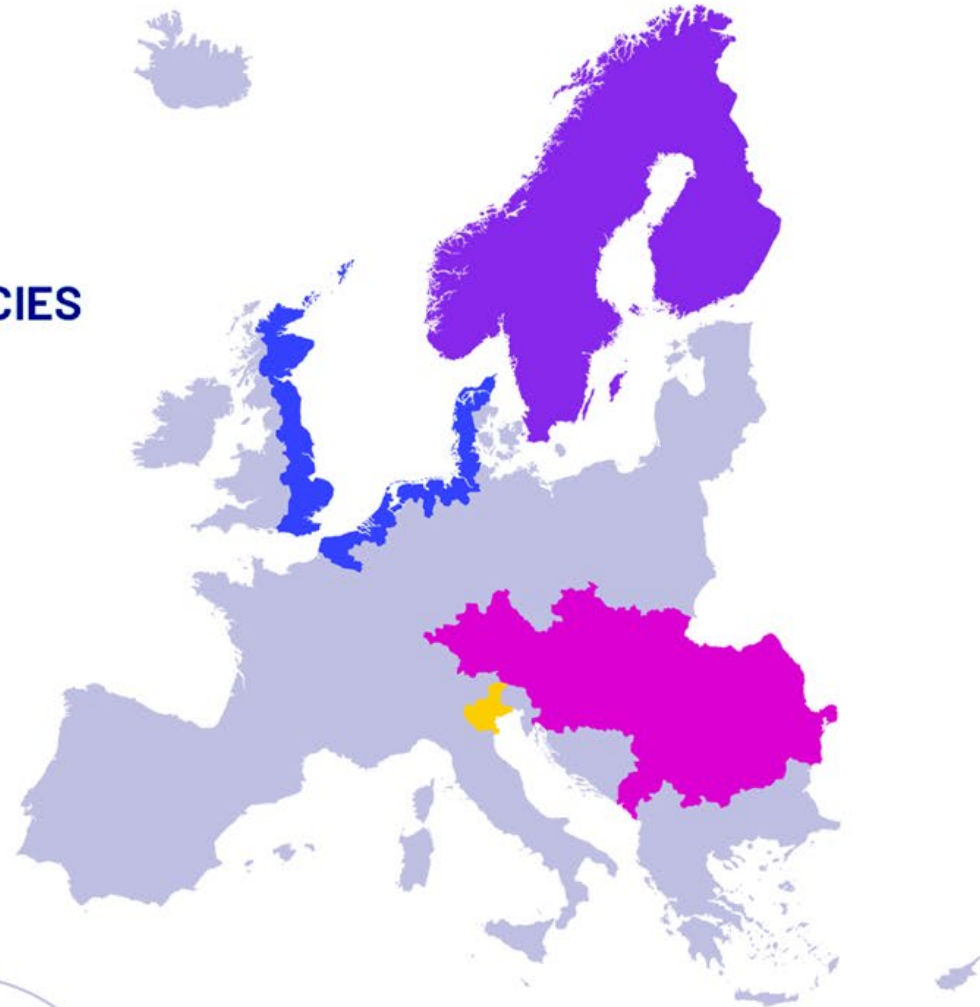# Representation of Indirect Risks

Benjamin Blanz, Davide Ferrario, María García, Elco Koks, Lin Ma, Noemi Padrón, Julius Schlumberger, Nikita Strelkovski, Jana Sillmann

Cross Border Climate Change Impacts Conference
16-18.10.2023

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# SYSTEMIC RISK INTERDEPENDENCIES THROUGHOUT EUROPE

## NORTH SEA

| SECTOR | HAZARDS | | |
|---|---|---|---|
| ECOSYSTEMS & FORESTRY | Biological hazard | Extreme wind | Flood |
| ENERGY | | | |
| INFRASTRUCTURE & TRANSPORT | Heat | Storm | Thunder and hail |

## SCANDINAVIA

| SECTOR | HAZARDS | | |
|---|---|---|---|
| ECOSYSTEMS & FORESTRY | Biological hazard | Drought | Fire |
| ENERGY | | | |
| FOOD & AGRICULTURE | Flood | Heat | Snow |

## DANUBE

| SECTOR | HAZARDS | | |
|---|---|---|---|
| FINANCE | Drought | Earthquake | Flood |
| FOOD & AGRICULTURE | | | |
| INFRASTRUCTURE & TRANSPORT | Heat | Landslide | Thunder and hail |

## CANARY ISLANDS

| SECTOR | HAZARDS | | |
|---|---|---|---|
| ENERGY | Earthquake | Flood | Landslide |
| FOOD & AGRICULTURE | | | |
| TOURISM | Storm | Tsunami | Volcano |

## VENETO

| SECTOR | HAZARDS | | |
|---|---|---|---|
| ECOSYSTEMS & FORESTRY | Biological hazard | Drought | Fire |
| FINANCE | | | |
| TOURISM | Flood | Landslide | Snow |

# Effects of Hazards

Total impact of a hazard

- Direct Effects
  - Sectoral, local and immediate impact of a hazard
- Indirect Effects
  - Intersectoral:
    - knock on effects between sectors
  - Interregional:
    - knock on effects between regions
  - Intertemporal:
    - persistence and dynamics of effects

