deluged 27,581 km^2.

Program Implementation Strategy

Residual recovery packages and relief assistance for all those who might be affected by upcoming, future disasters

- ▸ **Coordinated** : ACTED is part of the *Natural Disaster Consortium* (together with IOM, FAO, UNICEF, HANDS)
- ▸ **Responsive** : In the event of a natural disaster all individuals in need are eligible for aid
- ▸ **Comprehensive** : Multi-sectoral, integrated response - delivery of services encompasses a set of activities
- ▸ **Supply-focused** : Physical capital injections and provision of human capital

ACTED's Basic Humanitarian Aid Package

- **Water, Sanitation and Hygiene** [$81,176] : Construction of own household latrines, distribution of sanitation kits

- **Shelter** [$424,706 ; 74.72% of total] : Integration of disaster risk reduction practices into shelter construction ; conditional cash for construction work

- **Food Security and Livelihoods** [$62,585] : Training on agriculture, water and livestock management as well as vaccination trainings (examples are disease outbreak handling, provision of seeds that resist floods or can be harvested earlier, and kitchen gardening training)

Research Questions

1. Do humanitarian aid interventions make individuals more **prepared** for emergencies? (**Preparedness**)

2. Can an improvement in intermediate outcomes improve life quality, regardless of whether a disaster occurs or not? (**Greater Impact**)

3. Are households in fact more **resilient** once a recurrent extreme weather event strikes? (**Resilience**)

Data

- ▸ **Eligible pool** : Areas that have been heavily affected by disasters in the past, have not yet fully recovered from the massive 2010 and 2011 floods
- ▸ **Targeting** : Households with children under five years of age were selected randomly
- ▸ **Waves** : Yearly panel data over three waves (2015-2017), thereof 1 baseline and 2 follow-ups
- ▸ **Clustering** : Villages, named *goath* in Sindhi, combined into clusters (n=287)
- ▸ **Interviews** : 15 households per cluster, at least one 10+ villagers Focus Group Discussion
- ▸ **Stratification** : In two districts (Badin and Kashmore)
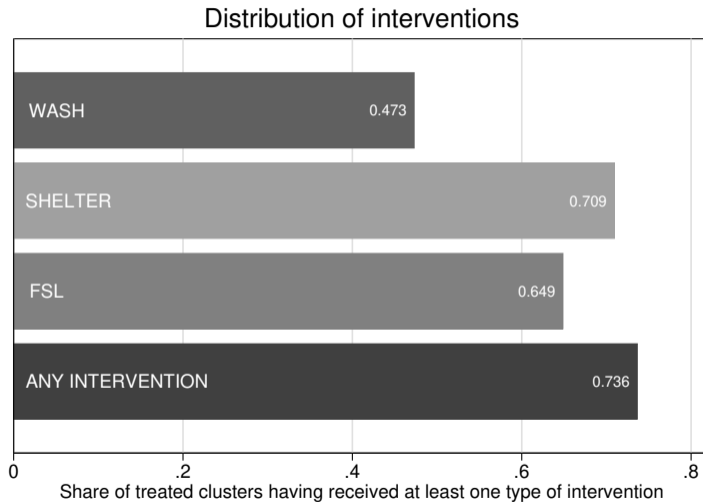
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Randomization and Intention-to-Treat Effect

