Linking process-based impacts to IAMs: Persistence and channels

Input for an improved integrated assessment of impacts

Process-based results
4 GCMs x 3 RCPs x N impact models

Econometric results
Aggregated and channel-specific

Carleton & Hsiang (2016)
We need to get more systematic

- Understand dynamics & persistence

Burke et al. (2015)

Piontek et al. (2018)
We need to get more systematic

• Understand dynamics & persistence
• Map the channels

**Biophysical impacts**
- Crop yields
- Water availability
- Extremes (floods, droughts, storms, heat waves ...)
- Sea-level rise
- Diseases

**Economic damages**
- Productivity (labor, capital, land)
- Labor
- Physical capital
- Human capital
- Energy
- Land
- Output

Indirect effects like conflicts

Overall economic effect
We need to get more systematic

- Understand dynamics & persistence
- Map the channels
- Operationalize the modeling chain

Process-based or econometric? Output or channel-specific? Endogenous or soft-coupled?
Three examples

• Operationalize the model chain: From ISIMIP biophysical impacts to economic damages – a process-based approach

• Understand dynamics & persistence
  • Growth effects and persistence – an econometric approach
  • Persistent damages in REMIND

Process-based or econometric? Output or channel-specific? Endogenous or soft-coupled?
From ISIMIP biophysical impacts to economic damages: Flood-related asset losses

Flood damage modeling chain:

Inundation modeling based on global hydrological models driven by ISIMIP historical climate observation data
= return periods and flood depth
+ exposed assets and flood depth
damage functions (JRC)
= damages

→ Short-term loss variability captured well by river flood simulations driven by observed weather

[Geiger, Reese et al. in prep.]
Flood-related asset losses

Socioeconomic vulnerability: 
\[ \log \left( \frac{D_{obs}}{D_{mod}} \right) = \alpha_j + \beta_j \log(GDP_{cap}) \]

[Geiger, Reese et al. in prep.]
Flood-related asset losses

Socioeconomic vulnerability: \( \log \left( \frac{D_{obs}}{D_{mod}} \right) = \alpha_j + \beta_j \log(\text{GDP}_{cap}) \)

- Hazard
- Exposure
- Vulnerability

Damage change per decade (%)

11 Eastern Asia

Log10 damage (USD)

[Geiger, Reese et al. in prep.]
Flood-related asset losses

Combine flood projections for different RCPs with SSP2 GDP projections

Future global asset loss in%

[Geiger, Reese et al. in prep.]
Flood-related asset losses

→ Limited by ISIMIP coverage of emission scenarios (RCP2.6, 6.0, 8.5)
→ Allows to track uncertainty from GCMs and impact models
→ Possible for different SSPs – issue different scenarios for future flood protection
→ Current focus: tropical cyclones, floods
From event-based to temperature-dependent damage functions

- Ensemble of time series of losses from ISIMIP: 2 RCP x 4 GCM x N impact models → link to global mean temperature
- SSP specific
- To be applied to capital directly → persistence through economic modeling
Three examples

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Process-based or econometric? Output or channel-specific? Endogenous or soft-coupled?
Econometric analysis of channel-specific growth effects: tropical cyclones & floods


\[ g_{j,t} = g_{j,t}^0 + \sum_{l=0}^{L} \beta_l X_{j,t-l} \]

unperturbed growth path (country fixed effects)  
climate effect

Tropical cyclone exposure (wind speed or energy)  
Drought severity indicator (SPI)
Affected population as common predictor across categories

Change in fraction of annually exposed population (%)

Change in global mean temp. — rel. to preindustrial (°C)

Colors = Climate models
Shading = Impact model uncertainty

[Lange et al., submitted]
Econometric analysis of channel-specific growth effects: tropical cyclones & floods

For each disaster category:
Correlate historical economic growth rates with people affected by climate extremes

\[
g_{j,t} = g_{j,t}^0 + \sum_{l=0}^{L} \beta_l P_{j,t-l}
\]

unperturbed growth path  
(country fixed effects)  
climate effect

Period: 1970-2012

Following Hsiang (2014), Berlemann & Wenzel (2016, 2018)
Long-term impacts of tropical cyclones & fluvial floods (global)  

Cumulative growth-effect $k$ years after exposure:  
$$ \Omega_k = \sum_{l=0}^{k} \beta_l $$

Work in progress

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**Tropical cyclones**

Cumulative GDP growth effect [%] per 1% change in normalized affected population

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**Fluvial floods**

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[Krichene et al., in prep].
Channel-specific damage functions with persistence

\[ g_{j,t} = g_{j,t}^0 + \sum_{l=0}^{L} \beta_l P_{j,t-l} \]

\[ \delta_{j,t} \left( \{P_{j,t-l}\}_{l=0}^{L} \right) = \sum_{l=0}^{L} \beta_l P_{j,t-l} = \delta_j(P_j(\Delta T)) \]

→ To be applied to output as growth effect
Three examples

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• Understand dynamics & persistence
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The persistence of damages

Burke et al. (2015)
Modified Burke et al. (2015): Between level and growth effect

\[ D_{r,t} = \prod_{t'=1}^{t} \left(1 + \delta_{r,t'} 2^{-(t-t')/\tau_H}\right) \text{ with } \delta_{r,t} = \beta_1 (T_{r,t} - \bar{T}_r) + \beta_2 (T_{r,t}^2 - \bar{T}_r^2) \]
Persistence uncertainty (CBA with REMIND)

2030 carbon price
[$ per t CO2eq]

DICE 0 5 15 30 Burke

Burke long run (LR)
Burke short run (SR)
DICE2013
Integrated assessment with soft-coupled damage and climate module

Schultes et al. (in prep.)
Analytic expression for the SCC

\[ SCC_t = \sum_r \sum_{t'=t}^T \Phi_{t',t} Y_{r,t'} D_{r,t'} \sum_{t''=t}^{t'} \Theta_{r,t',t''}(T) \kappa_{r,t'',t} \Delta T_{t'',t} \]

\( \Theta_{r,t',t''} \): marginal damage from incremental temperature increase

\( \kappa_{r,t'',t} \Delta T_{t'',t} \): regional temperature response at time \( t'' \) to emissions at \( t \)

unperturbed income

discount factor
damage factor

Schultes et al. (in prep.)
Connecting REMIND with ISIMIP impacts

Channel-specific impacts with persistence

1) As output growth effect – persistence included
2) Directly in the channel – persistence dynamics are modeled directly
   → require temperature-dependent damage function
   → analytic expression for the SCC or numeric calculation
   → currently: capital damages from floods and tropical cyclones
   → future: labor productivity, droughts
Closing the loop with ISIMIP impacts

→ What do different channels (in particular extreme events) contribute to the social cost of carbon?
→ How persistent are impacts and how can we capture these dynamics properly?
→ What are the most relevant channels to include in integrated assessment?
→ Community-based effort on integrating impacts – model intercomparison(?)
Thank you!