Energy transition in the EU: a multi-national analysis

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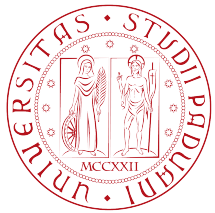

Motivation

- European countries are currently undertaking an energy transition to renewable energy sources to face climate change and energy security problems
- IEA: the current growth trend of CO_2 emissions is not consistent with the goal of global sustainability (2021)
- A delay in taking actions to reduce emissions could lead to high economic and social costs

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- The COVID-19 pandemic has highlighted the crucial role of a stable and resilient electricity system
- In 2021, Russian gas represented 45% of EU imports and almost 40% of EU gas consumption
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Background

- Marchetti (1980): energy sources are like commercial products competing for a market niche. The dynamics of energy systems have been studied according to an innovation diffusion approach with the logistic equation

- Models initially developed in the marketing literature (early 2000s), found suitable also for energy problems, i.e., the Bass model and the Generalized Bass model

$\Rightarrow$ highlight the central role of final consumers as well as the importance of policy actions able to stimulate the growth of a new energy source

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$\Rightarrow$ If consumption and policy actions are key factors to understand the diffusion of a new energy source, a fair analysis also needs to account for competitive dynamics between different energy sources

- UCRCD model allows interplay between two energy sources *(Guseo & Mortarino, 2014)*
- UCTT model account for three competitors within the market *(Savio et al., 2022)*

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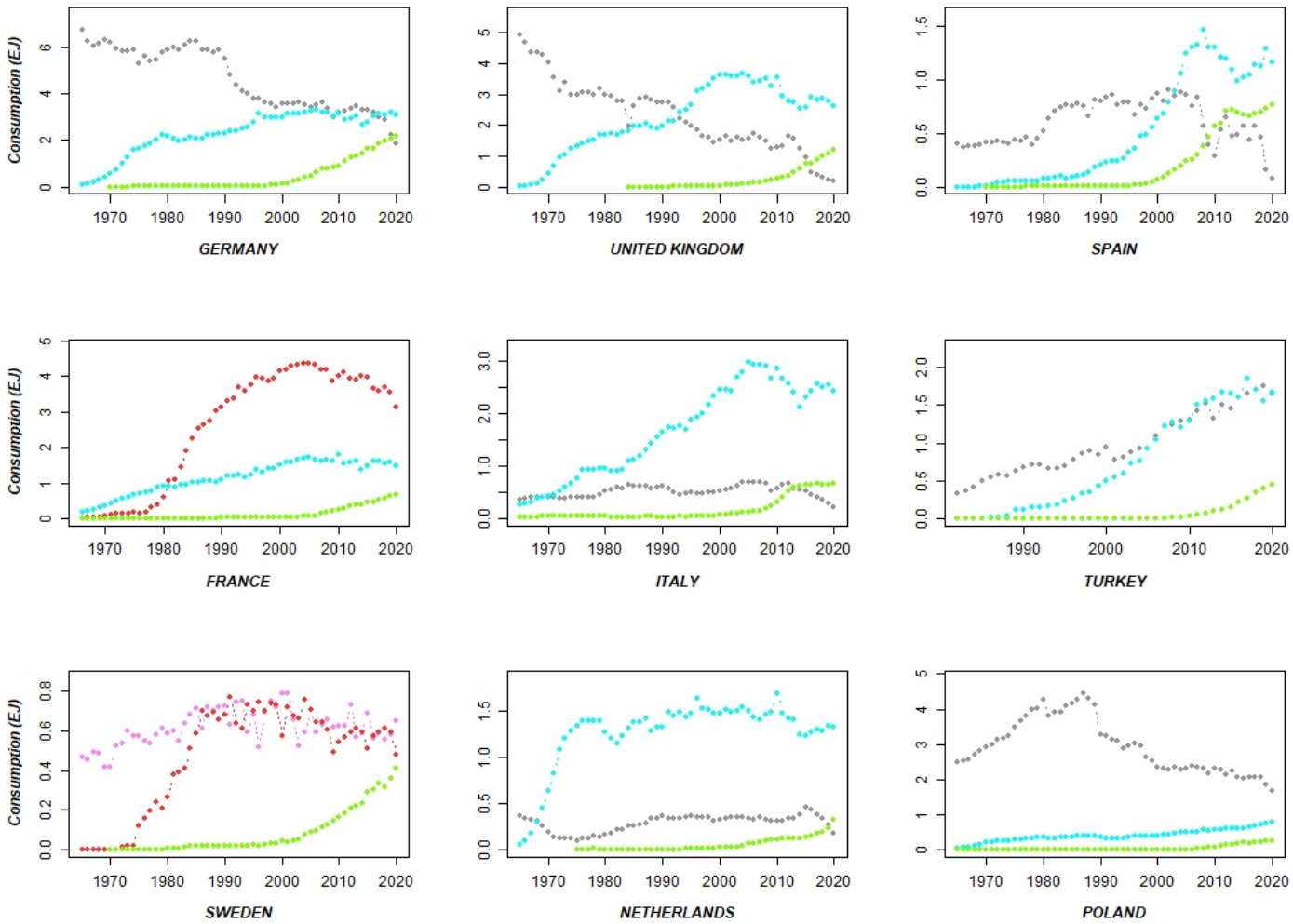
Data

We analyzed the interplay between *renewables* and other primary energy sources (*coal*, *gas*, *nuclear*, or *hydroelectric*) in the top 18 renewables energy consumption EU nations in 2020.