$$Y_{it} = \alpha_t + \beta D_i + \mathbf{X}_i \delta + u_{it},$$

- where Y_{it} is an outcome in *goath* cluster i ($i = 1, ..., 287$) in wave t ($t = midline, endline$) i.e., $N = 574$
- α_t are wave fixed effects
- D_i is an indicator for being assigned to the climate adaptation program, β identifies the intent-to-treat impact of the program on *goath* cluster i
- $\mathbf{X}_i$ is the vector of baseline covariates (all variables that treatment was randomized on at baseline, i.e., at t=baseline)
- same clusters over 3 waves of data collections, i.e., standard errors are clustered at the *goath*-cluster level
- reported statistical significance : * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
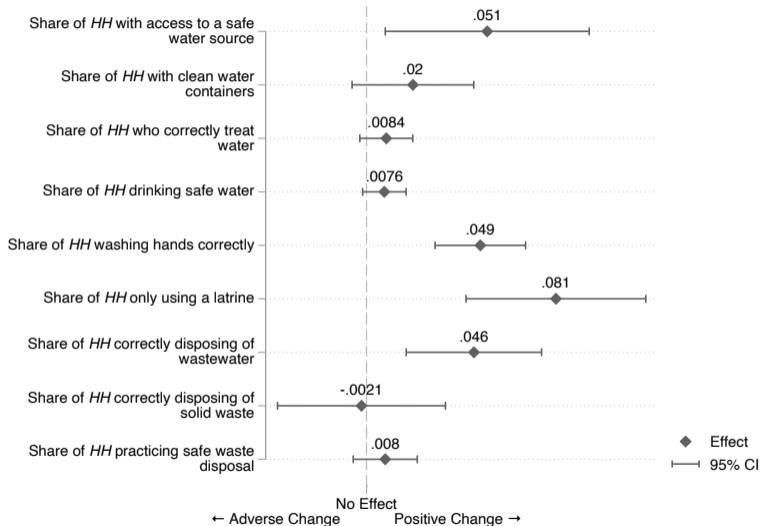
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Baseline Data : Treatment vs. Control Group

	(1) D	(2) Control	(3) Diff/SE
	T1 Treatment	Control	Diff/SE
Exposure to Natural Disasters/ Extreme Weather Events			
Number of times affected by disasters since 2010 (*FGD*)	1.696	1.737	-0.041 (0.057)
Number of people that migrated out of village	187.142	178.878	8.264 (34.530)
Number of people that migrated into village	10.020	10.691	-0.670 (5.157)
Share of *HH* with employment loss as a reason for income loss	0.507	0.515	-0.008 (0.035)
Share receiving assistance in the past 5 years	0.541	0.576	-0.035 (0.055)
WASH			
Share of people washing hands with water only	0.730	0.726	0.005 (0.024)
Share of *HH* with no access to latrines	0.800	0.805	-0.005 (0.026)
Share of respondents with no access to latrines (*HH* survey)	0.840	0.849	-0.009 (0.028)
Average toilet score	0.438	0.422	0.015 (0.067)
Share of *HH* : at least 1 member had diarrhea last month	0.227	0.218	0.008 (0.021)
Housing/ Shelter			
Share of shelters destroyed/ fallen apart in 2010	0.488	0.518	-0.030 (0.057)
Share of shelters destroyed/ fallen apart in 2011	0.514	0.522	-0.008 (0.059)
Share of shelters destroyed/ fallen apart in 2012	0.474	0.481	-0.006 (0.057)
Share of shelters destroyed/ fallen apart in 2013	0.013	0.007	0.006 (0.011)
Share of shelters destroyed/ fallen apart in 2014	0.017	0.018	-0.001 (0.013)
Share of shelters destroyed/ fallen apart in 2015	0.110	0.104	0.006 (0.034)
FSL			
Share of *HH* with poor or borderline *FCS*	0.619	0.644	-0.025 (0.029)
Share of *HH* with problems covering their food needs	0.531	0.561	-0.029 (0.032)
Share of *HH* that have own land	0.264	0.249	0.015 (0.030)
Average size of own land (in acres)	0.888	0.802	0.086 (0.134)
Share of *HH* that own livestock	0.715	0.709	0.007 (0.029)
Nutritional Status			
Share of malnutritioned children (weight-for-age)	0.409	0.392	0.017 (0.016)
Share of malnutritioned children (length-to-height-for-age)	0.568	0.566	0.002 (0.016)
Share of malnutritioned children (*BMI*-for-age)	0.096	0.090	0.006 (0.009)
Share of malnutritioned children (arm circumference-for-age)	0.199	0.180	0.019 (0.012)
Share of *HH* with access to a malnutrition program	0.298	0.337	-0.040 (0.048)
Household Characteristics			
Average number of *HH* members	7.904	7.653	0.251 (0.184)
Average age of respondent	36.442	36.716	-0.274 (0.477)
Average number of rooms per person	0.190	0.187	0.002 (0.004)
Share of non-educated *HH* heads	0.608	0.625	-0.017 (0.024)
Share of *HH* with all children attending school	0.374	0.379	-0.006 (0.023)
Average poverty score	18.680	18.593	0.087 (0.631)
Median monthly *HH* income	7704.560	7789.748	-85.188 (303.187)
Share of *HH* with air conditioner	0.012	0.012	0.000 (0.005)
Share of *HH* with cooking stove	0.061	0.068	-0.007 (0.022)
Share of *HH* with a vehicle	0.088	0.090	-0.002 (0.016)
Share of *HH* with a TV	0.085	0.088	-0.003 (0.013)
Average number of *HH* members in productive age	2.898	2.791	0.107 (0.087)
Share of *HH* with a refrigerator, freezer or washing machine	0.046	0.050	-0.004 (0.012)
*Goath-*Cluster Background Information			
Average program eligibility score	24.558	24.732	-0.174 (0.581)

