

Integrating Spatial Granularity into Climate Policy Analysis

A CGE–GIS Framework for the European Union

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1

Climate policy analysis often uses CGE models at national/global level.

2

Sub-national disparities (economic, demographic, emissions) are overlooked.

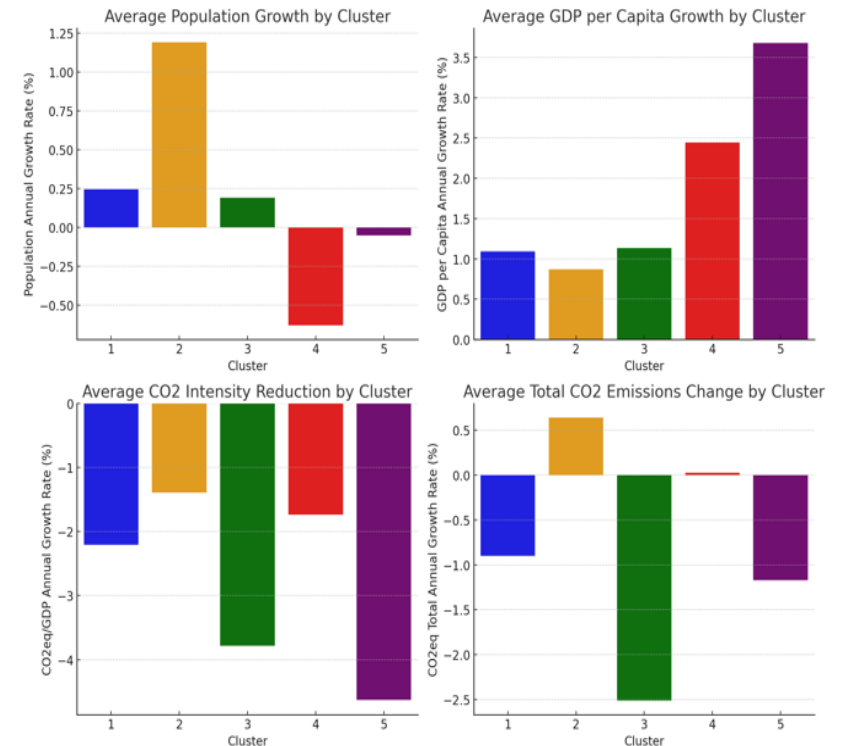
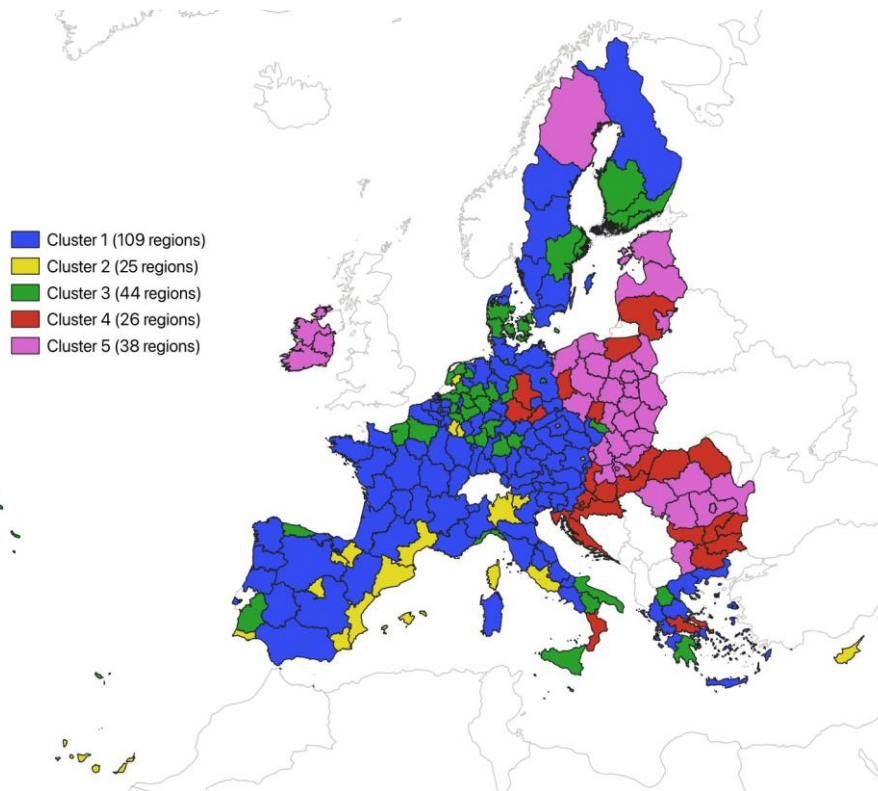
3

