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Long Lasting Macroeconomic Impacts of Natural Disaster Events

An Econometric ARIMA Modeling Approach

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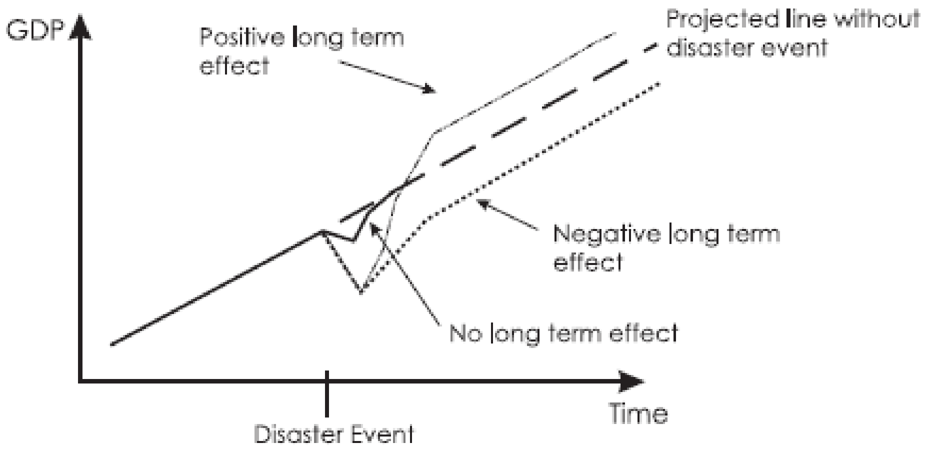
Motivation: Natural Disaster Consequences on the Long Run

Focus: Country level
Macroeconomic performance measure: GDP
Effects after natural disaster events
Empirical and modeling approach

Problem Statement:

Generally speaking natural disaster events can have three different effects on future macroeconomic performance



Literature: Analyses based on real ex-ante performance only

Study	Response variables	Vulnerability variables predicting adverse macro effects
Charveriat (2000)	•GDP	•Size of the economy, degree of diversification and size of the informal and agricultural sectors.
ECLAC and IDB, Freeman et al. 2002), Mechler (2004), Hochrainer (2006)	•GDP, fiscal variables	•Ability to refinance losses and provide relief to the affected population (financial vulnerability) •Availability of implicit (aid) and explicit (insurance) risk sharing arrangements
Benson and Clay (2004)	•Total GDP annual change •Agricultural GDP annual change •Non-Agric. GDP annual change	•Structure of the economy •Size •Income level and stage of development •Prevailing socioeconomic conditions
Noy (2007)	•GDP	•Literacy rate •Quality of institutions •Per capita income •Openness to trade •Levels of government spending •Foreign exchange reserves •Levels of domestic credit •Openness of capital accounts
Raschky (2008)	•GDP	•Availability of financial risk sharing institutions
Toya and Skidmore (2005)	•Disaster-related deaths •Damages/GDP	•Educational attainment in population aged 15 and over •Economic openness (exports+imports)/GDP •Financial sector level of development (M3/GDP) •Government consumption •Additional variables that determine the deaths caused by disasters (population, land area, disaster type).
Burton et al (1993); Kahn (2003)	•Deaths due to natural disasters	•Income

