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THE CAUSAL EFFECT OF ENVIRONMENTAL CATASTROPHE ON LONG-RUN ECONOMIC GROWTH: EVIDENCE FROM 6,700 CYCLONES

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Introduction

- We examine how a specific type of environmental disaster, tropical cyclones, affect countries’ growth in the long-run.
- We construct a novel data set of all countries’ exposure to all cyclones on the planet
- We obtain estimates that are both economically large and statistically precise.
- each additional meter per second of annual nationally-averaged wind exposure lowers per capita economic output 0.37% twenty years later.
  - It is “globally valid”.

Literature Review

- The structure and impact of short-run macroeconomic disasters:
  - Barro (2006); Jones and Olken (2008); Gabaix (2012))
- The long-run growth effects of specific shocks:
  - Cerra and Saxena (2008): Currency crises, banking crises, political crises and civil wars
  - Reinhart and Rogoff (2009): Financial crises
  - Romer and Romer (2010): Tax increases
  - Dell, Jones and Olken (2012): Changes in temperature
- All long-run effects are negative, But
- In addition to human-caused political and financial crises, large-scale natural environmental disasters play a important role in shaping patterns of global economic activity

Literature Review

Long run <-> Time

Table 1: Effects of cyclones and other shocks to income per capita

Event Type	Effect on Income	Observed After	In-Sample Probability
Temperature increase (+1°C)*[1]	−1.0%	10 yrs	6.4%
Civil war[2]	−3.0%	10 yrs	6.3%
Tax increase (+1% GDP)**[3]	−3.1%	4 yrs	†16.8%
1 standard deviation cyclone	**−3.6%**	**20 yrs**	**14.4%**
Currency crisis[2]	−4.0%	10 yrs	34.7%
Weakening executive constraints [2]	−4.0%	10 yrs	3.7%
90th percentile cyclone	**−7.4%**	**20 yrs**	**5.8%**
Banking crisis[2]	−7.5%	10 yrs	15.7%
Financial crisis[4]	−9.0%	2 yrs	<0.1%
99th percentile cyclone	**−14.9%**	**20 yrs**	**0.6%**

*Poor countries only. **USA only. †Number of quarters with any tax change.

[1]Dell, Jones & Olken (AEJ: Macro, 2012), [2]Cerra & Saxena (AER, 2008), [3]Romer & Romer (AER, 2010), [4]Reinhart & Rogoff (AER, 2009)

Literature Review

- The location of storms are determined by geophysical constraints.
- Cyclones occur regularly and repeatedly, often striking the same population
- Incomes do not recover after a cyclone for a long time.
- Accumulation of income losses over time

Literature Review

- This result informs two important literatures:
- First, the role of geography in economic growth:
  - Geographic condition may matter because they determine the “initial conditions”.
  - Geographic conditions determine the “boundary conditions” throughout its development, perhaps by affecting the health of a population or the costs of trade.
- Our results:
  - Do not reject any of these theories
  - provide empirical evidence that repeated exposure to cyclones is a specific boundary condition to development.

Literature Review

- Second, the economic impact and optimal management of global climate change is
  - heavily researched with strong theoretical foundations
  - but less satisfying empirical grounding

- Prior Work:
  - Temperature's effect on agriculture, health, labor, energy, social conflict and growth.
  - Yet, the growth impact of tropical cyclones has not been considered in previous assessments of climate change.

Background

Four Competing Hypotheses:

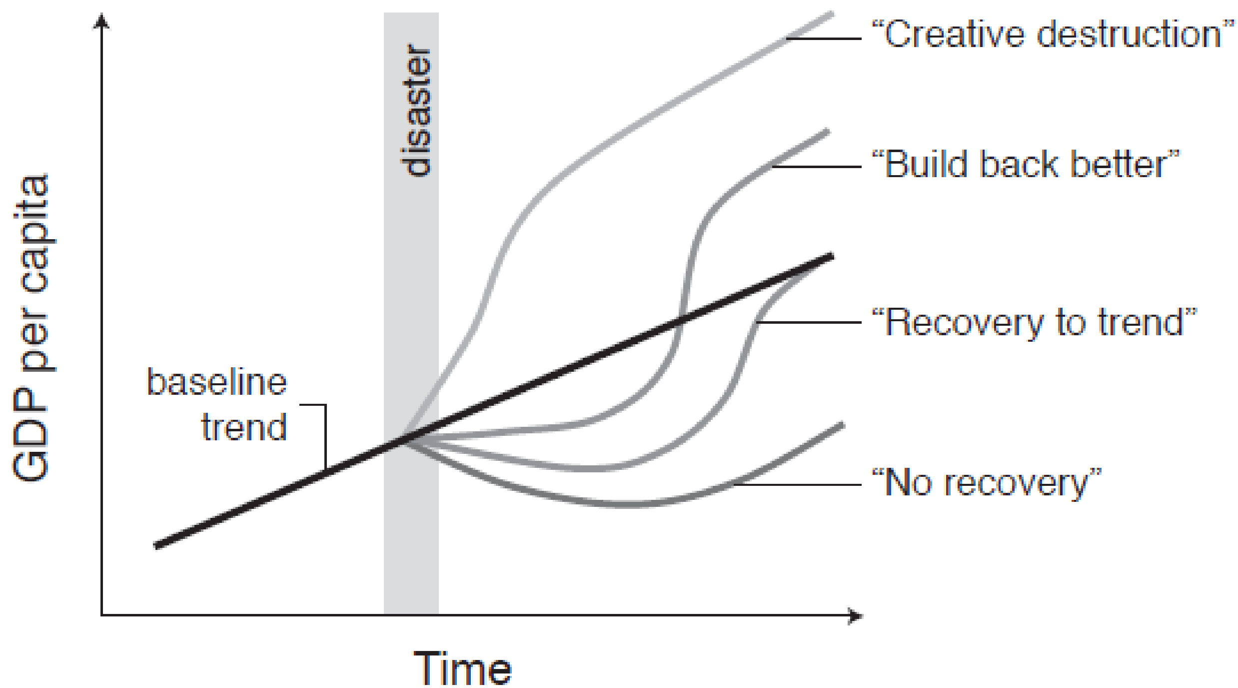


Figure 1: Four hypotheses, proposed in the literature, that describe the long-term evolution of GDPpc following a natural disaster.

Background

- Creative Destruction Hypothesis
  - Inflowing international aid and attention following disaster may promote growth
  - Environmental disruption stimulates innovation

  - motivated by the observation that construction industries often exhibit short-lived (1-2 year) increases in output after catastrophes
  - but it is unknown if this transient sector-specific response has enduring impact on the broader economy.

Background

- Build Back Better Hypothesis
  - Growth may suffer initially
  - However the gradual replacement of lost assets with modern units has a positive net effect on long-run growth

- Recovery to Trend Hypothesis
  - It is argued that this rebound should occur because the marginal product of capital will rise when capital and labor become relatively scarce after a disaster

- No Recovery Hypotheses
  - According to this hypothesis, post-disaster output may continue to grow in the long run, however it remains permanently lower than its pre-disaster trajectory.

Background

- Recent attempts have not convincingly demonstrated whether any of the four hypotheses above can be rejected or hold generally
- We resolve this indeterminacy by using better data.

- The quality of prior estimates are affected by the endogenous nature of their independent variables:
  - self-reported disaster counts and losses that are usually from the Emergency Events Database (EM-DAT).
  - The quality and completeness of these self-reported measures are known to depend heavily on the economic and political conditions in a country.
  - The exists omitted variables bias.

Background

- We focus on tropical cyclones: Hurricanes, Typhoons, Cyclones and tropical storms
- We estimate that roughly 35% of the global population is seriously affected by tropical cyclones.
- We reconstruct every storm observed on the planet during 1950-2008.
- Our objective measures of wind speed exposure and energy dissipation are fully exogenous.

Data

Table 2: Summary statistics for key variables in cyclone-exposed countries

Variable	Mean	Std. Dev.	Min.	Max.	N
Economic Characteristics					
Log GDPpc (Penn World Tables)	8.093	1.235	4.913	11.637	4914
Log GDPpc (World Development Indicators)	7.366	1.462	4.084	10.876	4248
Population (thousands)	32864	124191	7	1317066	6017
Small Island Developing State dummy	0.306	0.461	0	1	7905
Below median income (1970) dummy	0.643	0.479	0	1	5508
Physical Characteristics					
Tropical cyclones					
Wind speed (meters per second)	5.869	9.379	0	78.344	7905
Energy (standard deviations)	0.386	†1.271	0	19.41	7905
Log(land area)	9.606	3.984	-1.386	16.101	7905
Latitude (degrees north of Equator)	8.319	19.598	-41.577	59.388	7905