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# Modelling Methods used in myriad_eu

- **Veneto Pilot**
  - Empirical and Machine Learning Methods

- **Scandinavian Pilot**
  - Computational General Equilibrium model GRACE

- **Danube Pilot**
  - Macroeconomic Agent Based Model

- **Canary Islands Pilot**
  - Descriptive Impact Assessment

- **North Sea Pilot**
  - Dynamic Adaptive Policy Pathways – Integrated Assessment Meta Models

- **WP5 with VUE**
  - Multiregional Impact Assessment Model

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# Comparing Models

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Spatial Resolution | Global | National | Coarse Grid / NUTS 2 | Fine Grid / NUTS 3 | Household |
| Temporal Resolution | Multiyear timestep | Yearly | Coarse sub year | Monthly | Daily |
| Sectoral Coverage | Single production function | Single explicit sector others aggregated | 2-6 Sectors | Single digit industry identifier 7-20 Sectors | Two digit industry identifier >20 Sectors |
| Regional Coverage | Single subnational region | national | multinational region | multi continent | whole globe |
| Time/Prediction Horizon | sub year | single year | decade | century | centuries |
| Computational Requirements | long on supercomputer | fast on supercomputer | | long on laptop | fast on laptop |

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# Comparing Models: Indirect Effects

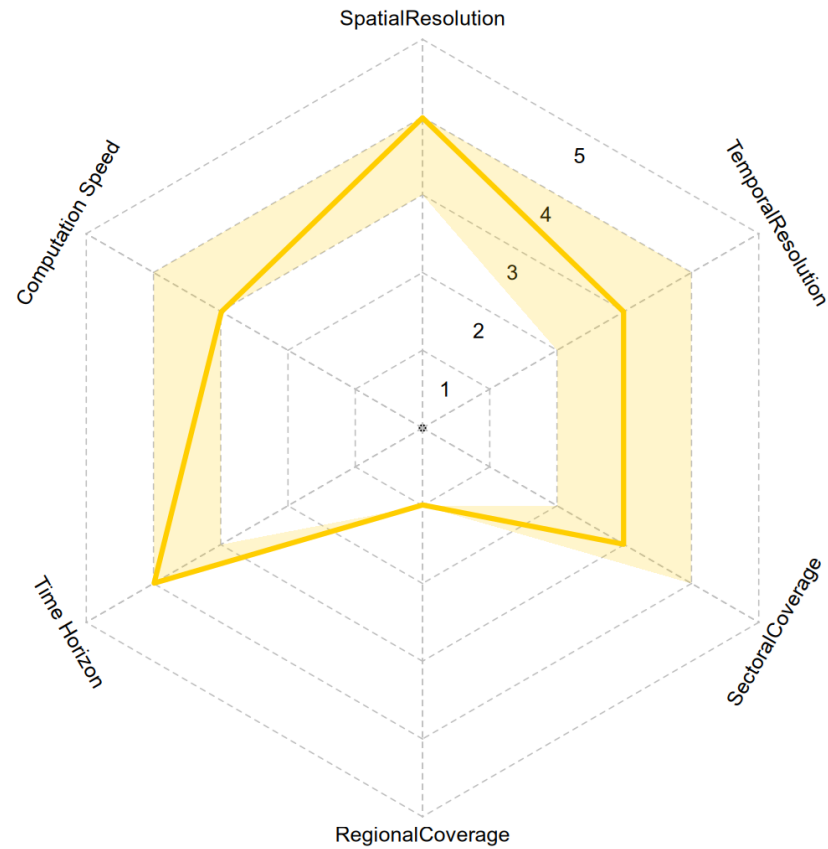| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Intersectoral indirect effects | only direct effects | | linear sectoral dependencies | | non-linear sectoral dependencies |
| Interregional indirect effects | only local effects | | simple trade or physical links between regions | | detailed trade and physical feedbacks |
| Intertemporal indirect effects | only contemporary effects | | simple lagged effects | | fully dynamics representation of effects |

Indirect effect representation is quantified within the bounds of the modelling approach. E.g. it is possible to have a highly detailed representation between two sectors.

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# Empirical and ML Modelling

- Neural networks for sector specific endpoints
  - Water quality along river flows
  - Vegetation stress
  - Tourism numbers

- Indirect effects captured by the connectivity within the neural net

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# Empirical and ML Modelling