Motivation: Natural Disaster Consequences on the Long Run

Problem Statement

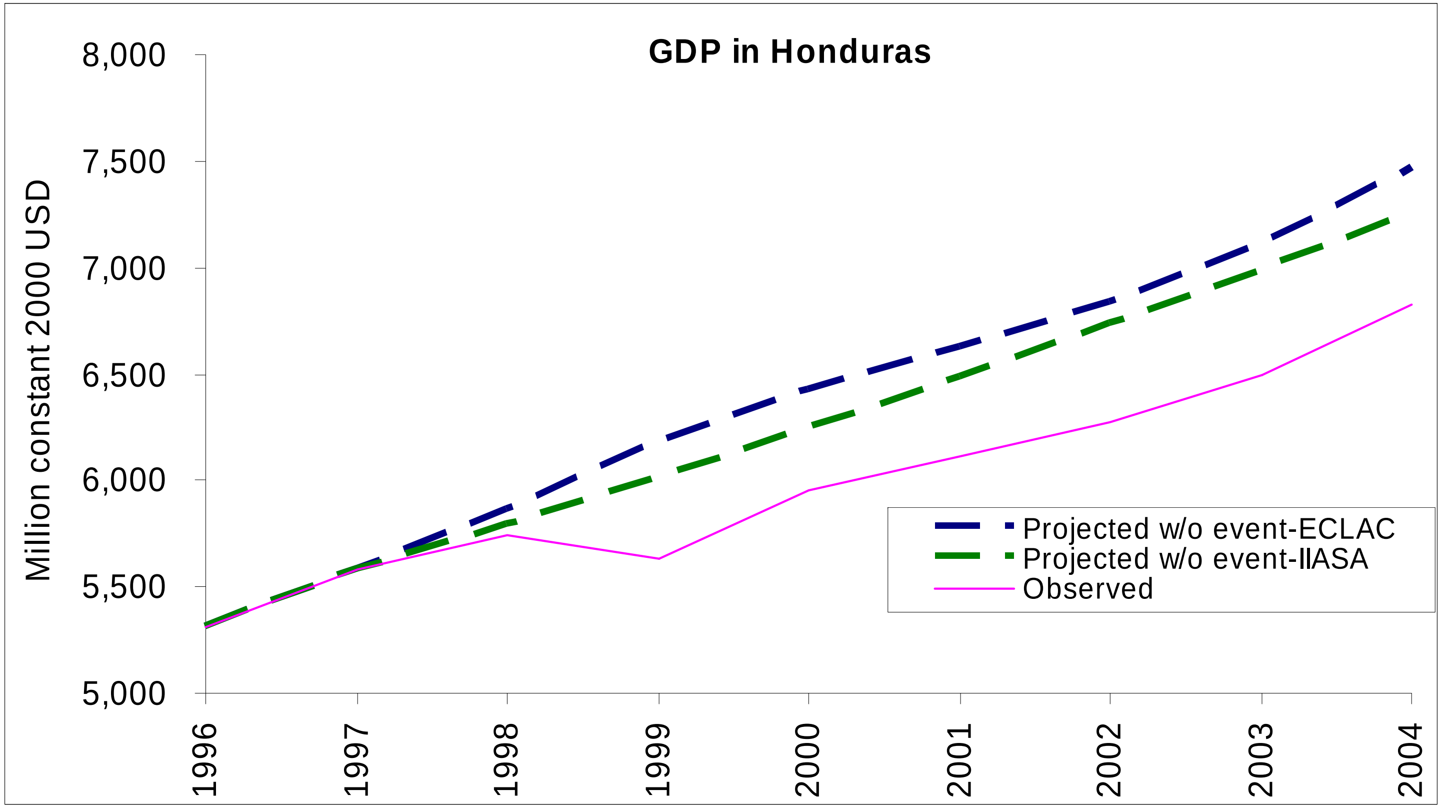
- While the balance of evidence and studies in the literature seems to imply adverse economic disaster effects in terms of the “negative” trajectory stylized above, there are important “outliers” that merit more investigation.
- Furthermore the studies generally have a short-term focus, and in their analyses often do not go beyond the year following an event.
- Finally, analyses generally compare key indicators of interest after the fact to their pre-disaster states, rather than comparing the counterfactual, i.e. the system without a shock, to the observed.

New Approach

In order to identify the net effects of disaster events, one has to compare the counterfactual ex-post to the actual ex-post, not the actual ex-post to the actual ex-ante.

Natural disaster consequences on the long run: Example

Honduras, Hurricane Mitch end of 1998.



Absolute GDP with the event and projected GDP without an event were estimated. In 2004: 6 percent below potential GDP.

Projections into the future: Sample and modeling approach

Large Sample of disaster event observations:

- **more than 200 disaster events from 150 countries**
- **Specific economic models for each of these countries not feasible due:**
  - **clear cause and effect relationship not at hand**
  - **time consuming**
  - **data issues**
- **Use of an econometric model approach**
  - **has to be broad enough to be useful for all countries**
  - **must have good predictive performance**

-> ARIMA modelling approaches are chosen because they are sufficiently general to handle virtually all empirically observed patterns

Estimation Methodology: ARIMA(p,d,q) process

Autoregressive Integrated Moving Average model:

- Autoregressive process of order **AR(p)** can be defined as

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + \varepsilon_t$$

- Moving-average process of order **MA(q)** may be written as

*

$$x_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q}$$

- **ARMA(p,q)** process, with p autoregressive and q moving average terms

$$x_t = \phi_1 x_{t-1} + \ldots + \phi_p x_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q}$$

ε are white noise stochastic error terms.