Distribution of interventions

	Share of treated clusters having received at least one type of intervention
WASH	0.473
SHELTER	0.709
FSL	0.649
ANY INTERVENTION	0.736

Results

Disaster Preparedness : WASH

Disaster Preparedness : Shelter

Share of shelters made of bricks and/or concrete — .02

Share of shelters constructed on an elevation — .099

Share of shelters with strong foundations — .078

Share of shelters with a resilient structure — -.00093

Share of waterproof shelters — .12

Share of shelters with safety improv. constr. techn. — .013

♦ Effect
⊢—⊣ 95% CI

No Effect
← Adverse Change   Positive Change →

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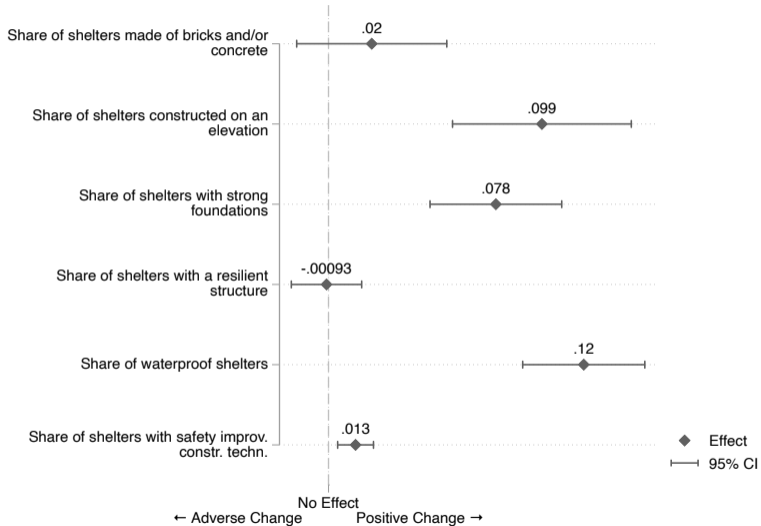
Disaster Preparedness : FSL
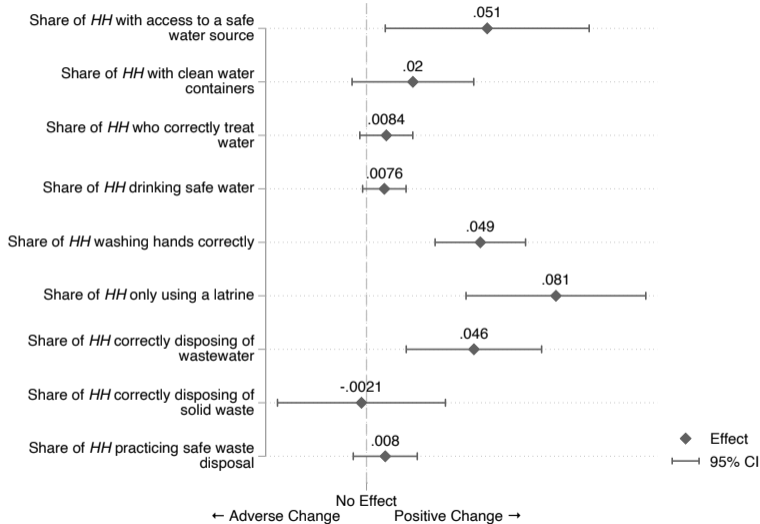
Disaster Preparedness : Summary
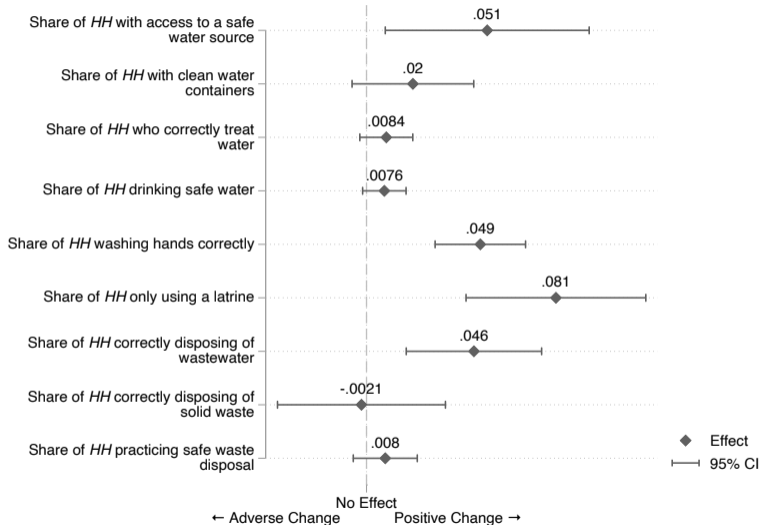
Direct Program Impacts