## General Descriptives



## Representation of indirect Effects



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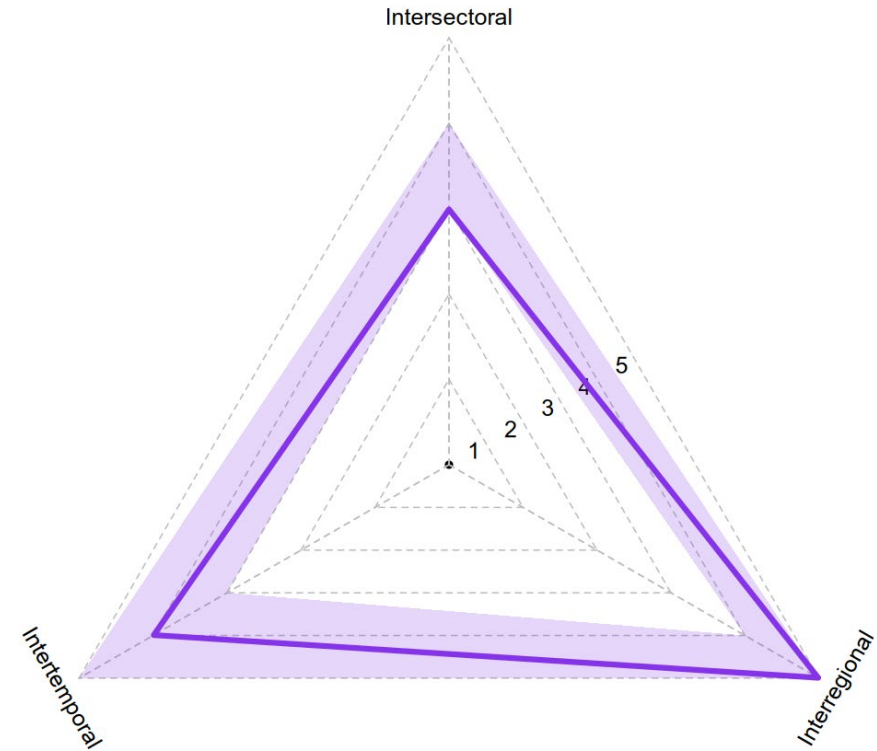Reducing risks together
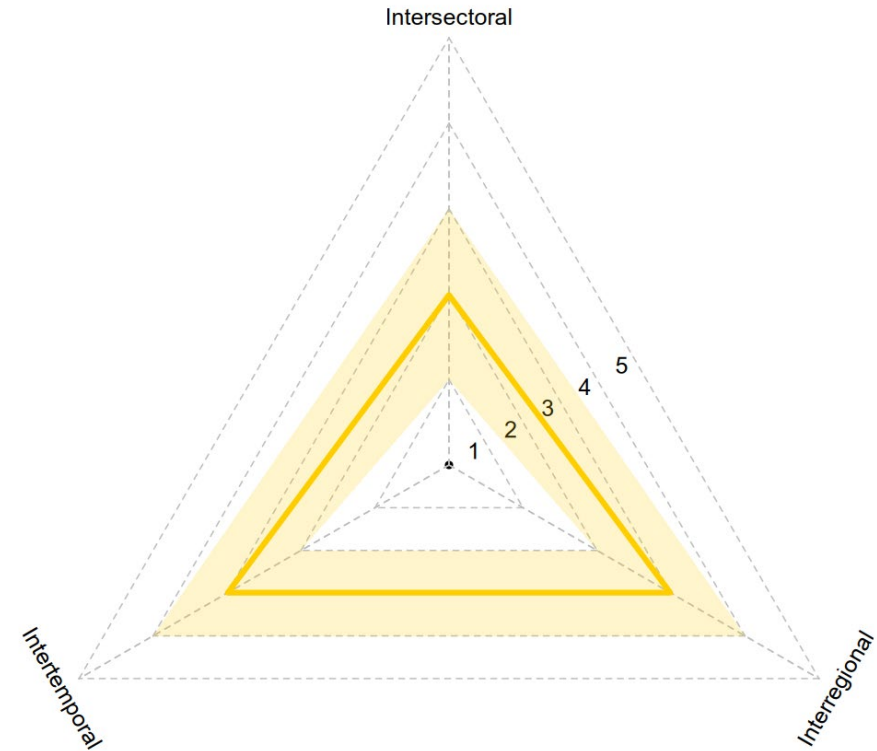
# CGE (GRACE)

- Global model: Country level or aggregated regions
- Annual time step
- Regional myopic optimising behaviour
- Detailed interdependent sectoral production
  - Elastic substitution of inputs
- Endogenous international trade

 Aaheim, H. A., Orlov, A., Wei, T., & Glomsrød, S. (2018). GRACE model and applications. *CICERO Report*.

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# CGE (GRACE)