θ ϕ are parameters to be estimated

Estimation Methodology: ARIMA(p,d,q) process

First order regular difference of y_t

$$\Delta y_t = y_t - y_{t-1}$$

Using a back-shift operator denoted as

$$B^k z_t = z_{t-k}$$

$$\Delta^d y_t = (1-B)^d y_t$$

ARIMA(p,d,q) model can then be expressed as

$$\boxed{\phi_p(B)(1-B)^d y_t = \theta_q(B)\varepsilon_t}$$

with

$$\phi_p(B) = 1 - \phi_1 B - \ldots - \phi_p B^p$$

$$\theta_q(B) = 1 - \theta_1 B - \ldots - \theta_q B^q$$

Estimation Methodology: ARIMA(p,d,q) process

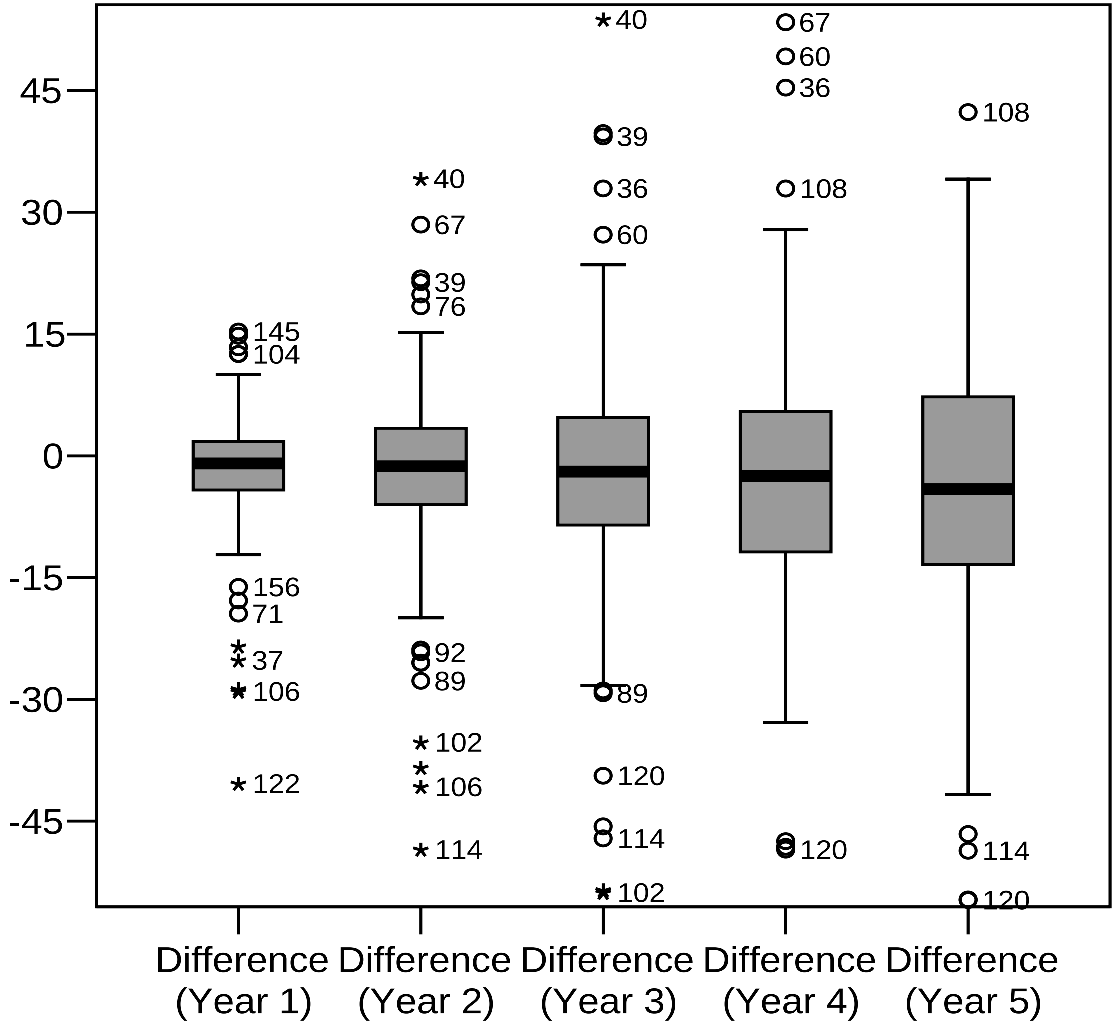
Forecasts into the future are performed with the selected models and then compared with actual outcomes. (Box-Jenkins Method)

Increases or decreases of GDP in subsequent years are measured as a percentage increase or decrease to the baseline level which is defined to be GDP one year before the disaster event.