Data

BP Statistical Review of World Energy 2021: yearly consumption in Exajoule (1965-2020) of *renewables*, *coal*, *gas*, *nuclear*, *hydroelectric*.



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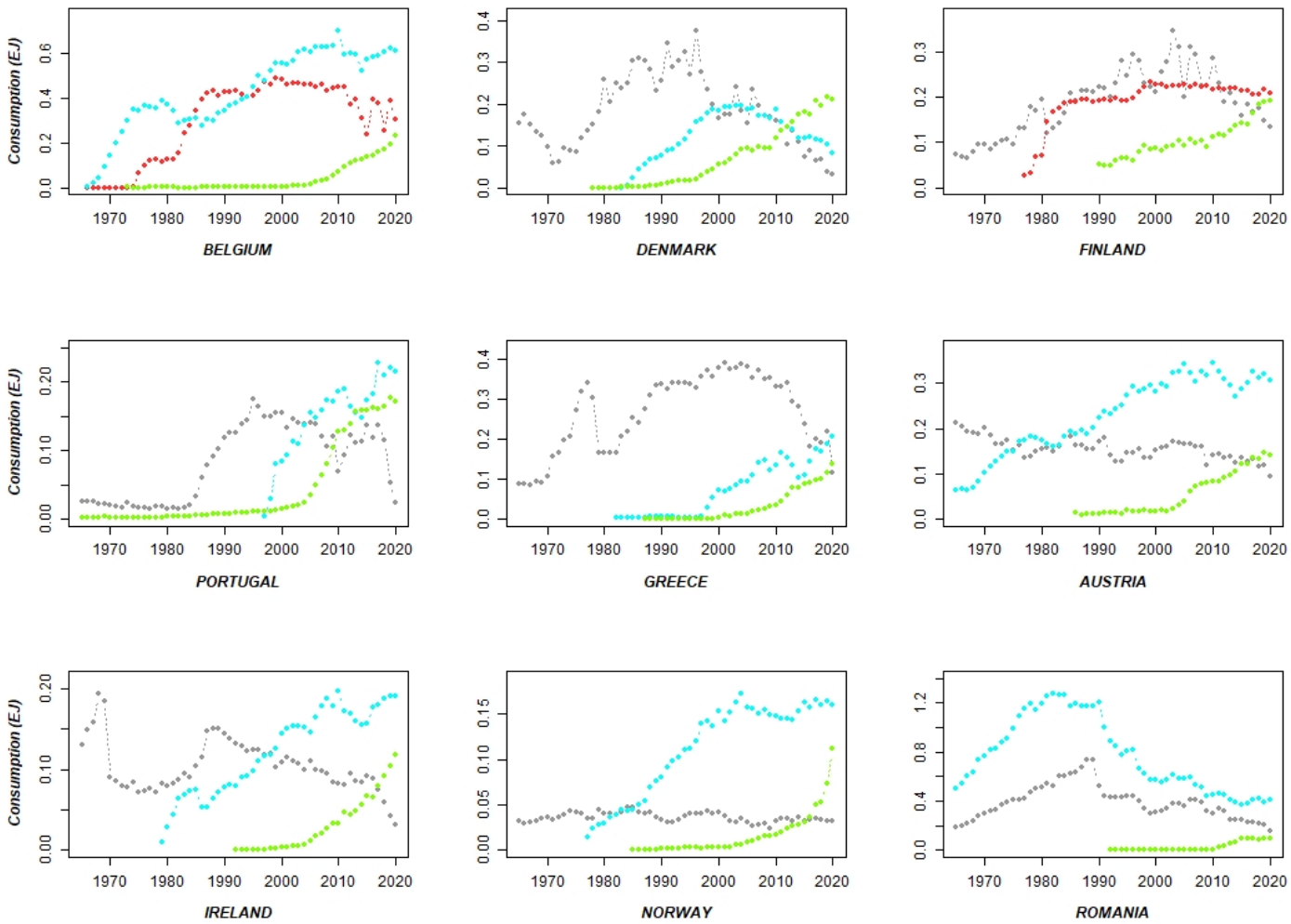