Difference at Regional: eq. Industrialized vs less industrialized.

Spatial Aggregation Bias

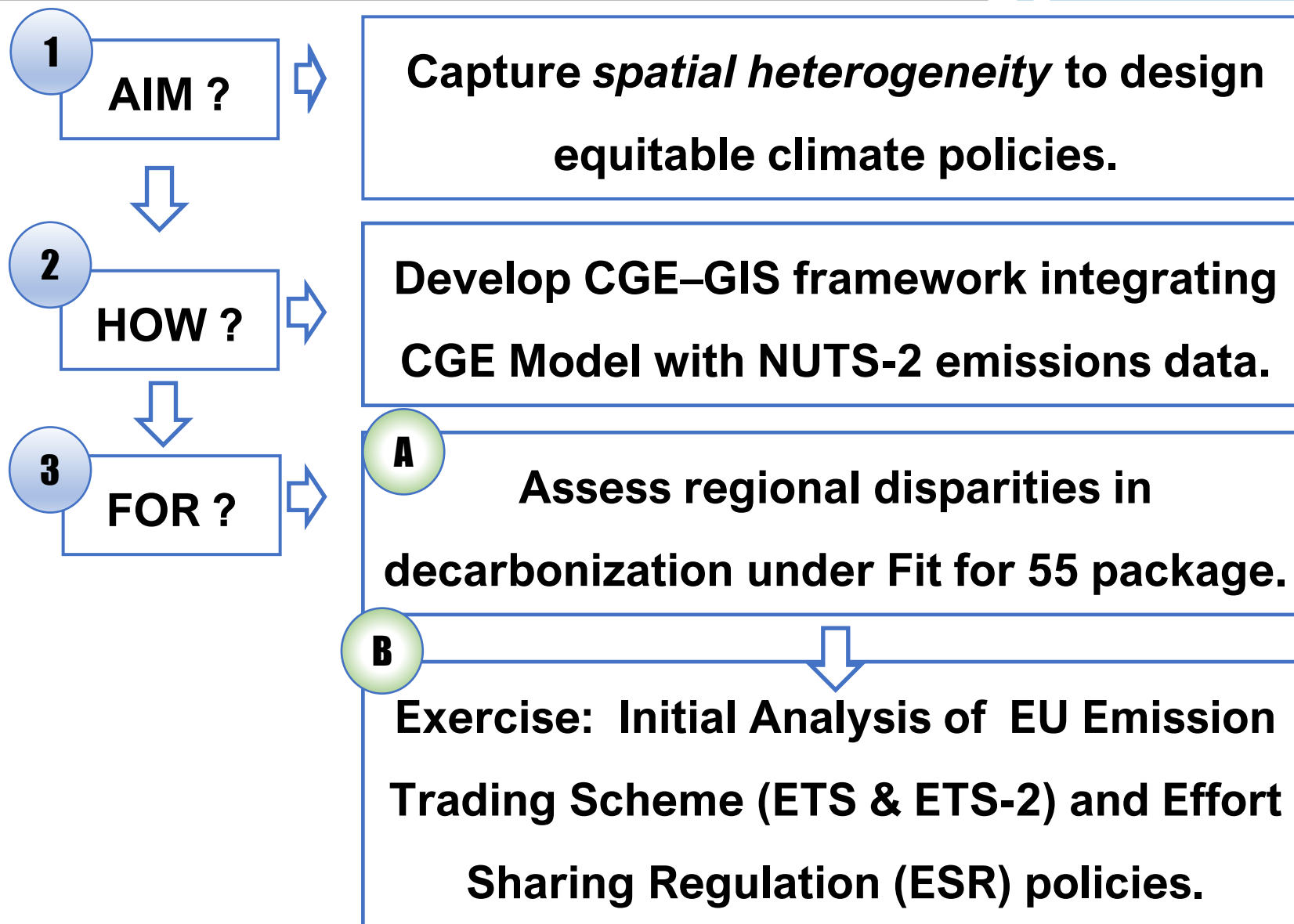


Historical Decarbonization – Clustering Analysis



Source: Authors' estimation from EDGAR and ARDECO (1995-2023).
Indicators include population dynamic, economic activity and carbon intensity





Base Model:

- GEMINI-E3 (recursive-dynamic CGE).

Coupling:

- GIS-based NUTS-2 data (242 EU regions).

Dataset:

- EDGAR; Eurostat;
- Beyond Fossil Fuel (Power Plant Inventory); IEA (Heat Production)

242 European Regions :

BE10 Brussels Hoofdstedelijk Gewest
BE21 Prov. Antwerpen
BE22 Prov. Limburg
.
.
.
SE23 Västsverige
SE31 Norra Mellansverige

9 sectors :

-Agriculture
-Petroleum refinery