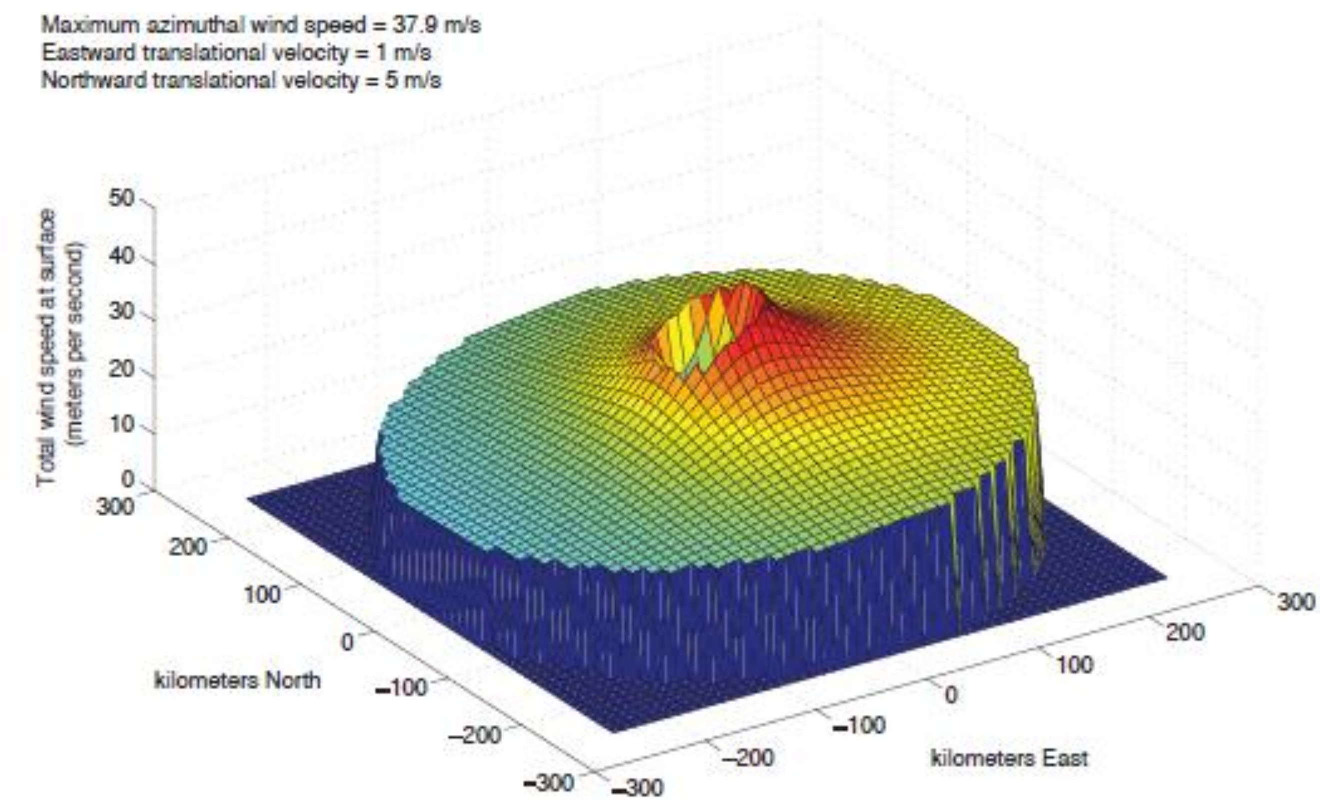
†The standard deviation of standardized *energy* is not equal to one because these summary statistics are computed for exposed countries only.

Data Reconstructing a global history of tropical cyclone exposure

- We use IBTrACS records for 6,712 storms observed during 1950–2008.
  - International Best Track Archive for Climate Stewardship
- IBTrACS reports:
  - The location of a cyclone's center
  - Its minimum central surface air pressure
  - Its maximum sustained surface winds
- every six hours.
- This sequence of point-wise observations allows researchers to plot the trajectory of a storm's center and it's core intensity on a map, but it is difficult to infer the exposure of national economies to these events using only this single line.
- For example, the recorded trajectory of Hurricane Allen in 1980 completely missed the national boundaries of Haiti but it would be a mistake to conclude that Haiti was not exposed to the storm
- It caused $400 million (1980 USD) in damage.

Data Reconstructing a global history of tropical cyclone exposure

- We estimate the instantaneous wind field within the storm at each moment in time
  - Limited Information Cyclone Reconstruction and Integration for Climate and Economics (LICRICE) model)