UCTT Model

Unbalanced Competition among Three Technologies model

$$
\begin{aligned}
z_1'(t) &= m\Bigg\{ \left[p_{1a} + q_{1a}\frac{z(t)}{m}\right] I_{t<c_1} + \\
&+ \left[p_{1c} + (q_{1c}+\delta)\frac{z_1(t)}{m} + q_{1c}\frac{z_2(t)}{m}\right] I_{c_1\le t<c_2} \\
&+ \left[p_{1d} + (q_{1d}+\zeta)\frac{z_1(t)}{m} + q_{1d}\frac{z_2(t)+z_3(t)}{m}\right] I_{t\ge c_2}\Bigg\}\left[1-\frac{z(t)}{m}\right] \\
z_2'(t) &= m\Bigg\{ \left[p_{2c} + q_{2c}\frac{z_2(t)}{m} + (q_{2c}-\gamma)\frac{z_1(t)}{m}\right] I_{c_1\le t<c_2} + \\
&+ \left[p_{2d} + q_{2d}\frac{z_2(t)}{m} + (q_{2d}-\rho)\frac{z_1(t)+z_3(t)}{m}\right] I_{t\ge c_2}\Bigg\}\left[1-\frac{z(t)}{m}\right] \\
z_3'(t) &= m\Bigg\{ \left[p_{3d} + q_{3d}\frac{z_3(t)}{m} + (q_{3d}-\xi)\frac{z_1(t)+z_2(t)}{m}\right] I_{t\ge c_2}\Bigg\}\left[1-\frac{z(t)}{m}\right]
\end{aligned}
$$

internal-influence: competition phase, double-competition phase

cross-influence: competition phase, double-competition phase

UCTT Model

Sing of cross-influence coefficients: competition - collaboration

q_{1d}	$q_{2d} - \rho$	$q_{3d} - \xi$	Interpretation
−	−	−	Full competition
−	+	+	(2,3) compete with 1, (1,3) collaborate with 2, (1,2) collaborate with 3;
−	−	+	(2,3) compete with 1, (1,3) compete with 2, (1,2) collaborate with 3;
−	+	−	(2,3) compete with 1, (1,3) collaborate with 1 (1,2) compete with 3;
+	+	−	(2,3) collaborate with 1, (1,3) collaborate with 2, (1,2) compete with 3;
+	−	+	(2,3) collaborate with 1, (1,3) compete with 2, (1,2) collaborate with 3;
+	+	+	Full collaboration

Results

The estimated diffusion parameters are characterized by common and critical social, economic, and geographical factors that enable or hinder renewables exploitation and suggest similar clustered countries.

Nations have been clustered following these indicators:

- Renewables present a negative cross-influence
  - Gas presents positive internal and negative cross-influence (Group 1)
  - Gas presents negative internal and positive cross-influence (Group 2)
  - Nations that use mainly *nuclear energy* (Group 3)
- Renewables present a positive cross-influence (Group 4)

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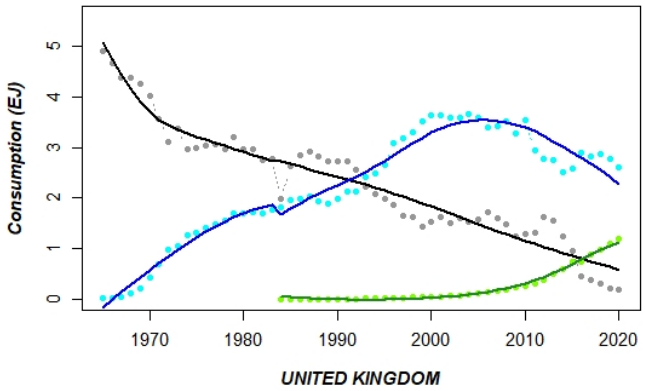
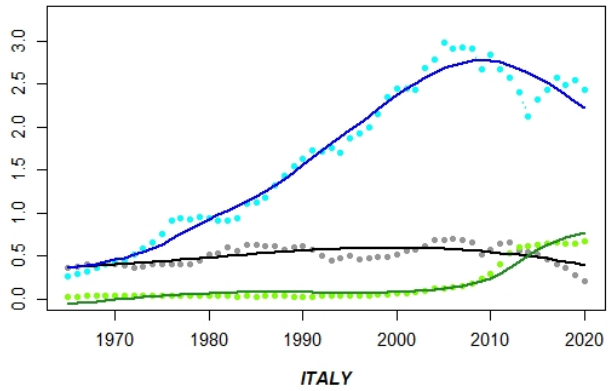
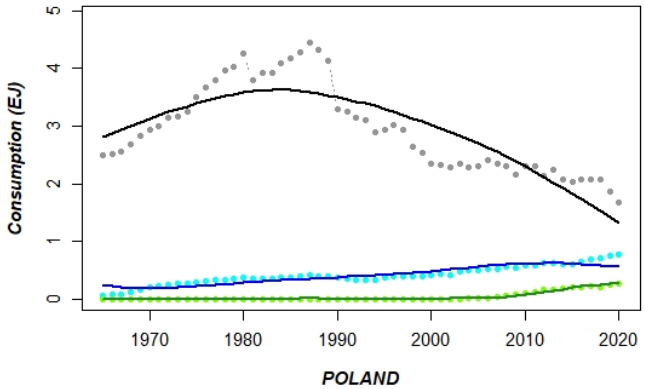
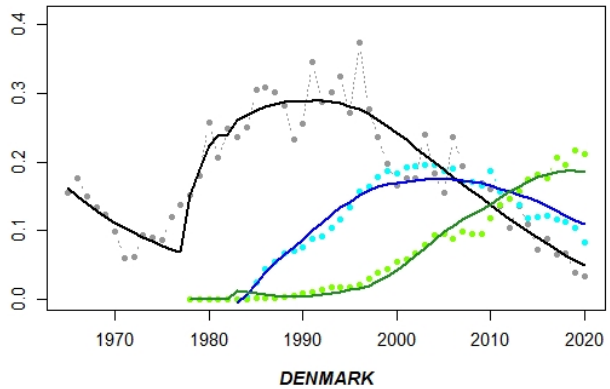