-Electricity coal
-Electricity gas
-Electricity oil
-Electricity other
-Industry
-Building
-Waste

4 GHG gases :

-CO₂
-CH₄
-N₂O
-F-gases

Time :

-Annual
-2022-2050



Methodology

Each Emissions in *Regional Module* is linked to GEMINI-E3 Driver

$$E_{i,t}^r = \alpha_i^r \cdot X_{i,t}^C \text{ where } r \in C$$

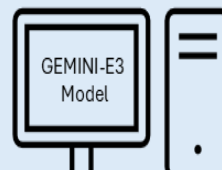
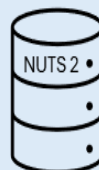
GHG Emission
region r ,
sector i , year t

Emissions
Driver

Calibrated
Coefficient

Step 1: Regional Model Calibration year 2022

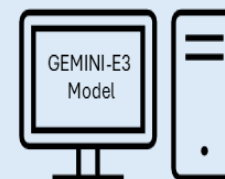
Edgard Database



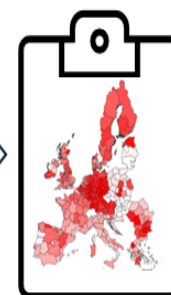
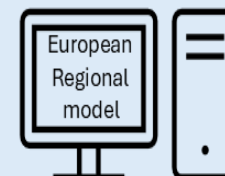
Set of coefficients linking
Edgard emissions and
GEMINI-E3 drivers