General Descriptives

Representation of indirect Effects
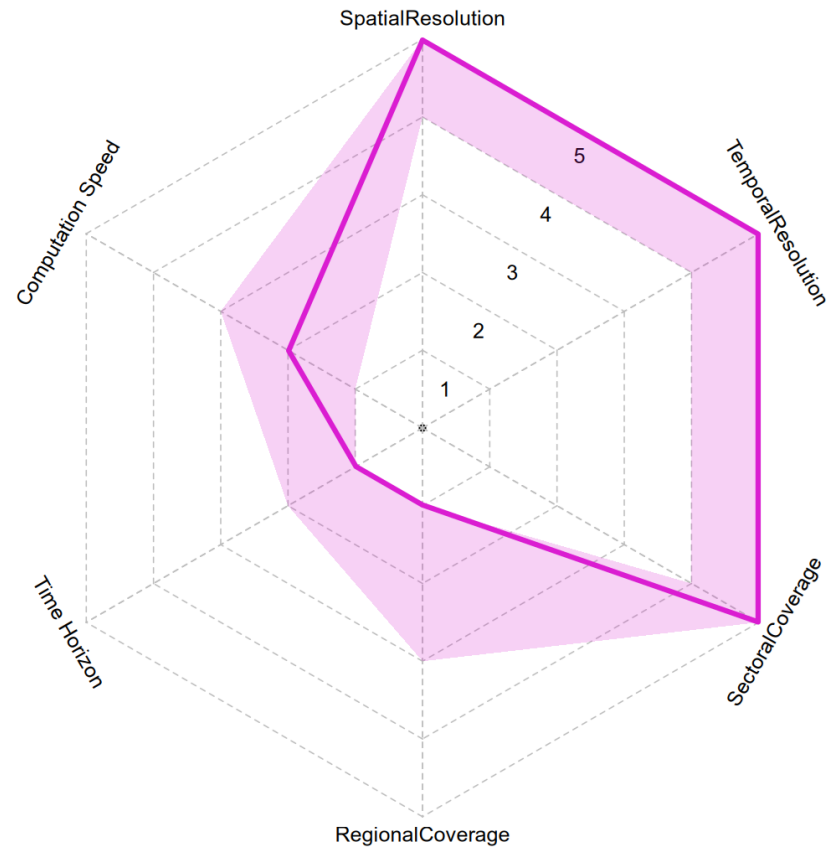
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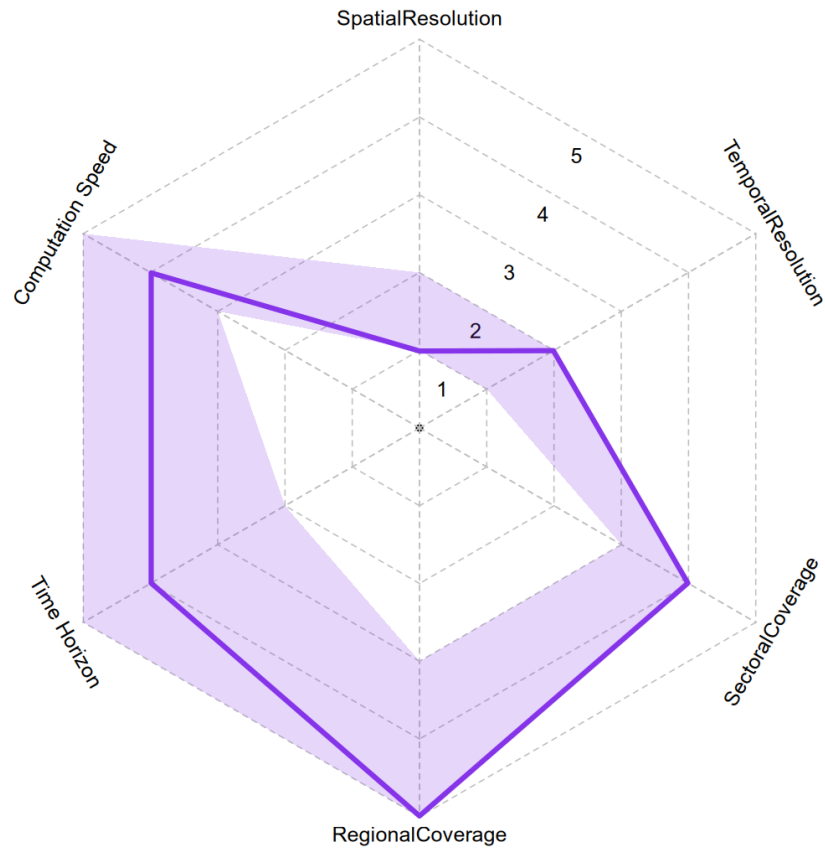
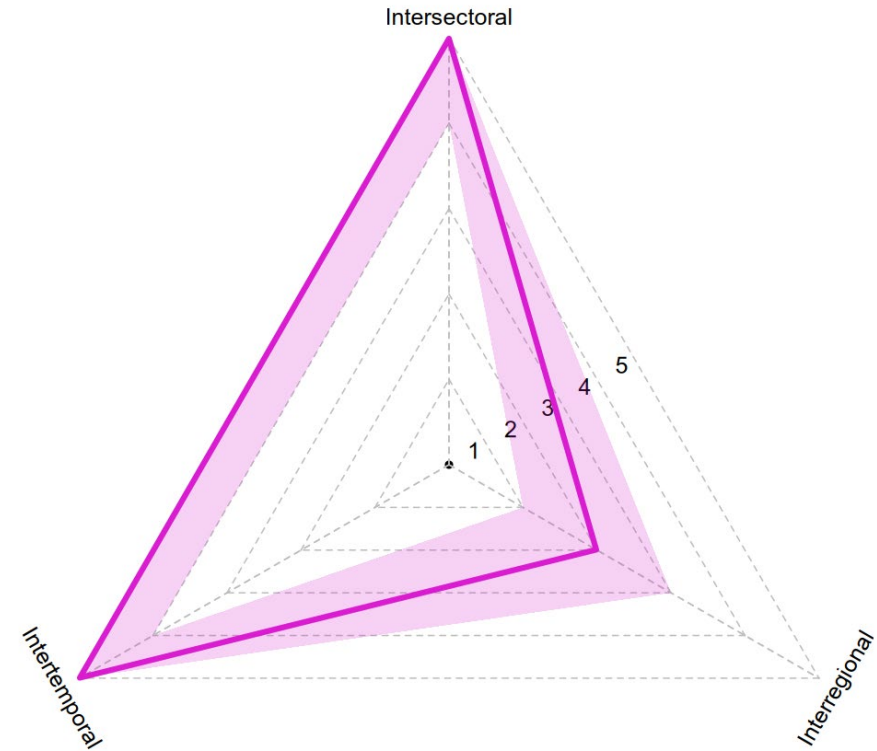# Macroeconomic Agent Based Model