Data Reconstructing a global history of tropical cyclone exposure

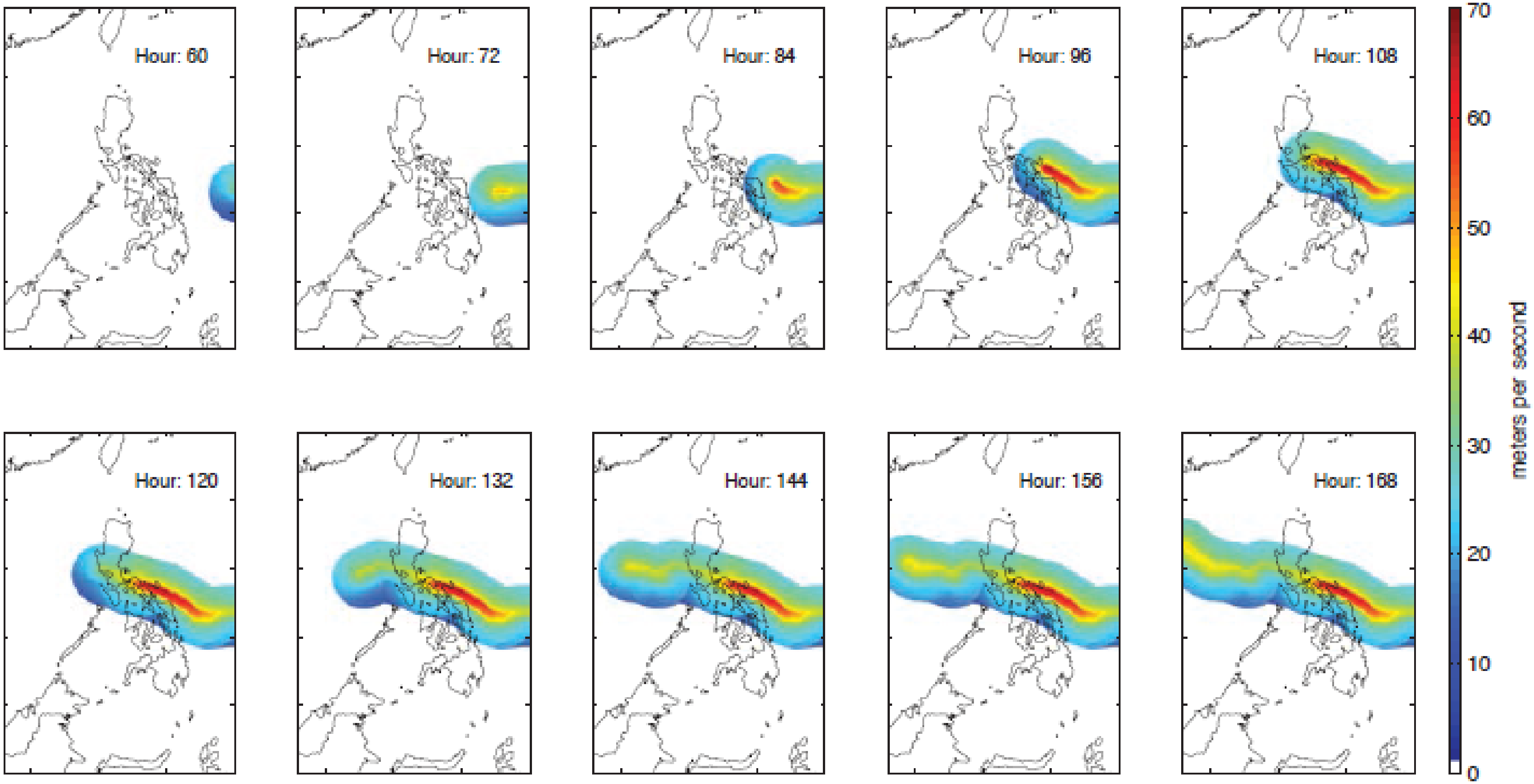


Figure 3: An example LICRICE reconstruction of location-specific tropical cyclone maximum wind speed exposure throughout the evolution of Super Typhoon Joan as it made landfall over the Philippines in October of 1970.

Data Matching cyclone data to economic units of observation

- The constructed data:
  - Each $0.1^\circ \times 0.1^\circ$ pixel of the Earth's surface takes different values every hour.
- Macroeconomic data
  - Country-by-Year.
- We collapse pixel-level wind exposure to the country-by-year unit using a spatially-weighted average over all pixels in a country:

$$\bar{S}_i = \frac{\sum_{p \in i} S_p a_p}{\sum_{p \in i} a_p}$$

- p: pixel index
- a_p: area in pixel p
- S_p: wind speed in pixel p
- $\bar{S}_i$: wind speed in country i