Step 2: GEMINI-E3 Scenario Analysis 2022-2050



Step 3: Regionalization



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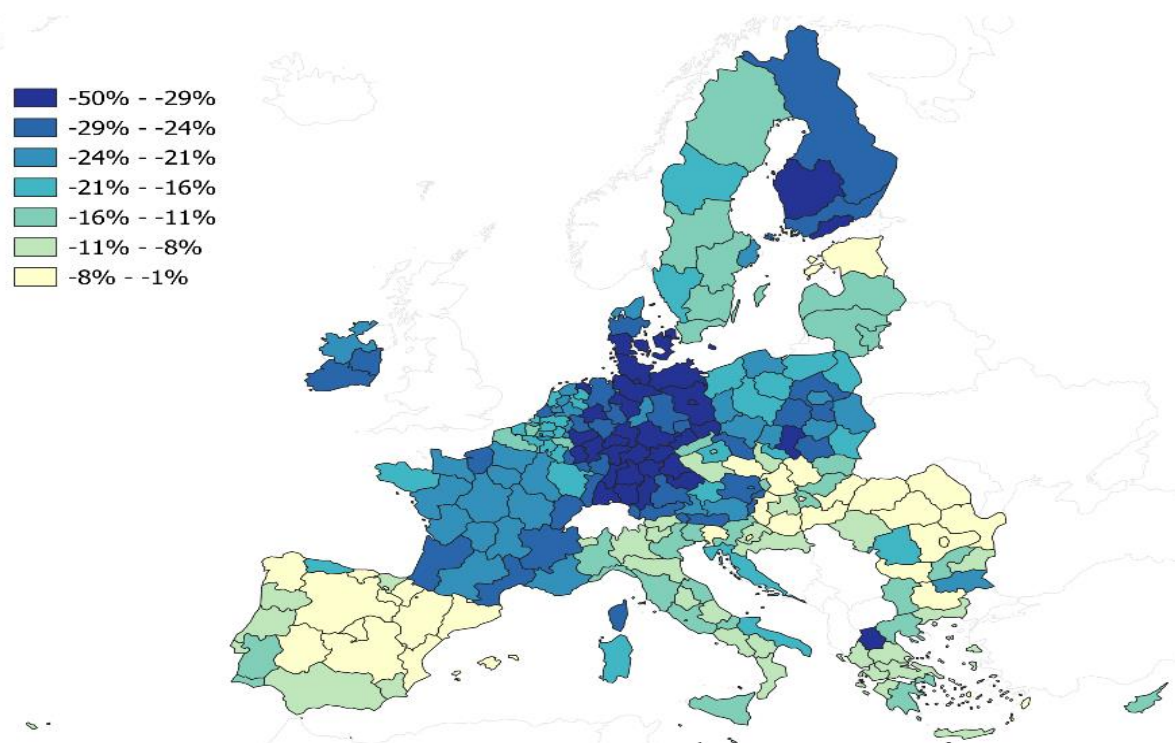
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Baseline (Pre Fit 55):

- -40% GHG by 2030
- -43% ETS Sectors by 2030
- National ESR Target (via Domestic Tax)
- Reflecting Current Policies Scenarios as in Giarola et al. (2021) and Sognaes et al. (2021)
- Updated Assumptions of Key Drivers (EC, WEO, IEA)



- ETS price ~65 US\$/tCO₂ in 2030.
- ESR prices highly uneven: 0–273 US\$/tCO₂.



The spatial distribution of reductions reveals a clear north–south gradient, with the most substantial decreases concentrated in Central and Northern Europe.



Fit for 55 Scenario:

- Fit for 55 Target + New ETS (ETS-2)
- ETS-2 → cover emissions from Building & Road Transport. Target 42% by 2030 from 2005

- ETS-2 will operate alongside ESR



Ambiguity between carbon pricing and decentralized state-led policy action

1

Without ESR Trading

Uniformly 42% Targets

2

With ESR Trading

Reconciled ETS-2 Target with ESR Targets



GHG prices before and after the Fit for 55 package - year 2030 in US\$2017 per ton CO2-eq

Category	Before	After Without ESR trade	After With ESR trade
EU ETS price	65	151	152
EU ETS-2 price		244	247
Germany	273		
France	123		
Italy	9		
Spain	9		
Netherlands	95		
Sweden	30		
Poland	94		
Belgium	57		
EU1 (Croatia, Cyprus, Greece, Portugal, Malta)	26		
EU2 (Austria & Luxembourg)	155		
EU3 (Czech, Hungary, Slovakia)	0		
EU4 (Bulgaria, Romania, Slovenia)	8		
EU5 (Estonia, Latvia, Lithuania)	33		
EU6 (Denmark, Finland, Ireland)	320		
Averaged ESR prices	101	244	247