- Regional model: Country level or subnational regions
  - Pan European extension
- Resolves all actors in the economy
  - Individual households and firms, banks, government
- Boundedly rational forward looking behaviour
- Quarterly time step
- Detailed interdependent sectoral production
  - Fixed input ratios
- Exogenous international trade
  - Endogenous within modelled region

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Poledna, S., Miess, M. G., Hommes, C., & Rabitsch, K. (2023). Economic forecasting with an agent-based model. *European Economic Review*, *151*, 104306. https://doi.org/10.1016/j.euroecorev.2022.104306

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# Macroeconomic Agent Based Model



General Descriptives

Representation of indirect Effects

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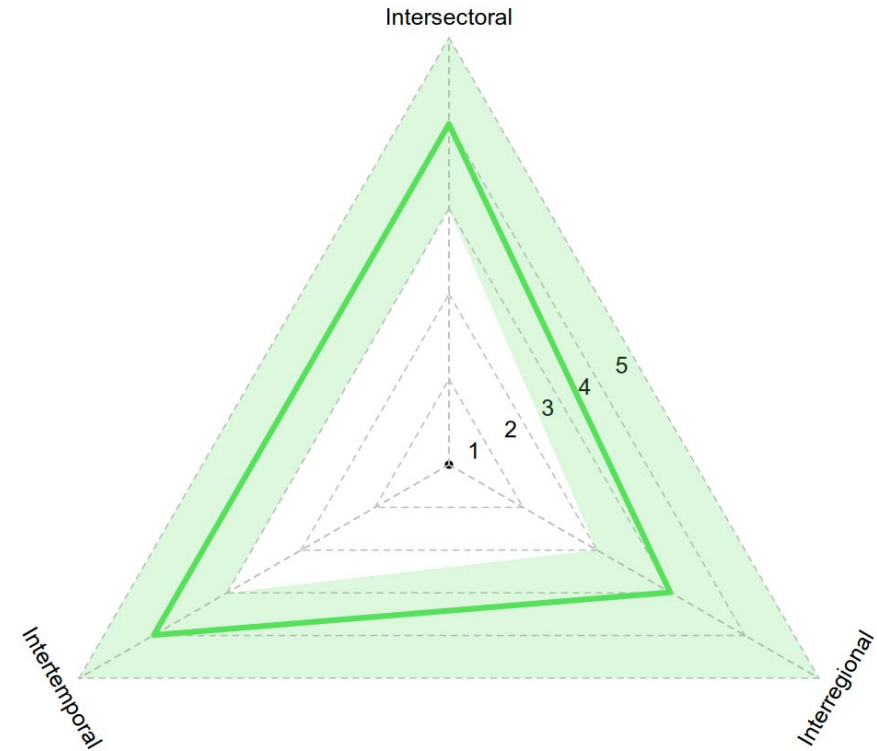Reducing risks together

# Descriptive Methods

- Detailed description of impact relationships not limited by model structures.

- Natural Hazards are partially independent
  - Geological and meteorological hazards

- Adaptation measures shift multi-risks from one territorial space to another
  - Avoiding geological hazards increases exposure to meteorological hazards

- Two sectors compete for land and water:
  - housing for tourism/residents and agriculture/farming