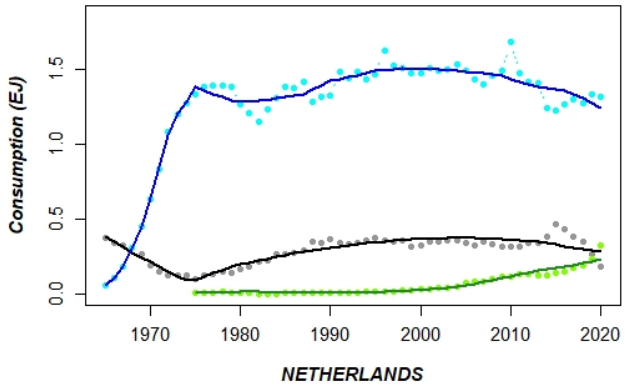


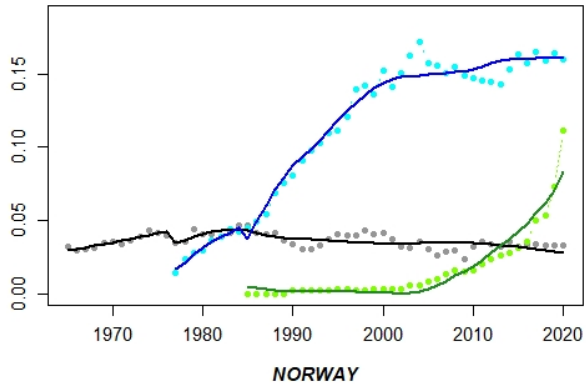


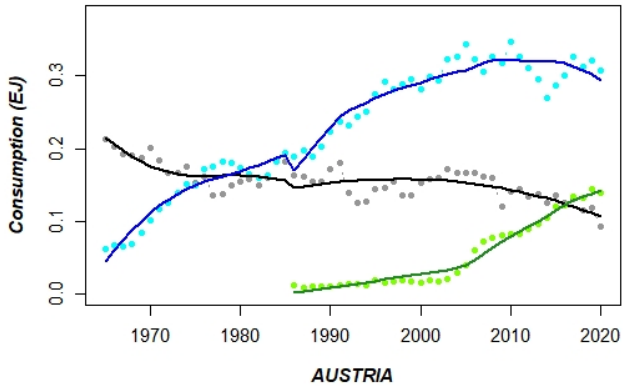


	ii-R	ci-R	ii-G	ci-G	ii-C	ci-C
UK	0.6321	-0.0023	0.0984	-0.0138	0.0069	-0.0035
Italy	0.3864	-0.0060	0.0895	-0.0288	0.0187	0.0047
Poland	0.7291	-2e-04	0.2723	-0.0179	0.0428	-0.0528
Denmark	0.3471	-0.0069	0.0021	0.0537	0.0426	-0.0417