Furthermore, the differences between observed values and projected ones are calculated and called Diff(t), e.g. percentage difference between observed and projected in year t.

We concentrate on projections up to 5 years into the future because of data limitations for the ARIMA models within the sample.

Results: Box-plot of Diff(1), Diff(2), Diff(3), Diff(4) and Diff(5)



Main Conclusion:

On "average" one can expect negative long run effects on the macroeconomic level due to natural disaster events.

	t+1	**t+2**	**t+3**	**t+4**	**t+5**
Mean	-1.40	-1.77	-2.30	-2.79	-3.60
Median	**-.56**	**-1.05**	**-1.84**	**-2.31**	**-4.11**
Std. Dev.	7.39	11.86	16.98	22.60	30.03
Skewness	-1.55	-1.25	-1.41	-2.26	-3.20

Non-parametric tests show that Null – Hypothesis (Diff(t)=0) has to be rejected for t=1,…, 5

Next question: What are good predictors to determine Diff(t).

Uncertainty Issues: Confidence bounds and sub-samples

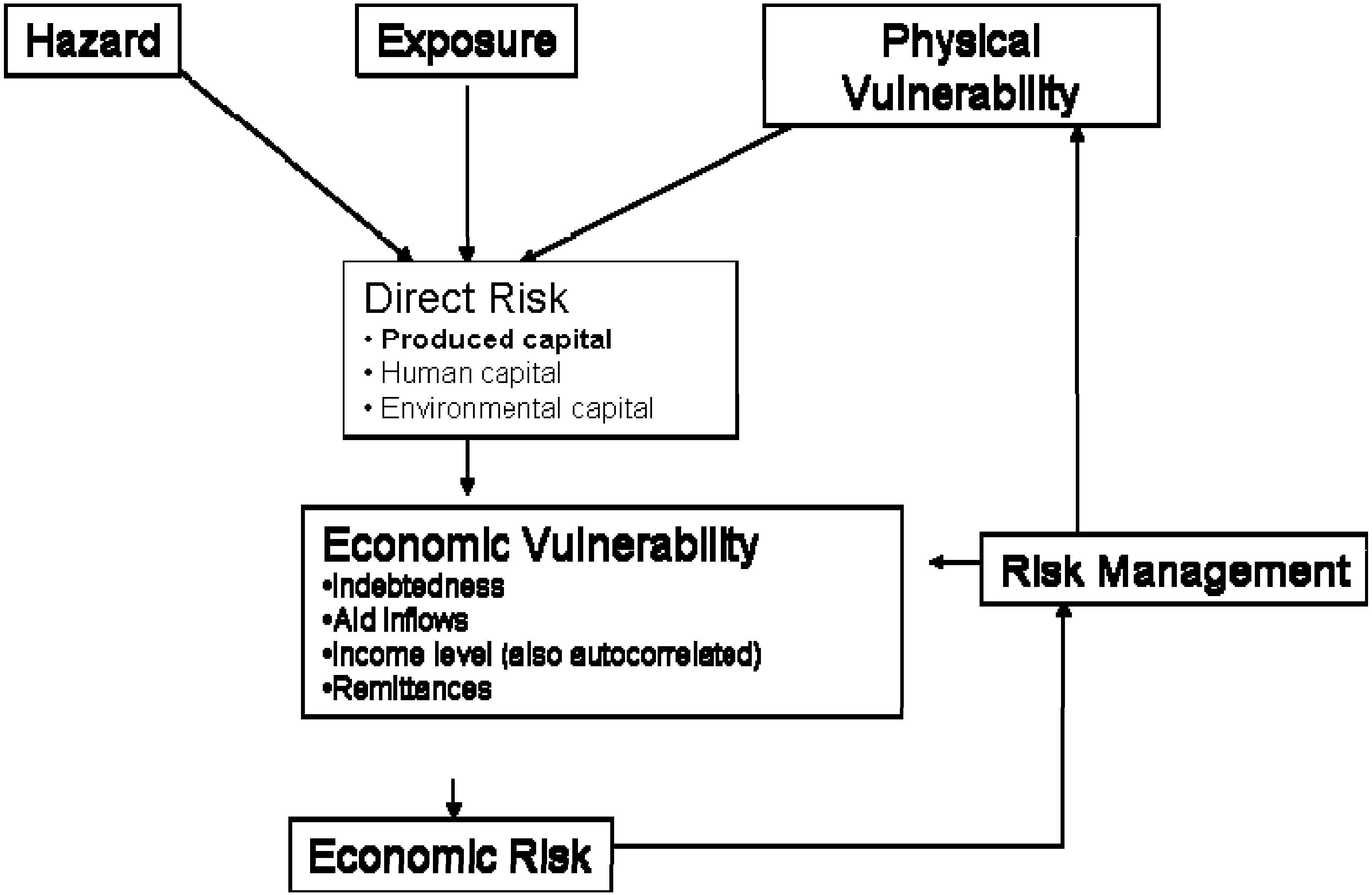
Mean and median of the sample differences using either the lower bound projections or the upper bound projections of the 95 percent forecast confidence intervals.