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# Descriptive Methods



General Descriptives
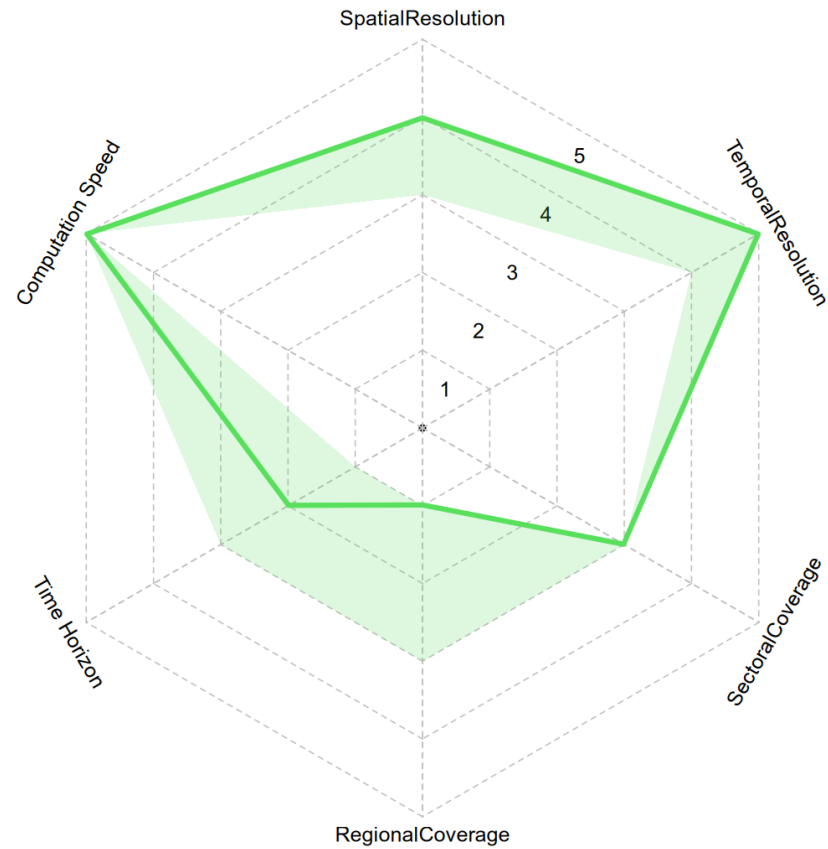
Representation of indirect Effects

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# Dynamic Adaptive Policy Pathways – Integrated Assessment Meta Models

- Dynamic Adaptive Policy Pathways
  - Evaluation of multiple policy options over time

- Integrated Assessment Meta Models
  - Emulator of more complex impact assessment models
  - Combines impact assessment of multiple impact types
  - Fast

- Combined in a representative sector agent model
  - Urban
  - Agriculture
  - Shipping

Haasnoot, M., Van Deursen, W. P. A., Guillaume, J. H. A., Kwakkel, J. H., Van Beek, E., & Middelkoop, H. (2014). Fit for purpose? Building and evaluating a fast, integrated model for exploring water policy pathways. *Environmental Modelling & Software*, *60*, 99–120. https://doi.org/10.1016/j.envsoft.2014.05.020

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# Dynamic Adaptive Policy Pathways – Integrated Assessment Meta Models



General Descriptives

Representation of indirect Effects

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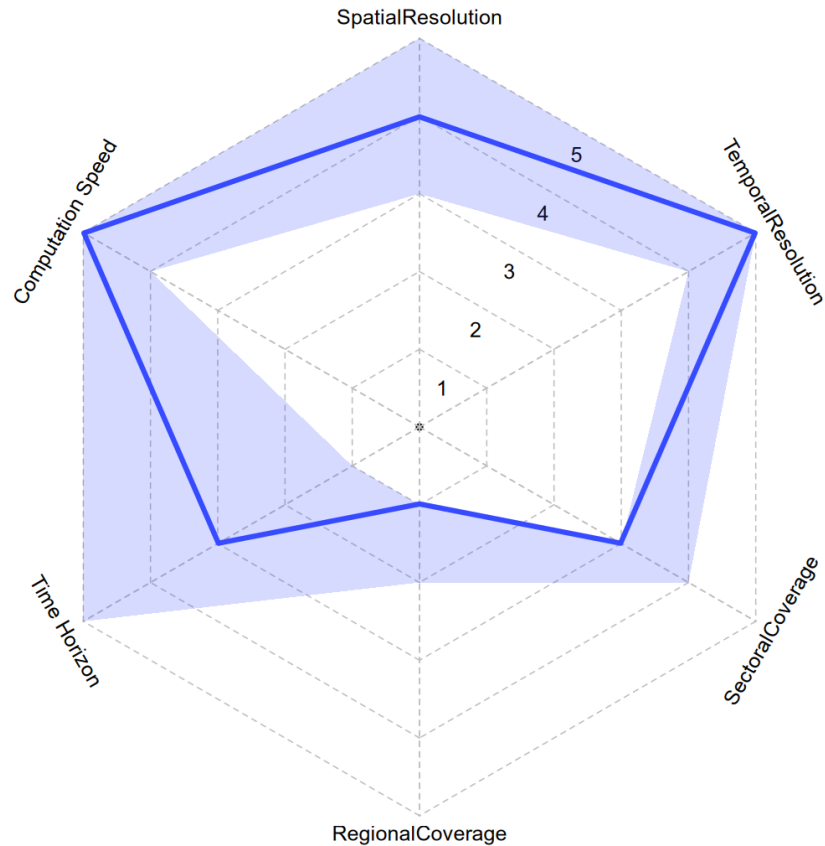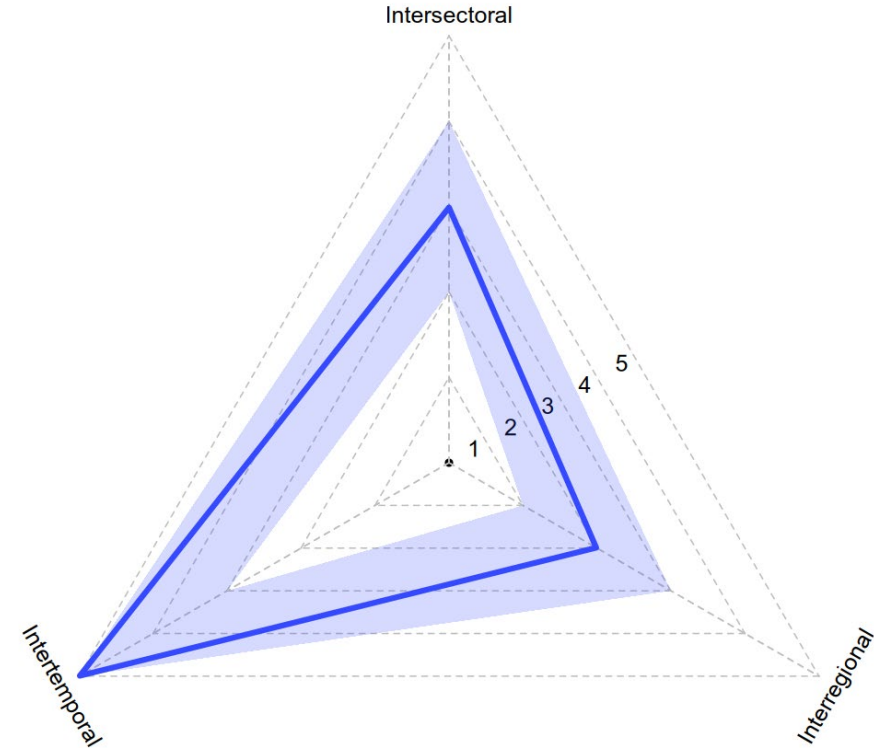
# Multiregional Impact Assessment Model (MRIA)