Results: Group 2

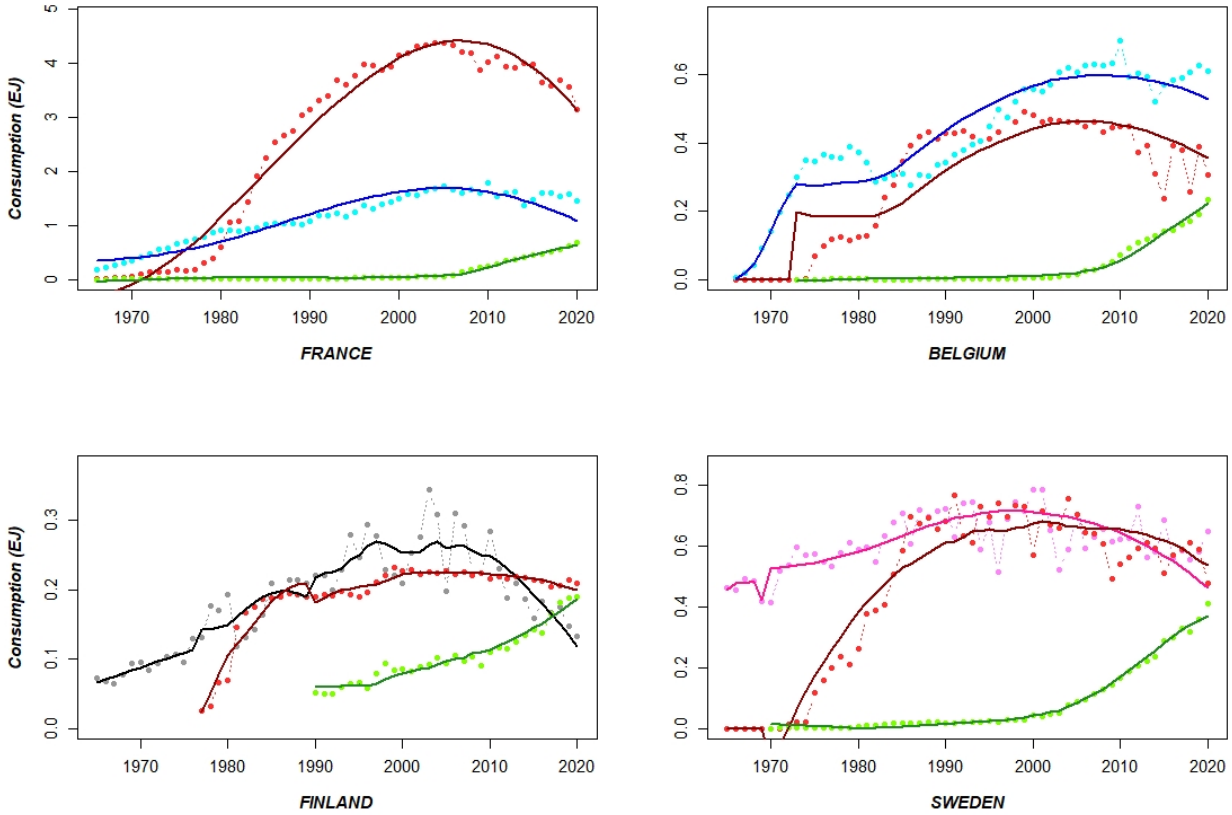






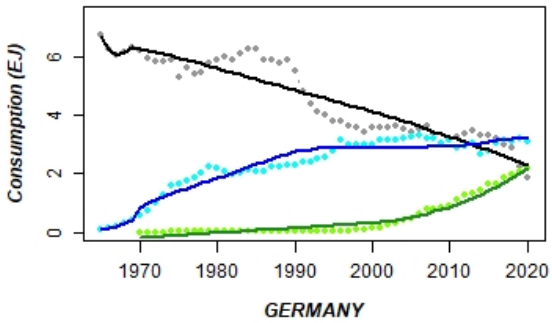
	ii-R	ci-R	ii-G	ci-G	ii-C	ci-C
Netherlands	0.3431	-0.0014	-0.0382	0.3274	-0.0307	0.0204
Norway	0.5073	-0.0091	-0.0389	0.3458	-0.0525	0.0194
Austria	0.2240	-0.0021	-0.0491	0.1645	0.0178	0.0052

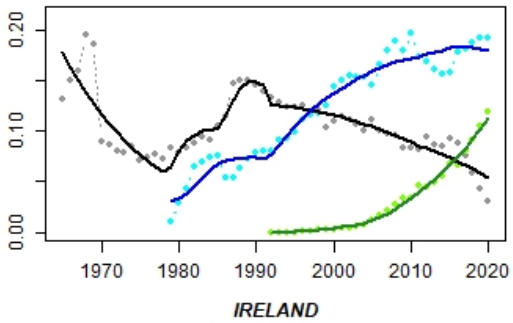
Results: Group 3

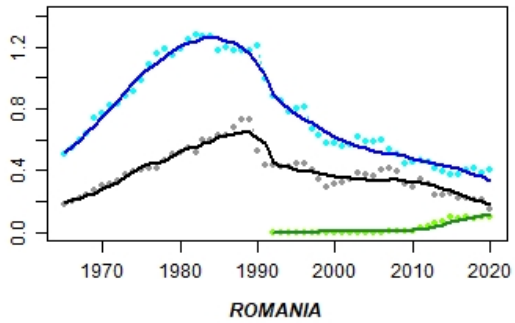


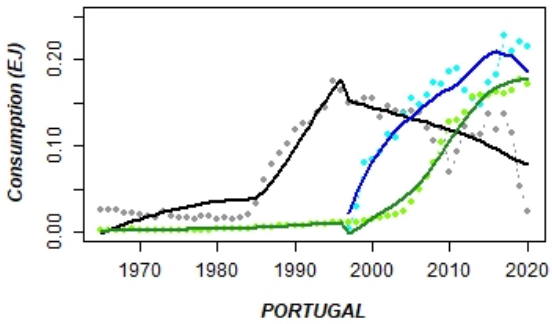
	ii-R	ci-R	ii-N	ci-N	ii-G	ci-G
France	0.5303	-0.0027	0.0130	0.1824	0.0447	0.0120
Belgium	0.3290	-1e-04	0.0779	-0.0220	-0.0111	0.0752
					ii-C	ci-C
Finland	0.2234	-0.0266	0.0959	-0.0359	0.1801	-0.1259
					ii-H	ci-H
Sweden	0.3926	-0.003	-0.0606	0.1065	0.0123	0.0306