Data Matching cyclone data to economic units of observation

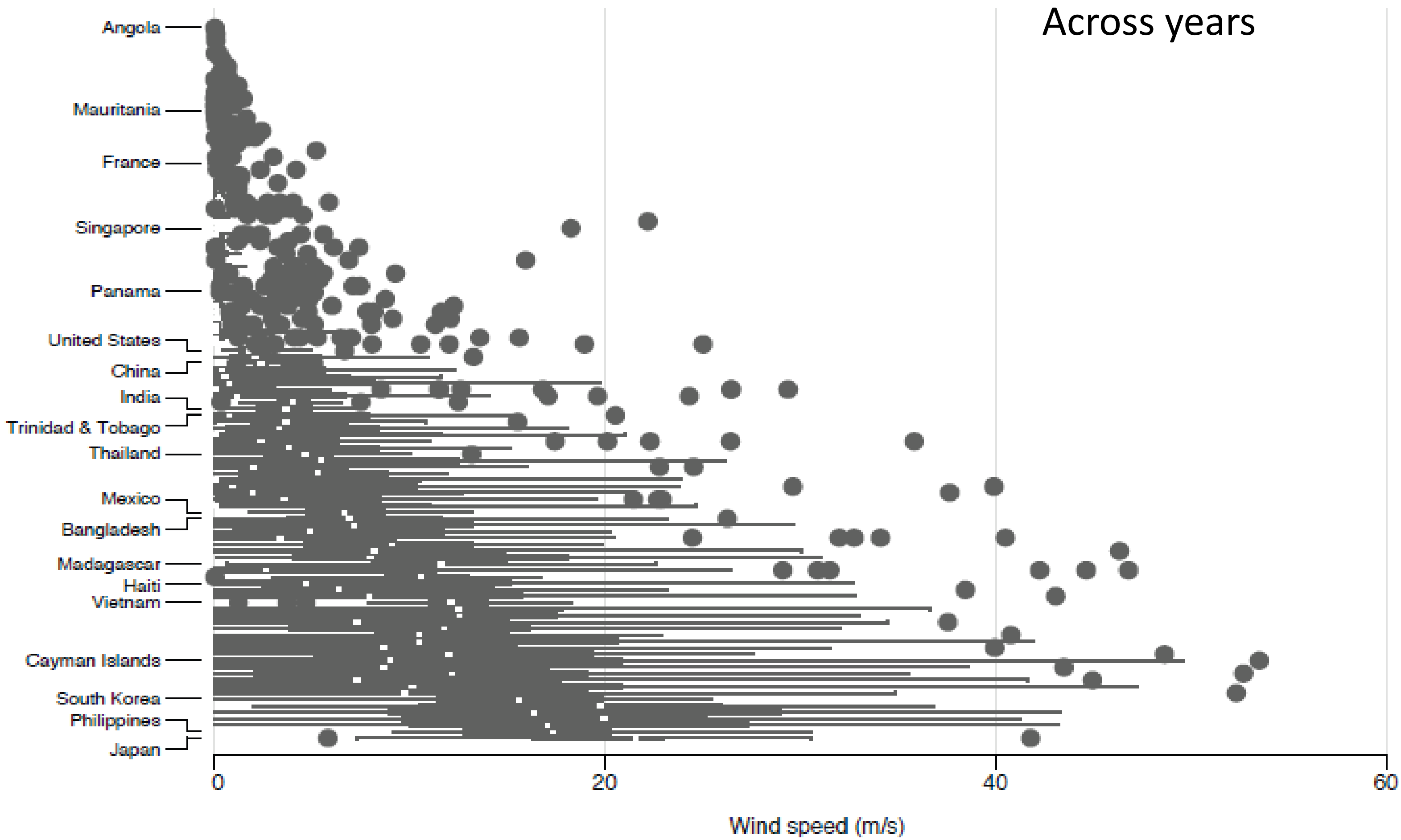


Figure 6: Boxplot of within-country distributions of country-by-year wind speeds during 1950-2008 for exposed countries. Boxes are interquartile ranges, white stripe is the median, circles are outliers. Countries are ordered according to their mean exposure across years. Countries with no positive exposure observations are not shown.

Empirical Approach

- Approach: differences-in-differences
  - Modeling first differences of the logarithm of GDP
  - A distributed lag model (With current and historical cyclone exposure)

$$\ln(GDP_{i,t}) - \ln(GDP_{i,t-1}) = \sum_{L=0}^{k} \left[\beta_L \times \bar{S}_{i,t-L}\right] + \gamma_i + \delta_t + \theta_i \times t + \eta \times X_{i,t} + \epsilon_{i,t} \qquad (2)$$

  - δ: Fixed year effect
  - θ: Country specific trends
  - γ: Fixed country effect
  - X: control variables
  - β: PARAMETERS of INTEREST

- OLS

Empirical Approach

$$\ln(GDP_{i,t}) - \ln(GDP_{i,t-1}) = \sum_{L=0}^{k} \left[\beta_L \times \bar{S}_{i,t-L}\right] + \gamma_i + \delta_t + \theta_i \times t + \eta \times X_{i,t} + \epsilon_{i,t} \tag{2}$$

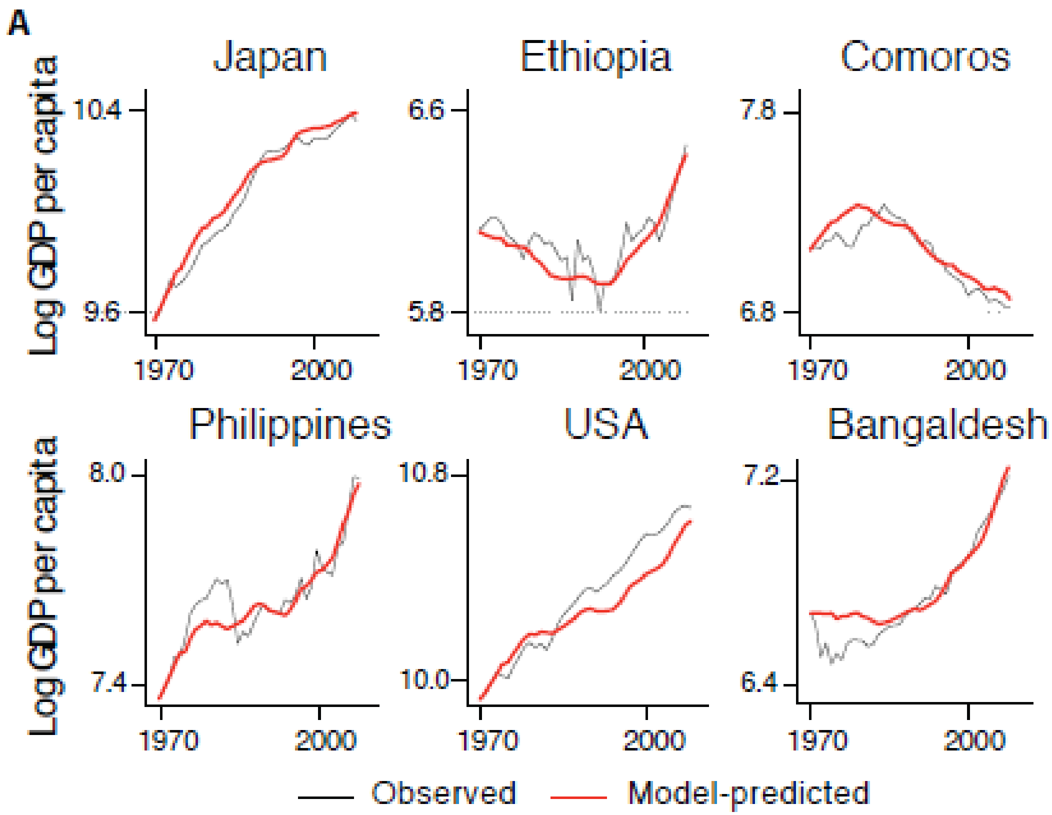
- Cumulative effect of cyclone j years after exposure:

$$\Omega_j = \sum_{L=0}^{j} \beta_L. \tag{3}$$

- In addition to our novel data, another innovation in our analysis is to examine a model that spans two full decades.
- In our results section we experiment with alternative lag lengths and observe no appreciable change in our results.
- Yet growth in the short run tends to be auto-regressive, leading many researchers to estimate auto-regressive distributed lag models in these settings
- We employ this latter approach in a robustness check (up to four years of lagged growth)

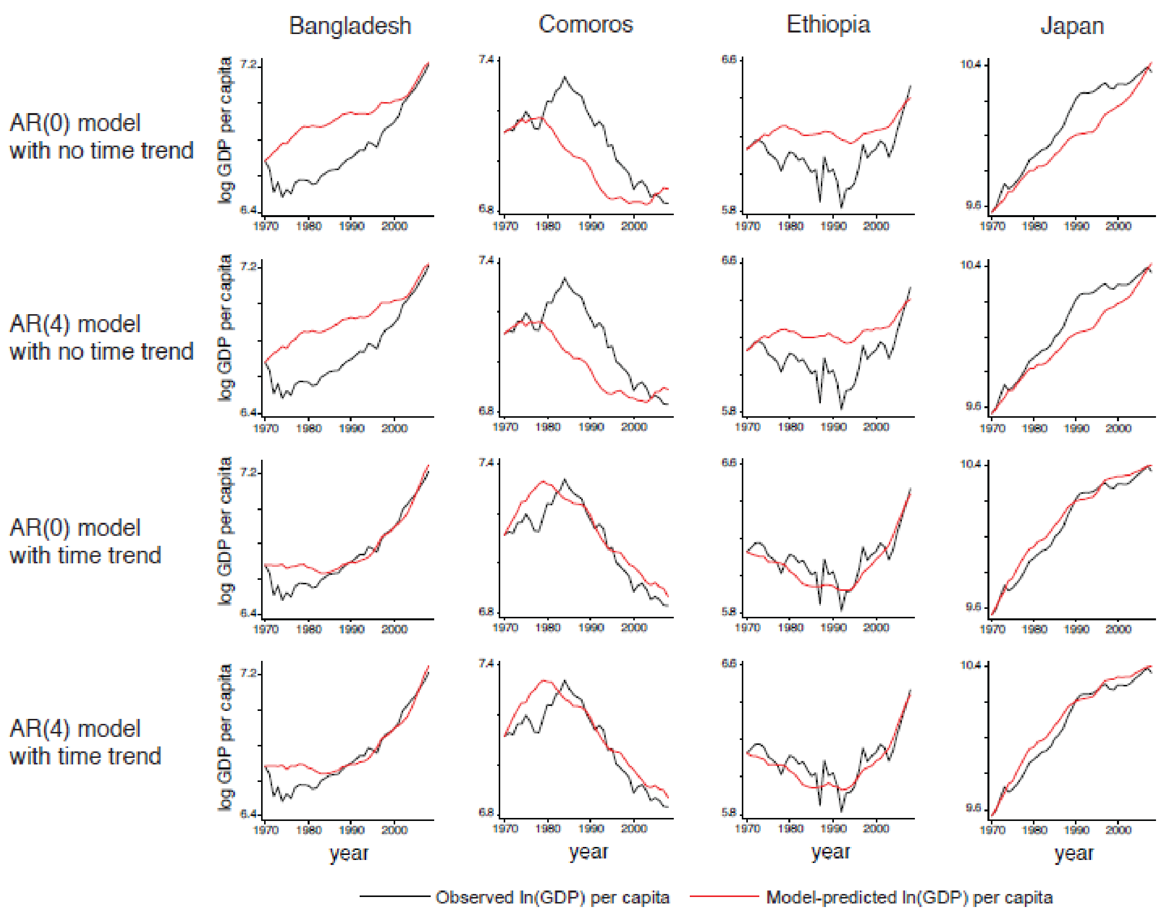
Empirical Approach

- The trend component (θ) of the model is likely important, since different countries within the sample have income trajectories that are convex and concave, as well as some with almost zero curvature.