- Pan European model at NUTS 2 level -> built on top of EUREGIO database

- Interregional trade connections

- Input-Output modelling with linear optimization
  - (Multiregional) substitution possibilities
  - Regional production technologies

- Dynamic recursive time dynamics

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Koks, E. E., & Thissen, M. (2016). A Multiregional Impact Assessment Model for disaster analysis. *Economic Systems Research*, *28*(4), 429–449. https://doi.org/10.1080/09535314.2016.1232701

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# Multiregional Impact Assessment Model (MRIA)



General Descriptives

Representation of indirect Effects

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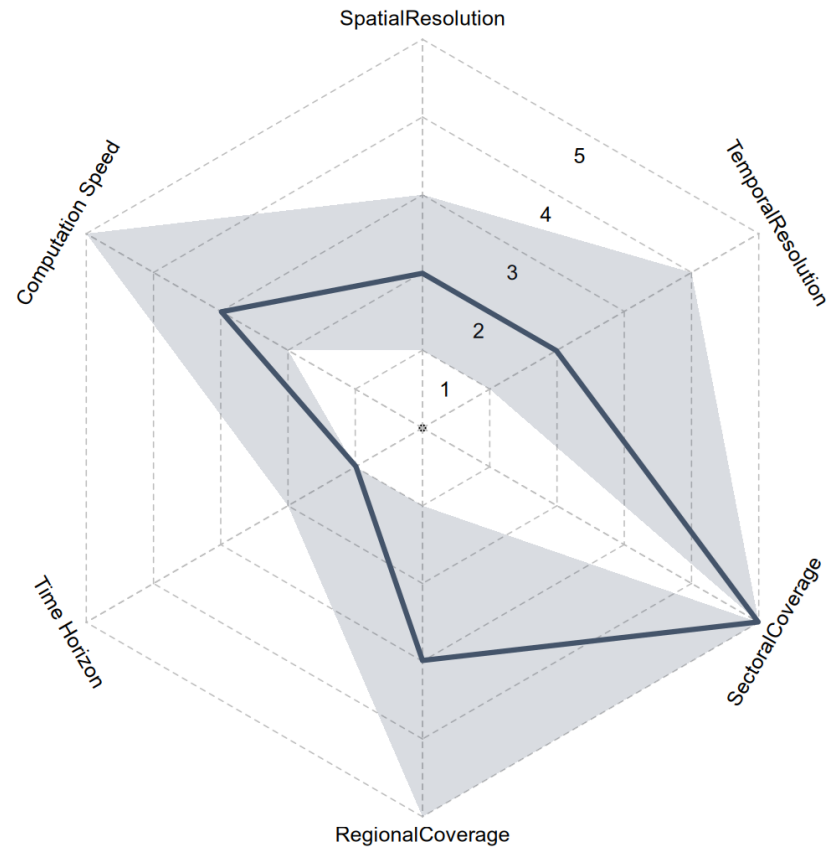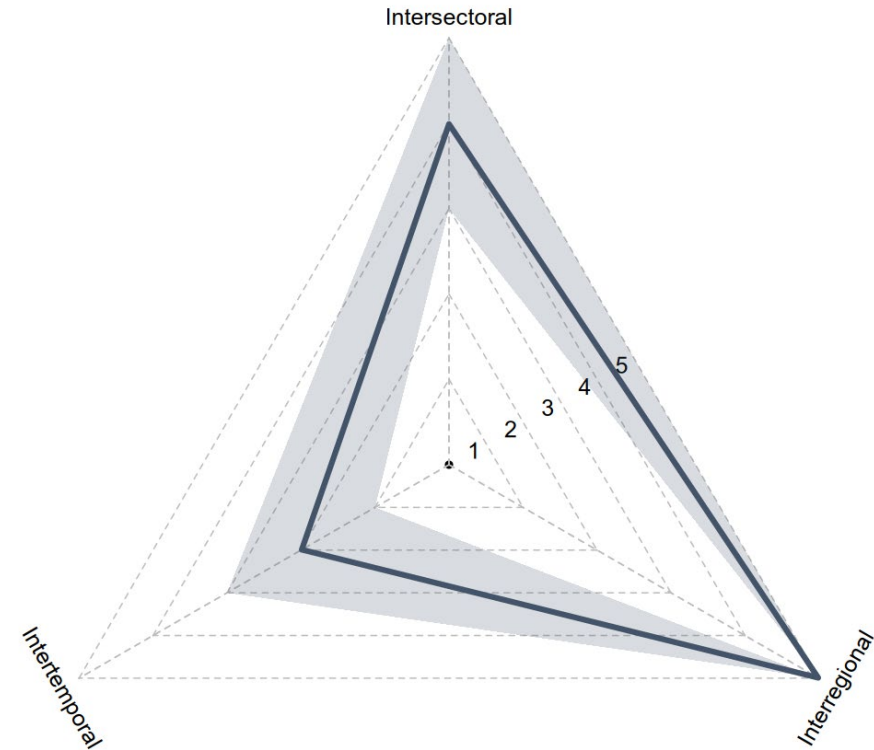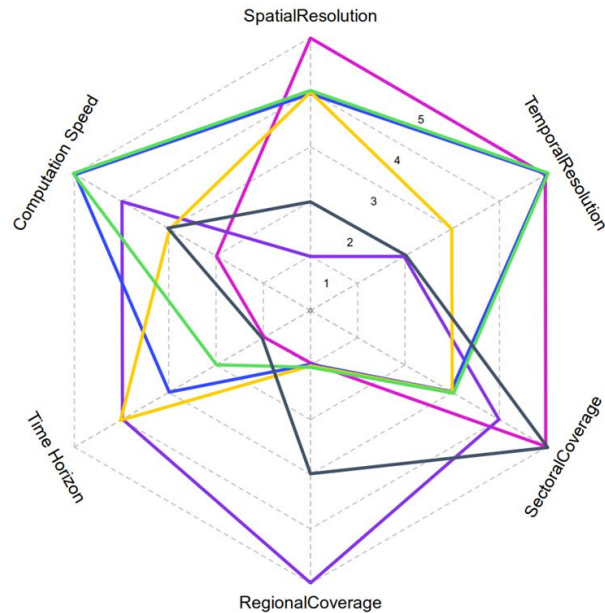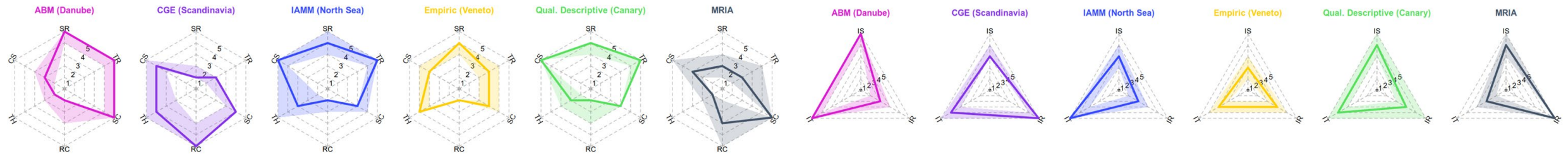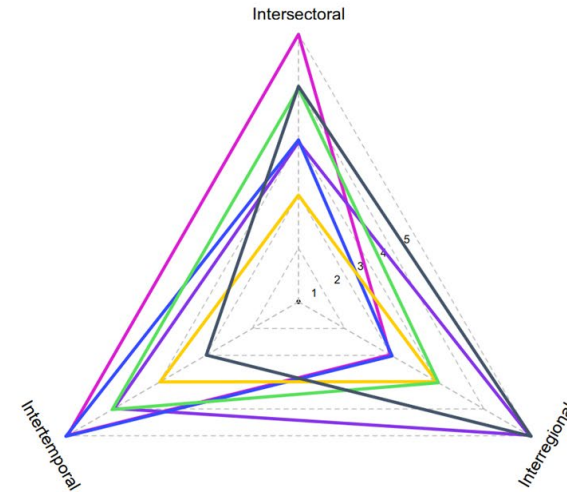
# Comparison of Modelling Approaches



General Descriptives

Representation of indirect Effects

# Outlook

- Evaluation of common hazard sets
  - Comparison of magnitude of indirect effects predicted
    - Sectors affected
    - Area affected
    - Persistence of effects

- Hazard sets
  - Floods
  - Earthquakes
  - Heat
  - ...

# Conclusion

- Indirect effects can make up a large part of the total impact of hazards

- Models are constructed for different research questions
  - Trade off between coverage, resolution and computational requirements

- Quantification of indirect effect magnitude in models with more resolution or coverage could be emulated in more compact models.

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# Get in touch

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