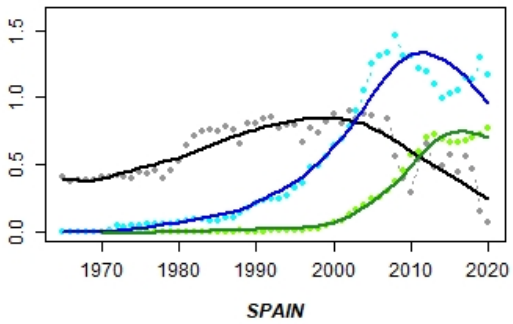
Results: Group 4

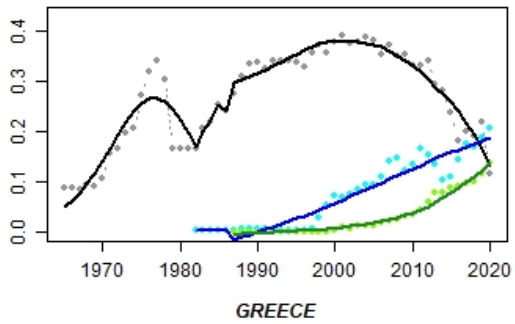


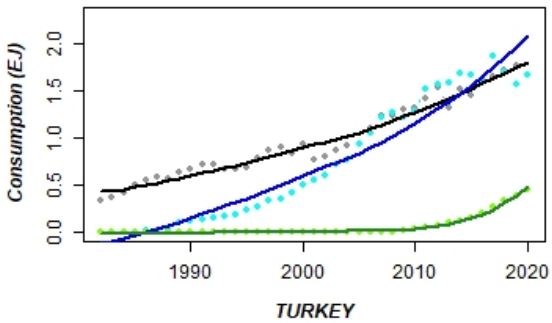










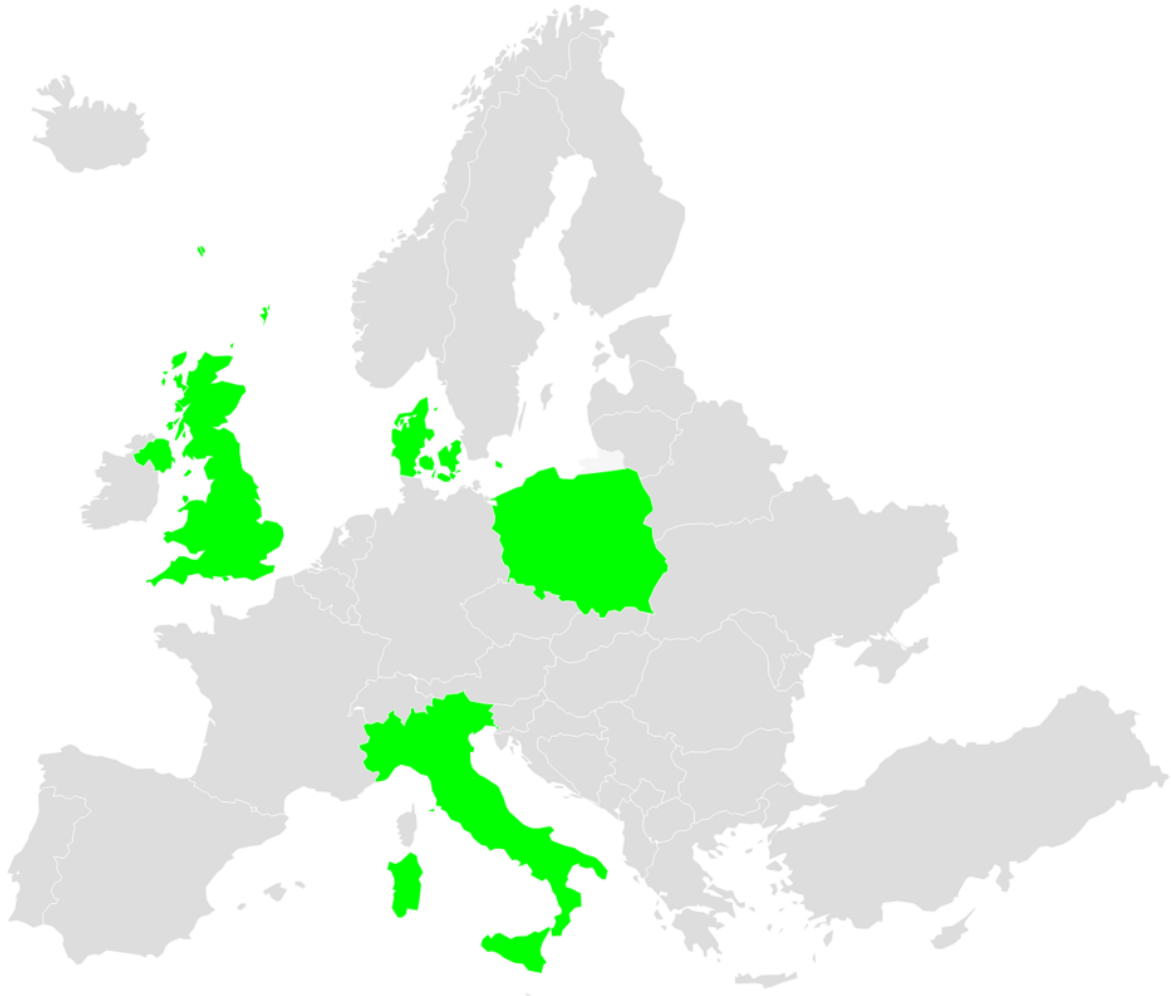


Results: Group 4

	ii-R	ci-R	ii-G	ci-G	ii-C	ci-C
Germany	0.0726	0.0020	-0.0330	0.0270	-0.0064	-0.0169
Ireland	0.2395	0.0014	-0.0137	0.0952	0.0183	-0.0128
Romania	0.5626	0.0012	-0.1940	0.3391	0.2697	-0.1397
Portugal	0.1566	0.0173	-0.1199	0.1776	-0.0065	0.0106
Spain	0.3510	3e-04	0.1767	-0.0034	0.0454	-0.0156
Greece	0.1026	0.0024	0.0053	0.0161	0.0233	-0.1049
Turkey	0.1952	0.0007	-0.0122	0.0628	0.0403	-0.0053