Empirical Approach

– Inclusion of four years of auto-regressive terms in the model does not correct for this issue



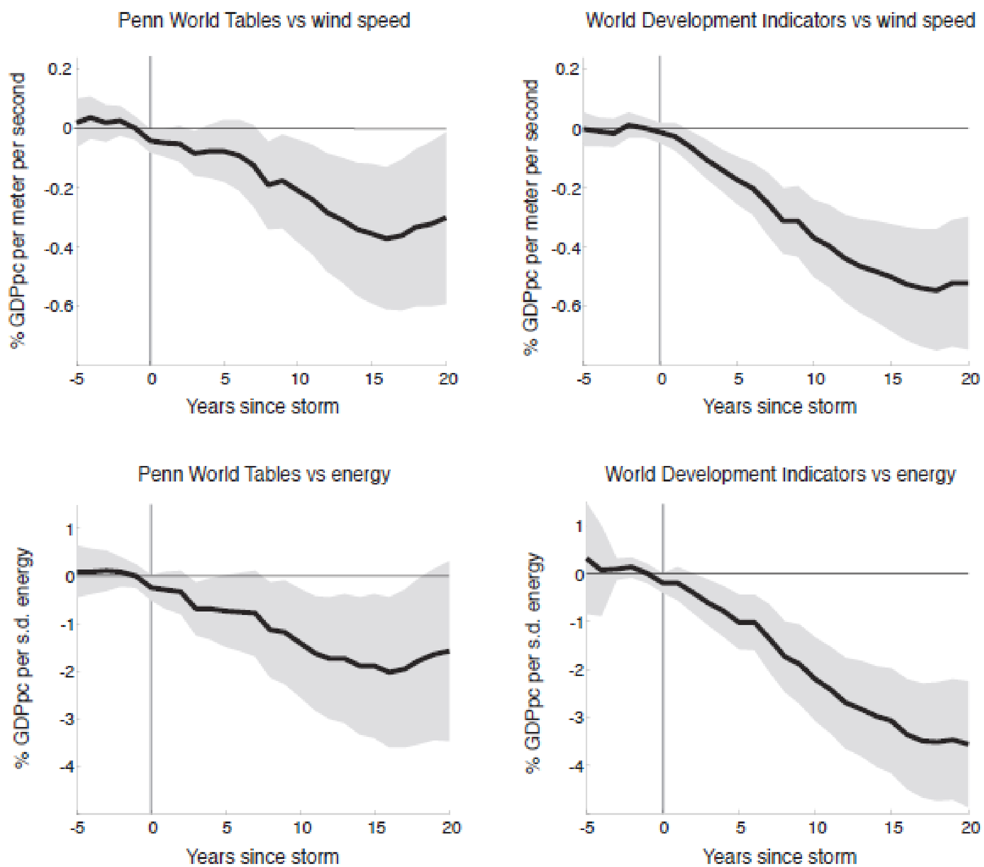
Empirical Approach

- Nonetheless, for completeness we also estimate a version of Equation 2 that omits θ as a robustness check.

- Auto-regressive models recover results that are indistinguishable from our benchmark model, which is AR(0).

Results

– the long-run effect of tropical cyclones on GDP relative to a country's pre-disaster baseline trend.



Fifteen years after a strike, GDP is 0.38 percentage points lower for every additional 1 m/s of wind speed exposure and exhibits no sign of recovery after twenty years.