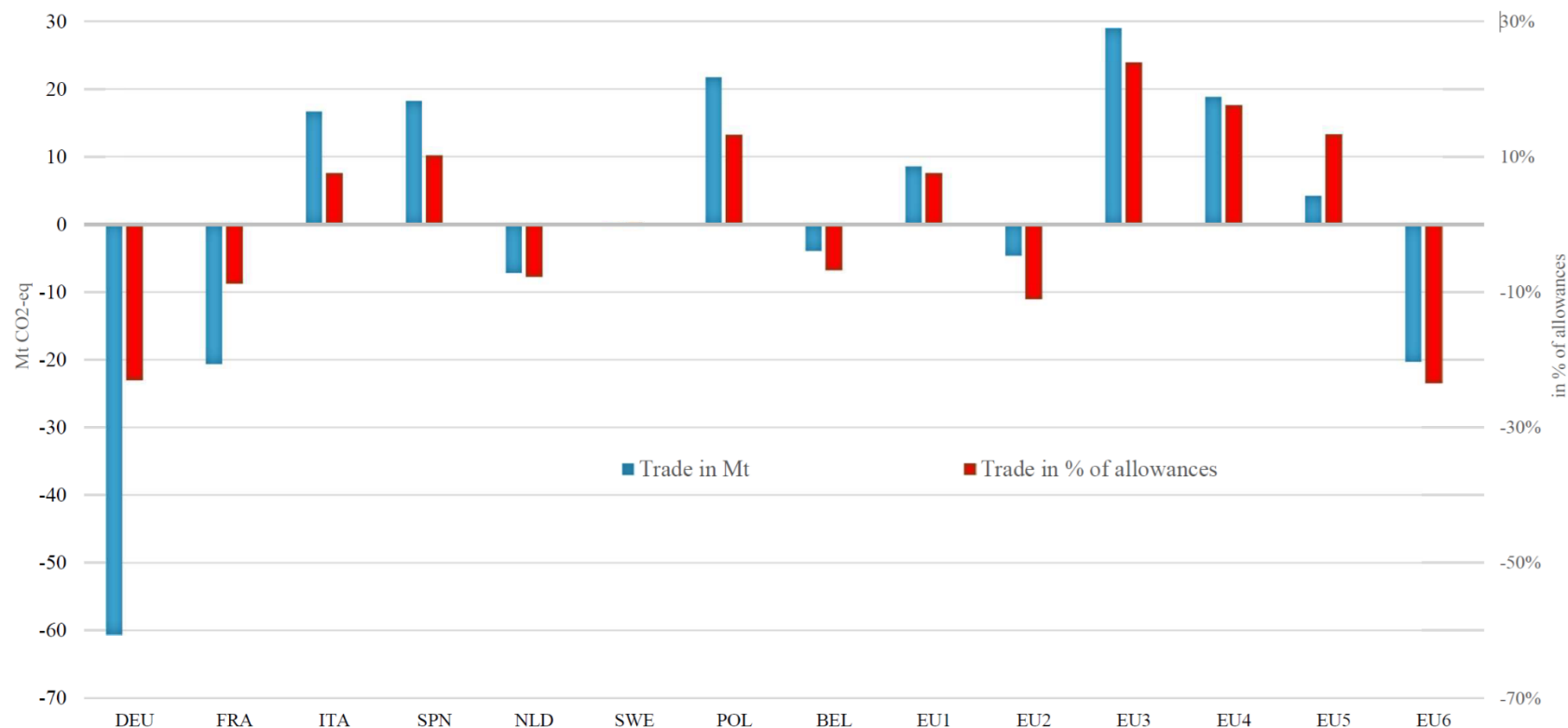
Welfare change in % of household consumption in 2030 - Fit for 55 scenario

Country	Without ESR Trade	With ESR trade
Germany	-0.5	-1.6
France	-0.4	-1.0
Italy	-0.7	-0.2
Spain	-0.1	0.6
Netherlands	-0.1	-0.7
Sweden	-0.3	-0.3
Poland	-1.8	0.5
Belgium	-0.4	-0.9
EU1	-0.1	0.8
EU2	-0.5	-1.1
EU3	-0.6	3.8
EU4	-0.8	2.2
EU5	0.4	2.6
EU6	-0.3	-1.8
EU 27	-0.5	-0.5