	(1)	(2)	(3)	(4)	(5)	
	C-Mean	C-SD	*N*	*D*	SE	
Panel A : Assets and Income						
Share of shelters with currently observable damages	0.396	0.226	574	**-0.083**	0.019	***
Share of *HH* that own any livestock	0.676	0.232	574	**0.043**	0.016	***
Average number of buffaloes owned by *HH*	0.857	0.667	574	**0.086**	0.050	*
Average monthly *HH* income	10580.208	3943.386	574	**301.766**	272.721	
Average outstanding *HH* debt	51107.268	36129.147	574	**-4360.660**	3265.406	
Average *HH* savings	272.699	554.965	574	**176.445**	100.858	*
Share poor *HH*	0.672	0.191	574	**-0.001**	0.013	
Average size of irrigation land and rain-fed land (in acres)	3.625	1.490	565	**-0.016**	0.144	
Panel B : Food-Security and Health						
Share of *HH* with poor or borderline *FCS*	0.564	0.220	574	**-0.020**	0.017	
Share of *HH* with problems covering their food needs	0.332	0.225	574	**-0.006**	0.018	
Share of *HH* : at least 1 member had diarrhea last month	0.205	0.152	574	**0.002**	0.012	
Share of *HH* : at least 1 member was sick last month	0.754	0.184	574	**-0.001**	0.014	
Share of malnutritioned children (weight-for-age)	0.429	0.211	570	**0.004**	0.014	
Panel C : Subjective Wellbeing						
Share of *HH* with high life satisfaction	0.695	0.216	574	**0.057**	0.015	***
Share of *HH* feeling prepared for fut. disaster or *EWE*	0.266	0.203	574	**0.058**	0.016	***
Coping Strategy Index	4.308	4.805	574	**0.715**	0.434	
Generalized Self-Efficacy Scale, 10/40	24.904	2.375	287	**0.547**	0.279	*
Generalized State-Trait Anxiety Inventory Scale, 10/40	27.806	1.966	287	**0.011**	0.213	

Short-term Benefits and Costs (in USD)

Part I: Costs	per HH (if 2,000 HHs are beneficiaries)	Total Costs
WASH	40.59	81,176.00
Shelter	212.35	424,706.00
FSL	31.29	62,585.00
Total	284.23	568,467.00
For a HH in the treatment area (n=8,895, given 60.1 HH per cluster):		
All	**65.03**	
Part II: Benefits		
	per HH	Benefits (for 2,000 HHs)
Estimates:	(ITT)	(ITT)
Full Sample		
Assets and Income	192.93	385,868.03
Shelter	28.06	56,114.00
All	**220.99**	441,982.00
Badin		
Assets and Income	213.74	427,487.47
Shelter	63.55	127,094.00
Health	73.21	146,425.81
All	**350.50**	701,007.31

"Resilience" ?