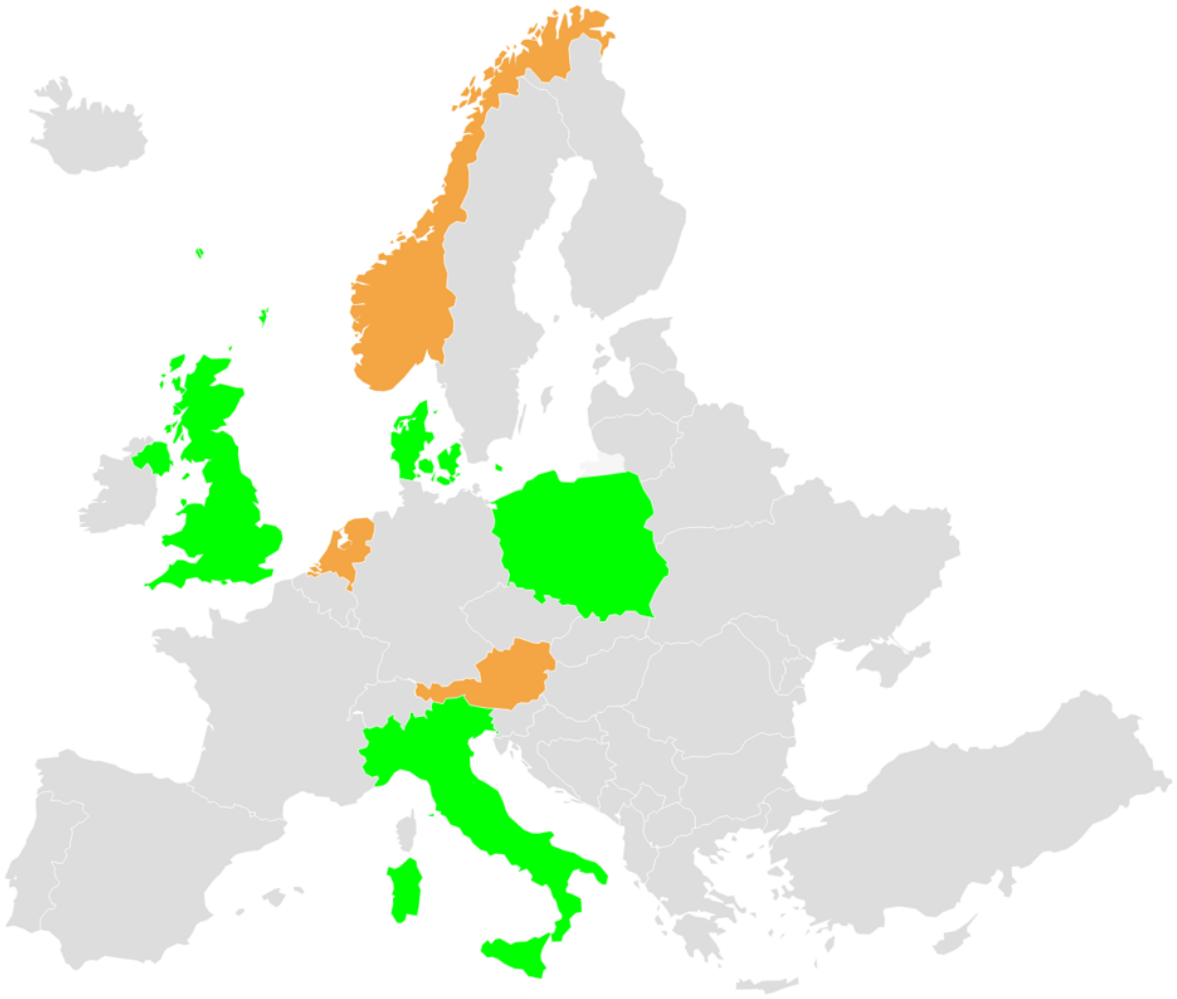
Results

Group 1: green