	t+1		t+2		t+3		t+4		t+5	
	low	up	low	up	low	up	low	up	low	up
Mean	-11.09	6.97	-22.95	14.18	-37.94	20.95	-56.15	27.06	-80.47	33.02
Median	-9.14	5.86	-19.10	13.10	-31.10	20.31	-44.95	27.79	-59.29	34.15

Summary results for differences of real and projected GDP levels for sub-sample

	t+1	t+2	t+3	t+4	t+5
Mean	-2.0558	-3.0284	-4.1281	-5.2683	-7.0973
Median	-.8355	-1.4487	-2.0793	-3.5084	-5.9910
Std. Dev.	7.75618	12.15134	17.14314	23.01776	30.86930
Skewness	-1.721	-1.764	-2.201	-3.200	-4.172
Observations	136	129	128	123	120

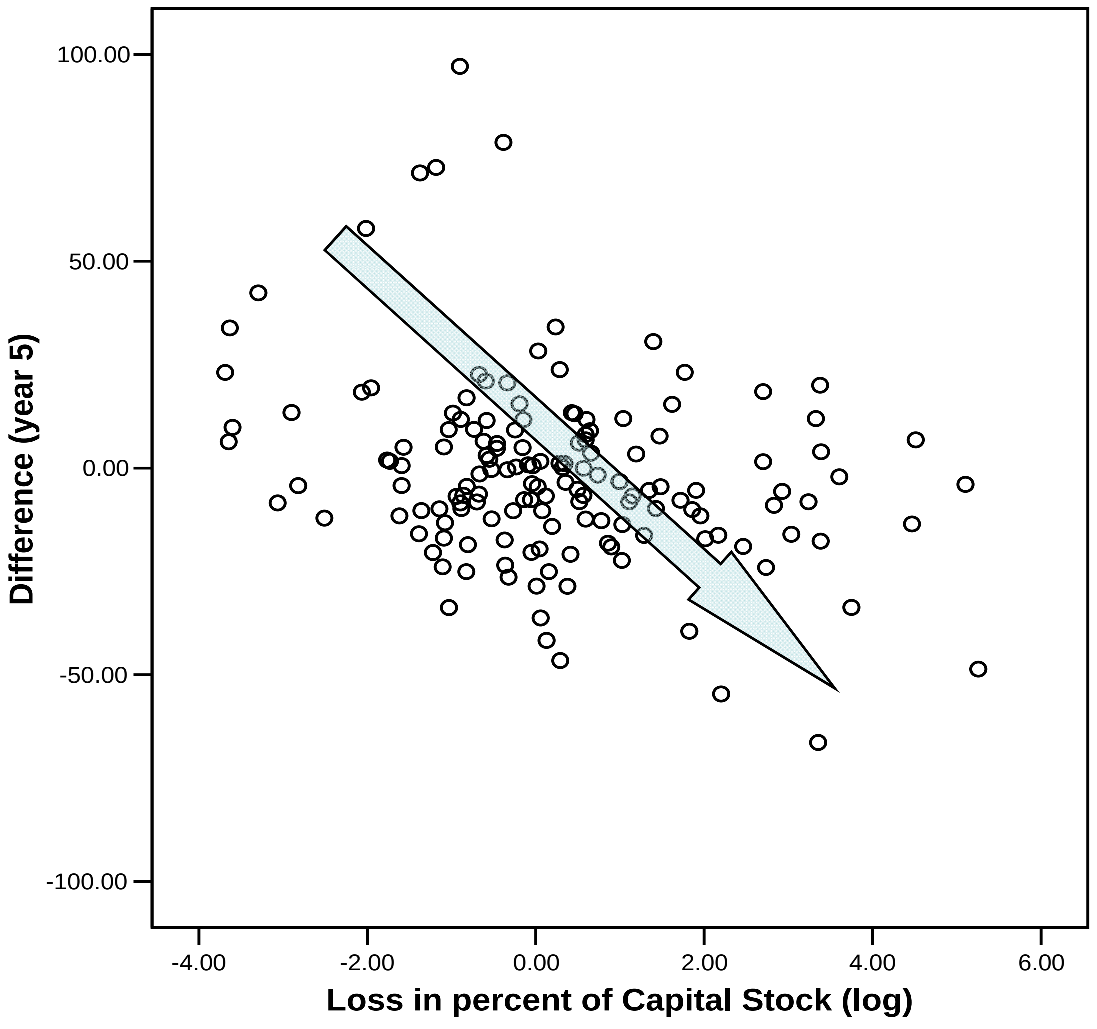
Disaster Risk Framework (CatSim)