- ▸ While policy planners plan for more "resilience" towards negative shocks, the concept itself is rarely rigorously defined or measured

- ▸ Generally : **Capacity to withstand and/ or recover**

- ▸ Here : **Resilience** is measured as the ability to withstand the (negative) effects of hazardous climate events

Extreme Weather Events in Badin

Heavy rainfalls in single months of July 2016 and August 2016, which coincides with the monsoon season.

Monthly Rainfall in Badin and Jacobabad in 2015 in mm
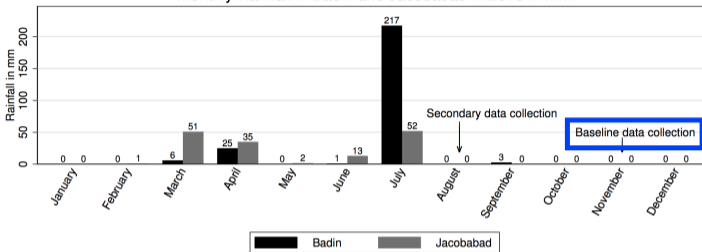
Monthly Rainfall in Badin and Jacobabad in 2016 in mm

No EWE in 2016
- 0.425
- 0.775
- 0.825
- 0.825

EWE in 2016
- 0.743
- 0.971
- 1.000
- 1.000

Legend:
- WASH
- Shelter
- FSL
- Any

Share of clusters with at least one type of intervention in program areas
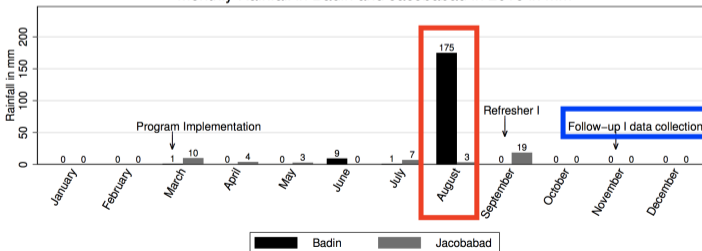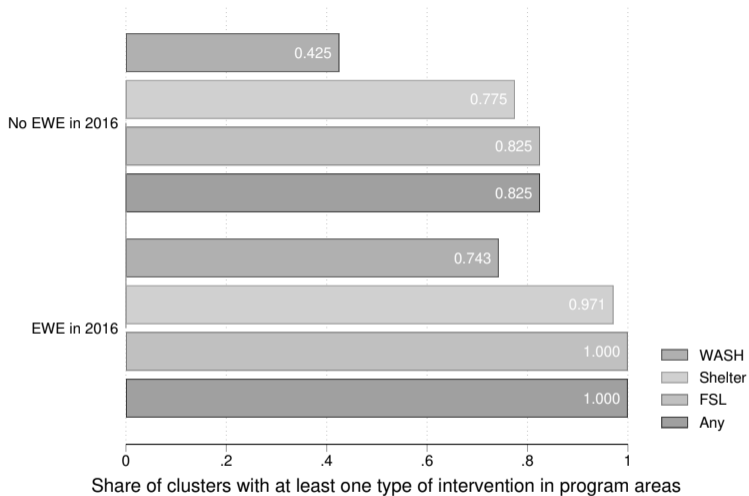
No statistical difference in likelihood of being exposed to the extreme weather event in 2016 between treatment and control group.