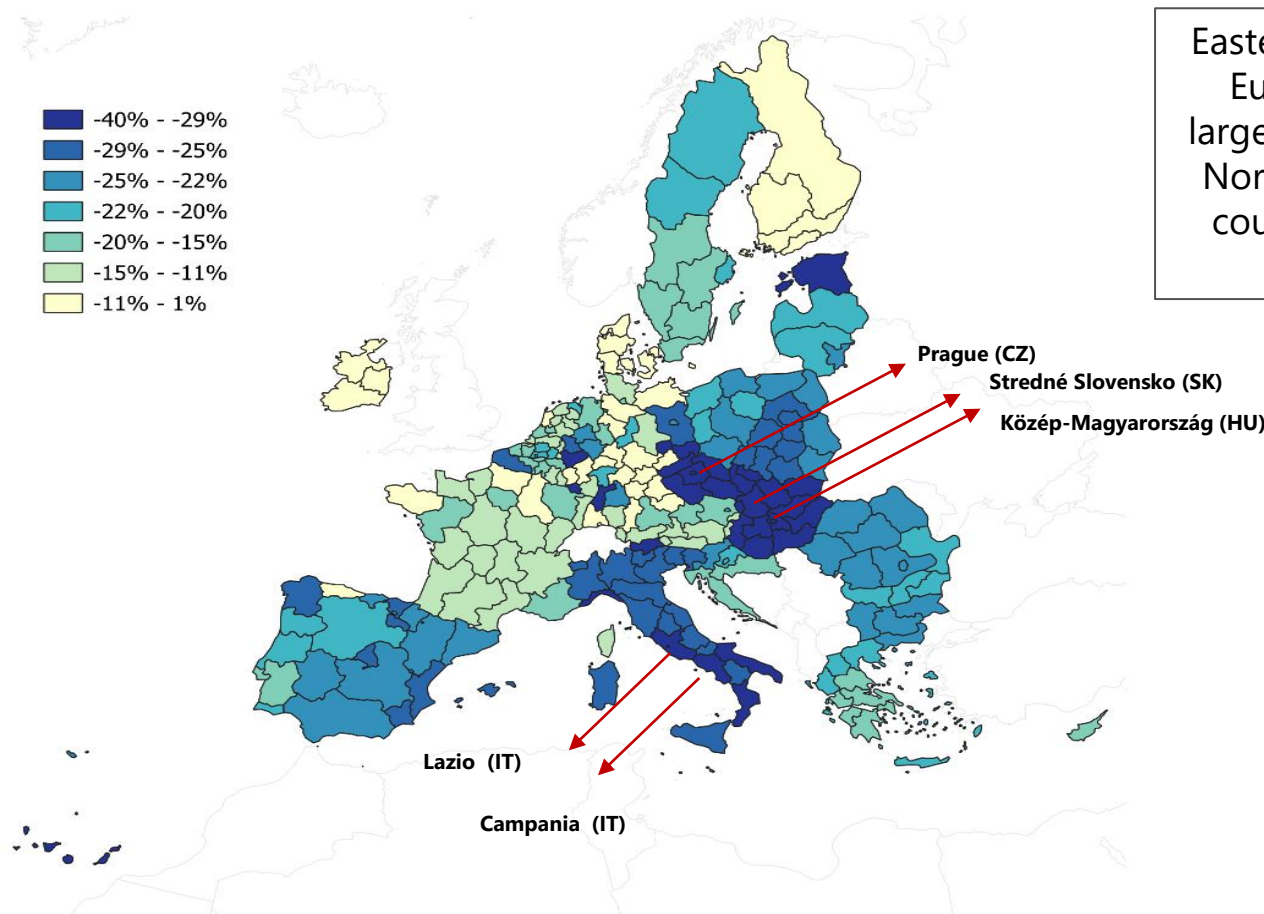
- **Without ESR trade:** welfare losses up to -1.8% (Poland, EU4).
- **With ESR trade:** redistribution → gains for CEE, losses for wealthier states.
- **Total ESR trade:** 117 MtCO₂-eq, ~29 bn US\$ in 2030.
- ***Highlights efficiency–equity trade-offs in burden sharing.***



Trade in ESR allowances in Mt CO₂-eq and in % of allowances - Year 2030 - (positive number means selling, negative one buying)

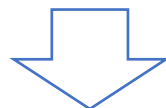


Difference in total GHG emissions between the “Fit for 55” (ETS-2 Trading Scenario) and the Baseline for 2030 for EU-27 NUTS-2 regions.



Eastern and Southern Europe show the largest declines, while Nordic and Western countries show the smallest.