Predictors separated around disaster risk framework

Predictors	Variables	Source
Direct Risk	Direct monetary losses	EMDAT, Munich Re as compiled by Okuyama, 2008
	Losses in percent of GDP	Okuyama 2008
	Losses in percent of Capital Stock	Own calculations
Exposure	GDP	WDI 2008
	Capital Stock	IIASA, 2008
	Total number of population	WDI 2008
Hazard	Hazard type: Storm, Flood, Earthquake, Drought, others	EMDAT, 2008 Munich Re, 2008
Economic vulnerability	Per capita income	WDI 2008
	Indebtedness level of country	WDI 2008
	Income level of country	WDI 2006
	Land Area	WDI 2008
	Literacy rate	WDI 2008
	Aid	WDI 2008
	Remittances	WDI 2008
	SIDS	WDI 2008

Example: Differences and loss of capital stock as predictor



Multivariate linear models forward regression:

Linear model with only covariates: Y=XB+E

Forward regression algorithm: Add variables to model till additional variables are not significant anymore

Model		Coefficients (Unstandardized) B	Coefficients (Unstandardized) Std. Error	Standardized Coefficients Beta	t	p-value
1	Constant	3.254	3.247		1.002	0.322
	Percent of Capital stock loss (log)	-4.600	2.076	-0.317	-2.216	0.032
2	Constant	-3.095	4.276		-0.724	0.473
	Percent of Capital stock loss (log)	-5.934	2.086	-0.409	-2.844	0.007
	Remittances	1.946	0.897	0.312	2.170	0.036

Capital Stock losses and Remittances highly significant

General Linear Model approach: Fixed Factors and Covariates

Including Fixed Factors: Hazard type, Indebtedness level, Income level, SIDS

		Value Label	N
Income	72.00	high income	19
	76.00	low income	46
	77.00	middle income	94
Indebtedness level	.00	NanN	20
	1.00	highly indebted	62
	2.00	middle indebted	18
	3.00	low indebted	59
SIDS	.00	no	118
	1.00	yes	41
Hazard type	1.00	Storm	55
	2.00	Flood	41
	3.00	Earthquake	26
	4.00	Drought	24
	5.00	other	13

General Linear Model: Combination of multivariate linear model and ANOVA (Analysis of Variance) models

General Linear Model: Results

Regarding the model specification, the model itself is highly significant (p-value=0.001) with about 70 percent of the variation explained (R-square)

Significant variables include the

- **Loss in capital stock**
- **Remittances**
- **Aid**

However, no interactions are significant as well as fixed factors.

Additional Problem: Model gets increasingly complicated and parameter estimates can not be easily computed due to the interaction effects.

Furthermore, general linear models are dependent on the type of Effects (I,II and type III effects). Above variables were significant for all type of models (but sometimes with lower R-square).

Conclusion

We found strong indications that negative consequences due to natural disasters can be expected even five years after the disaster event.

The negative effects are very dependent on the direct risk, as measured in percent loss of capital stock

Furthermore, higher aid as well as higher remittances lessen these negative consequences.

More detailed research about the cause and effect relationship as well as different variables contribution needed.

End of Presentation

Discussion