95% confidence intervals

Results

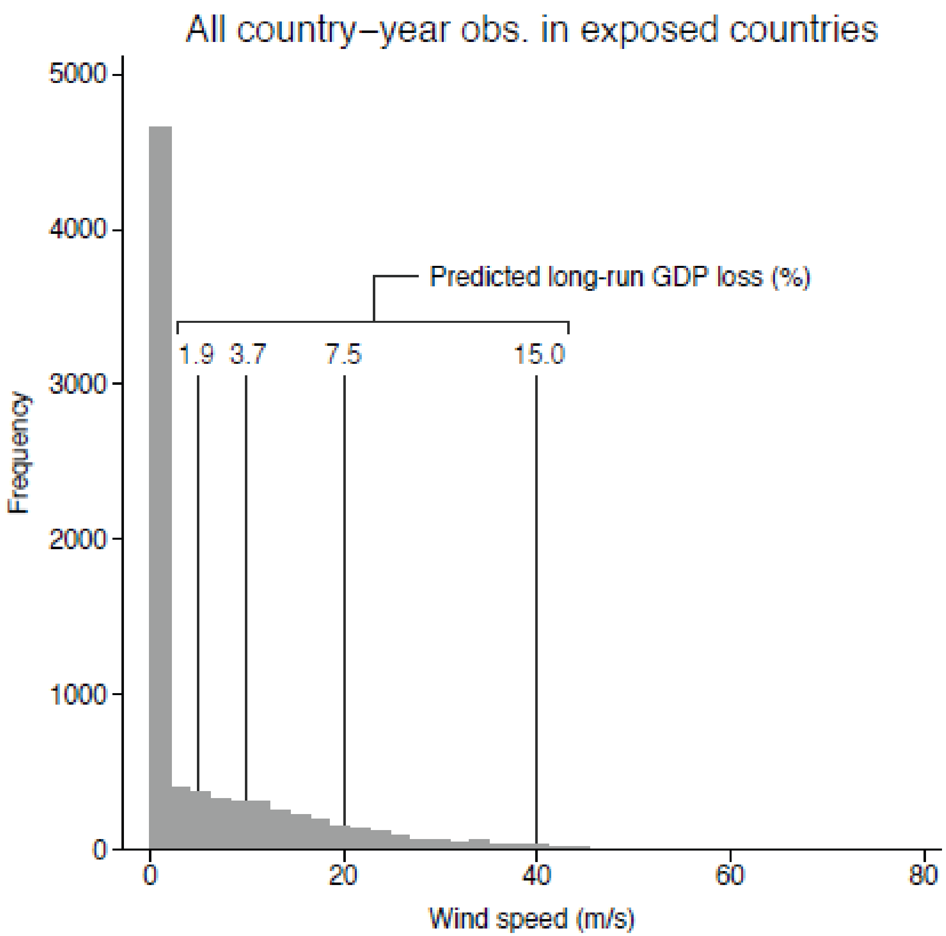


Figure 10: Pooled distribution of country-year tropical cyclone exposure. The expected long-run GDPpc loss associated with 5, 10, 20 and 40 m/s storm events are indicated.

Results

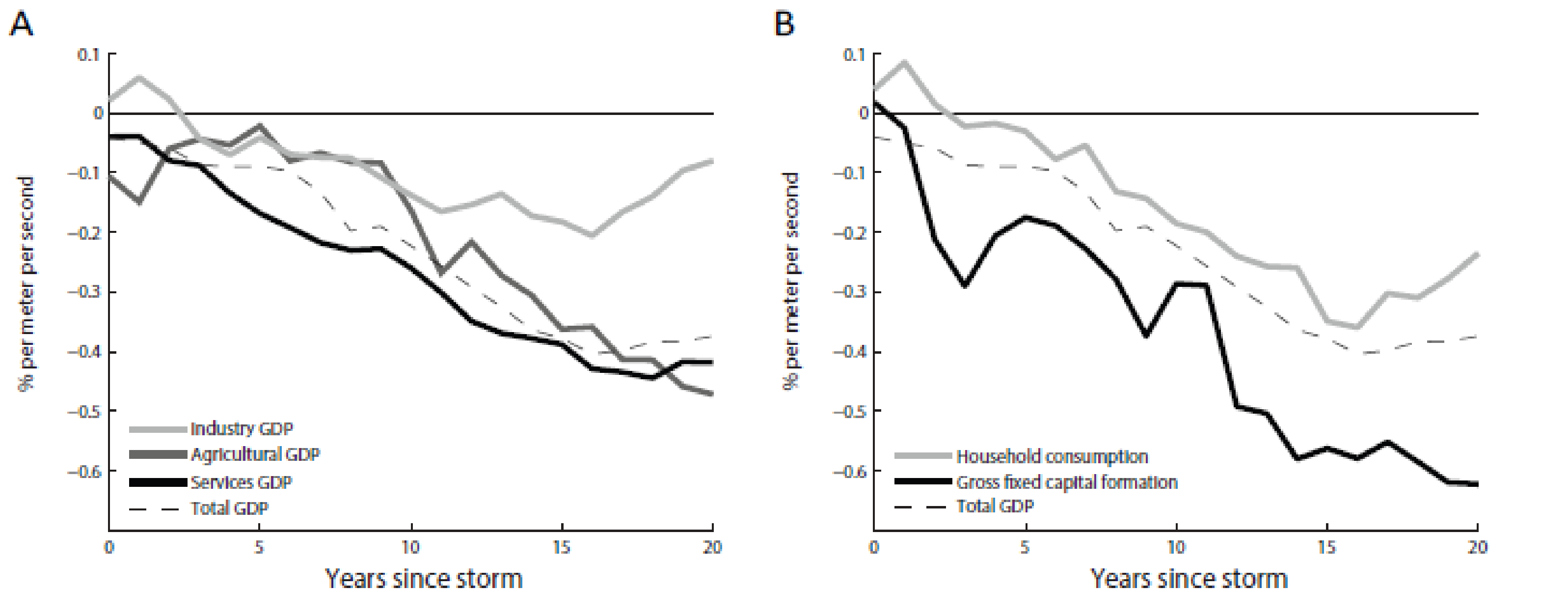


Figure 17: A) The estimated effect of cyclones on different components of GDP and B) on consumption and capital formation. Dashed line is the effect on total GDP for comparison.

Thanks.