Resilience

Do the program effects differ depending on whether an extreme weather event (EWE) occurred or not?

$$Y_{i,t} = \alpha_t + \beta_1 D_i + \beta_2 EWE_i \times D_i + \beta_3 EWE_i + \mathbf{X}_i \delta_1 + u_{it}$$

- where EWE_i is an indicator for having been affected by an extreme weather event
- β_2 resilience effect (captures the degree to which the communities recovers after the extreme weather event)
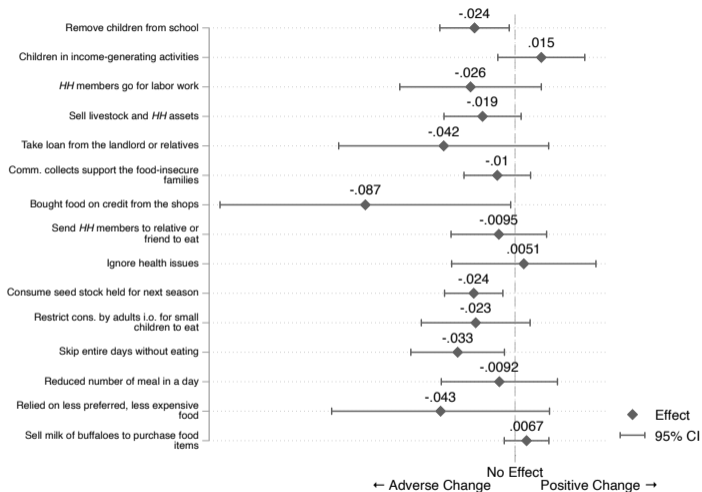- $\beta_1 + \beta_2$ preparedness effect
- sample : Badin

Resilience to Extreme Weather Events in Badin

	(I) Control Group		D		(II) Interaction Effects (incl. Resilience)				(III) Program Impacts (Adaptation, incl. Preparedness)		(IV) Targeting Heterogeneity
	Mean	SD	β_1	SE	D×EWE β_2	SE	EWE β_3	SE	$\beta_1+\beta_2$	$p_{\beta_1+\beta_2}$	$\Delta(x)$ nATE- rATE p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A: Assets and Income											
Share of shelters with currently observable damages	0.413	0.207	-0.090	[0.043]**	-0.064	[0.06]	0.032	[0.04]	-0.154	***	0.166
Share of HHs that own any livestock	0.571	0.234	0.007	[0.043]	0.091	[0.057]	-0.054	[0.038]	0.099	***	0.450
Average number of buffaloes owned by HH	0.474	0.399	0.000	[0.074]	0.111	[0.127]	-0.023	[0.083]	0.111		0.002 ***
Average monthly HH income	8422.735	1991.442	489.413	[427.685]	-134.426	[783.02]	134.854	[458.189]	354.986		0.016 **
Average outstanding HH debt	40159.478	26431.871	-1663.110	[6676.54]	-1375.835	[8294.325]	-1503.025	[6168.42]	-3038.945		0.327
Average HH savings	307.941	649.657	179.906	[221.548]	50.106	[312.09]	126.332	[214.619]	230.013		0.322
Share poor HHs	0.588	0.179	-0.047	[0.025]*	0.058	[0.04]	-0.033	[0.028]	0.010		0.002 ***
Average size of irrigation land and rain-fed land (in acres)	3.179	1.252	0.054	[0.34]	0.143	[0.471]	0.317	[0.272]	0.197		0.09 *
Panel B: Food-Security and Health											
Share of HHs with poor or borderline Food Consumption Score	0.634	0.213	-0.049	[0.044]	-0.004	[0.064]	0.023	[0.041]	-0.053		0.640
Share of HHs with problems covering their food needs	0.386	0.228	0.069	[0.037]*	-0.172	[0.052]***	0.107	[0.038]***	-0.103	***	0.543
Share of HHs: at least 1 member had diarrhea last month	0.172	0.131	0.058	[0.022]**	-0.118	[0.031]***	0.043	[0.025]*	-0.060	***	0.071 *
Share of HHs: at least 1 member was sick last month	0.676	0.181	0.042	[0.028]	-0.136	[0.044]***	0.068	[0.027]**	-0.094	***	0.043 **
Share of malnutritioned children (weight-for-age)	0.444	0.213	-0.002	[0.035]	0.005	[0.053]	0.061	[0.036]*	0.003		0.330
Panel C: Subjective Wellbeing											
Share of HHs with high life satisfaction	0.763	0.164	0.022	[0.027]	0.010	[0.041]	-0.024	[0.027]	0.032		0.727
Share of HHs feeling prepared for fut. disaster or EWE	0.262	0.165	0.055	[0.031]*	0.042	[0.048]	0.007	[0.032]	0.097	***	0.536
Coping Strategy Index	5.698	5.589	2.802	[1.149]**	-3.013	[1.468]**	2.717	[0.972]***	-0.211		0.483
Generalized Self-Efficacy Scale, 10/40	25.207	2.606	1.476	[0.7]**	-1.171	[0.999]	1.510	[0.728]**	0.306		0.327
Generalized State-Trait Anxiety Inventory Scale, 10/40	28.765	1.862	0.126	[0.422]	0.055	[0.602]	-0.218	[0.466]	0.181		0.107