- ETS → moderate costs, north & south pattern.
- ETS-2 → higher costs, more disparities.
- ESR trade redistributes welfare: East gains, West pays.
- Decarbonization is highly regional, not one-size-fits-all.



Spatially Targeted Policy for Equitable
climate strategies

Thank You

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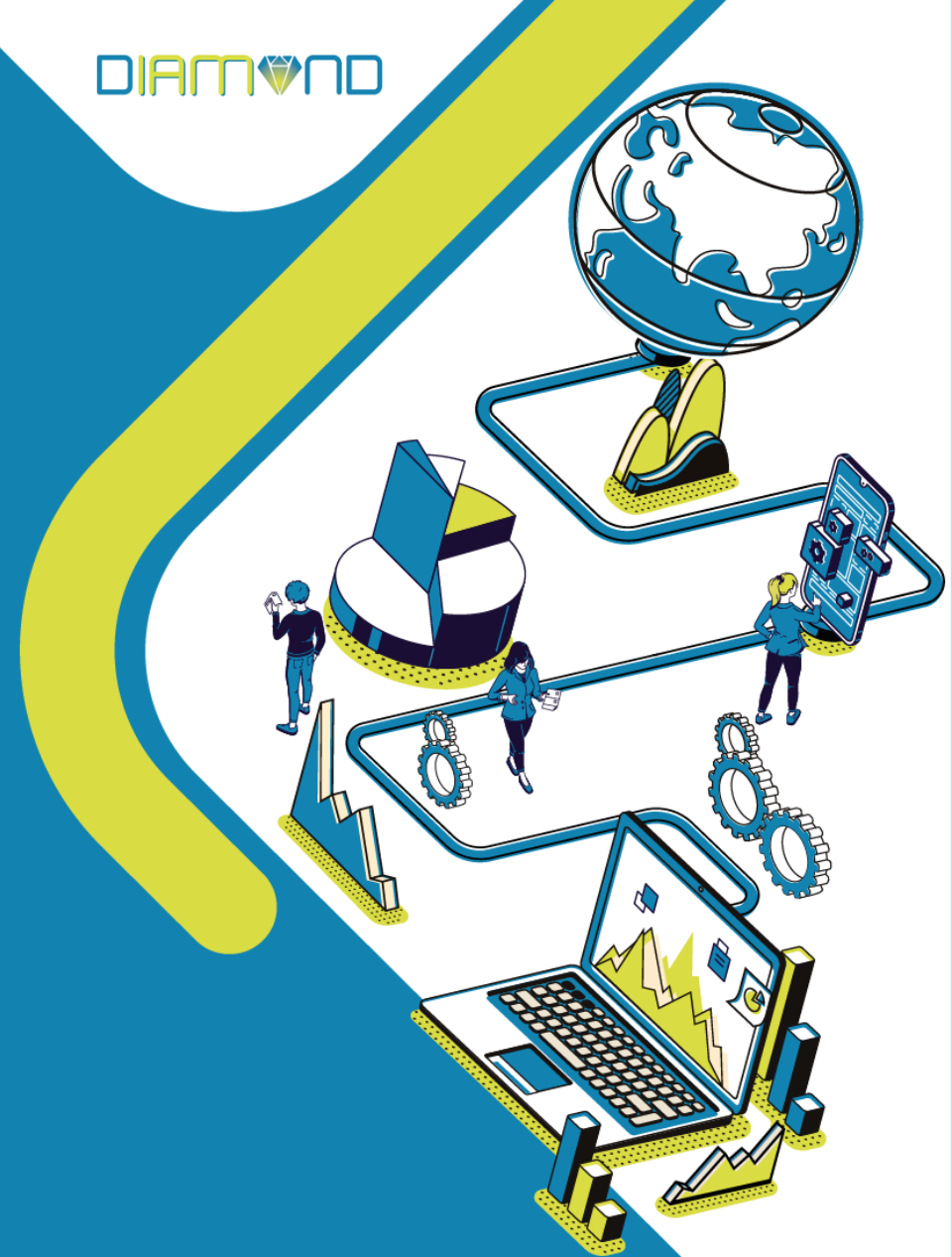
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