Deriving empirically based damage functions
for integrated assessment models

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Extreme events are rising

Munich Re (2015)

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Natural disasters 2015

Average annual weather losses 100 billion $US
Extreme events in a 2°C-world?

Crop models

Coastal infrastructure models

Fisheries models

Biomes models

Hydrological models

Models for tropical cyclones

Health models

Source: Munich Re, NatCatSERVICE, 2016
Global river flood modeling

- Daily Run-off simulation by 10 models from ISI-MIP
  - 1970-2012 driven by observed weather
  - present-2100 driven by 5 GCMs, all RCPs

- Floodplain flow scheme -> CaMaFlood [1]
  - Gridded flood protection FLOPROS [2]
  - Inundation areas & depth @ 0.01° resolution

- Validation in progress!

Global river flood impacts

- Exposed people (e.g. Pakistan)

- Stock losses
  - Damage functions by Juan Carlos [1]

Global tropical cyclone impacts

- Global best track archive IBTrACS
- 540k cyclone tracks from dynamical downscaling [1]
  - 6 GCMs: 1950-2005 & 2006-2100 (RCP 8.5)
- TC extension via wind field model [2]

Tropical cyclone impacts for USA

\[ \text{Loss} = \alpha \times f_1(\text{Hazard}) \times f_2(\text{Socio} - \text{Econ.}) \]

Empirical losses e.g. Munich Re

Wind-speed / Storm size

GDP per capita / Population

\[ L = \alpha \times f_1(H) \times f_2(S-E) \]
Different socio-economic scaling of losses

\[ \text{Loss} \propto \text{GDP}^{\beta_{\text{GDP}}} \times f_1(\nu_{\text{wind}}) \]

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>8 model-mean</th>
<th>8 model-median</th>
<th>8 model-range</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_{\text{GDP}} )</td>
<td>0.50</td>
<td>0.57</td>
<td>0.20 - 0.67</td>
</tr>
<tr>
<td>( \beta_{\text{GDPpc}} )</td>
<td>2.29</td>
<td>2.26</td>
<td>1.48 - 3.13</td>
</tr>
<tr>
<td>( \beta_{\text{Pop}} )</td>
<td>0.41</td>
<td>0.47</td>
<td>0.12 - 0.59</td>
</tr>
</tbody>
</table>

T. Geiger et al. (in review, 2016)
Skill of damage function ensemble

GDP only

GDP per capita / Population

T. Geiger et al. (in review, 2016)
Projecting future losses for USA

- Simulated TC tracks (Emanuel, 2013)
- Socio-economic vulnerability becomes strongest loss driver!

Loss/storm as median over 8 models & 6 GCMs

Loss difference for different development scenarios

T. Geiger et al. (in review, 2016)
From impacts to economic models

We have climate change impacts:
- Exposed population
- Stock damage

We have economic growth models:

\[ \text{Output (Y)} = \alpha \times \text{Growth engine} + (1-\alpha)Y \]

Climate damage

How will the output then change?
Extreme impacts have long-term effects

Effect depends on disaster type, resolution, and methodology

See also Felbermayer et al (2013), Strobl (2008), and others
Long term growth effects across impacts

- Unified predictor across impacts: Exposed population

\[ \Delta GDP_{i,t} = \sum_{L=0}^{k} \left[ \beta_L \times D_{i,t-L} \right] + C_{i,t} + \epsilon_{i,t} \]

Tropical cyclones

Flooding

Flooding by income
Will economic models be able to reproduce the observed long-term growth reduction?

IMPACTS
- Capital (K)
- Human Capital (H)
- Exhaustible Resources (R)
- Land (L)

Growth engine

VALIDATION
- Output (Y)
  (food, consumption, health)

Thank you!

Slide courtesy: Franziska Piontek