Coping Strategies : Preparedness × Extreme Weather Event

Remove children from school: -.024
Children in income-generating activities: .015
HH members go for labor work: -.026
Sell livestock and HH assets: -.019
Take loan from the landlord or relatives: -.042
Comm. collects support the food-insecure families: -.01
Bought food on credit from the shops: -.087
Send HH members to relative or friend to eat: -.0095
Ignore health issues: .0051
Consume seed stock held for next season: -.024
Restrict cons. by adults i.o. for small children to eat: -.023
Skip entire days without eating: -.033
Reduced number of meal in a day: -.0092
Relied on less preferred, less expensive food: -.043
Sell milk of buffaloes to purchase food items: .0067

◆ Effect
⊢—⊣ 95% CI

No Effect
← Adverse Change   Positive Change →

Notes : The figure displays on the left the indicators which are part of the coping strategy index. The figure displays the coefficients of the interaction effect of the variables D_i and *EWE*. Observations are measured at the household level, with standard errors being clustered at the *goath*-cluster level.

Resilience to Extreme Weather Events in Badin : Allows to Update Cost-Benefit Calculations

		(I) Control Group		D		(II) Individual Effects		EWE		(III) Joint Effects	
		Mean (1)	SD (2)	β_1 (3)	SE (4)	D×EWE β_2 (5)	SE (6)	β_3 (7)	SE (8)	$\beta_1+\beta_2$ (9)	$p_{\beta_1+\beta_2}$ (10)
(1)	Average value of livestock per HH	649.979	529.309	125.464	[106.178]	**21.257**	[149.755]	-11.711	[98.790]	**146.721**	[0.186]
(2)	Average value of livestock and income per year per HH	1605.628	576.211	143.144	[110.227]	**50.856**	[175.042]	-48.005	[111.576]	**194.000**	[0.175]
(3)	Average value of livestock, income per year, savings and debt per HH	1224.453	602.066	174.336	[121.319]	**39.408**	[187.434]	-19.759	[115.775]	**213.744**	[0.142]
(4)	Value of undamaged shelters per HH	294.768	108.429	47.711	[21.542]**	**15.836**	[30.115]	-34.704	[19.925]*	**63.547**	[0.002]***
In sum:											
(5)	Value of livestock, income, net savings and shelter per HH	1519.221	614.148	222.047	[123.821]*	**55.244**	[190.787]	-54.463	[121.380]	**277.291**	[0.061]*
(6)	Disease burden from diarrhea per HH	257.401	198.831	70.901	[33.909]**	**-144.114**	[50.093]***	47.010	[34.680]	**-73.213**	[0.043]**

… adding few more assumptions on how the impacts would develop over a ten-year period, the returns on investment are : \$1 spent on the adaptation measures generates \$11 in socio-economic benefits

Conclusion

Presenting first causal estimates of the effects of climate adaptation program :

- ▶ **Preparedness** : Villagers have adapted and applied the messages and interventions delivered by the NGO
- ▶ **Greater Impact** : Households reportedly feel better prepared for natural disasters, own more livestock and have more savings
- ▶ **Resilience** : In interaction with 2016 excessive floods, greater resilience w.r.t. food needs and diarrhea (of children)
- ▶ A **cost-effectiveness analysis** suggests solid returns to investment (cost \$1 : benefits \$11)
- ▶ **Policy** implication : Background analysis to (a) update program locally at ACTED and for discussions in UK parliament and (b) WFP guidelines on malnutrition prevention.

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