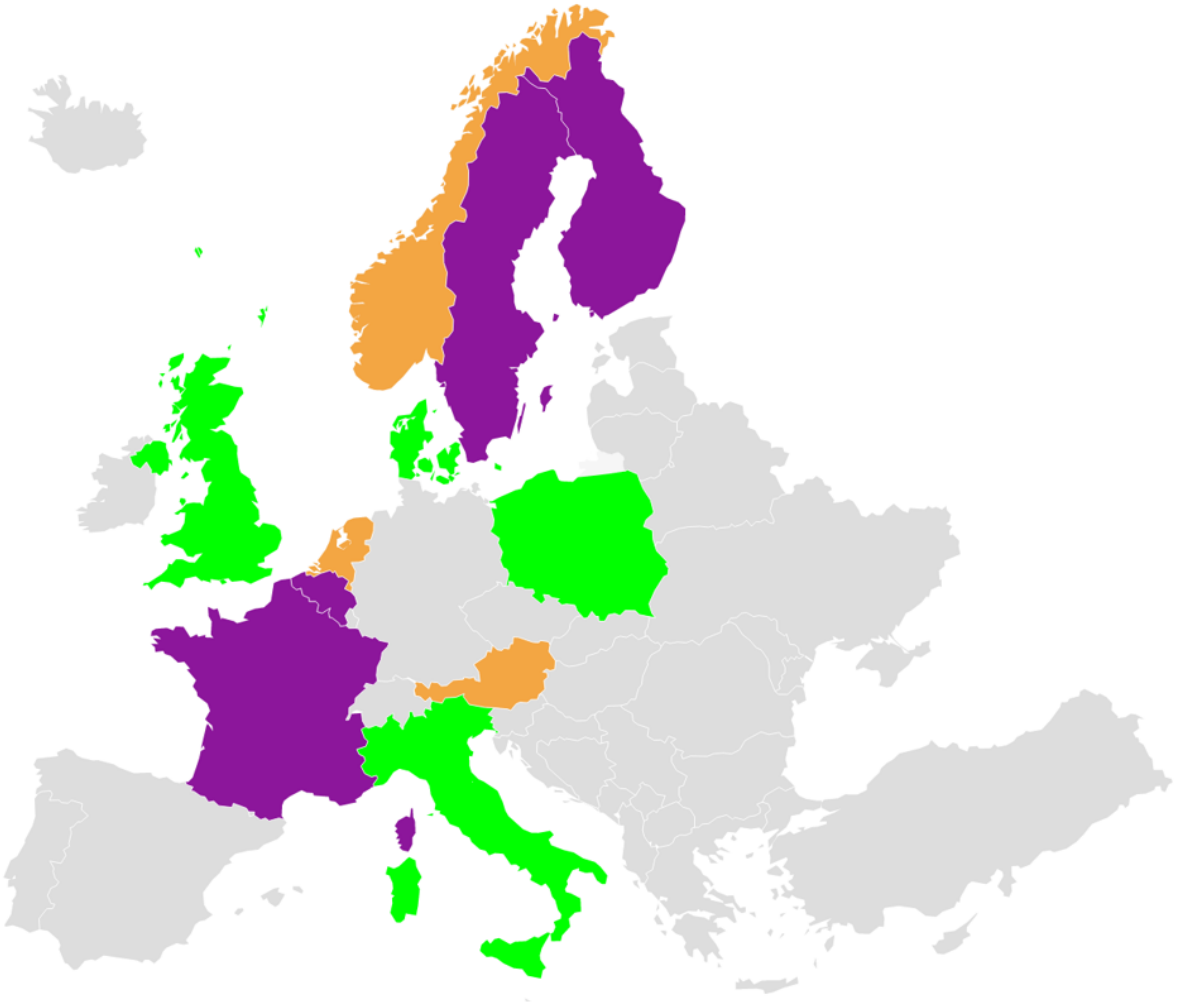
Results

Group 1: green, Group 2: orange



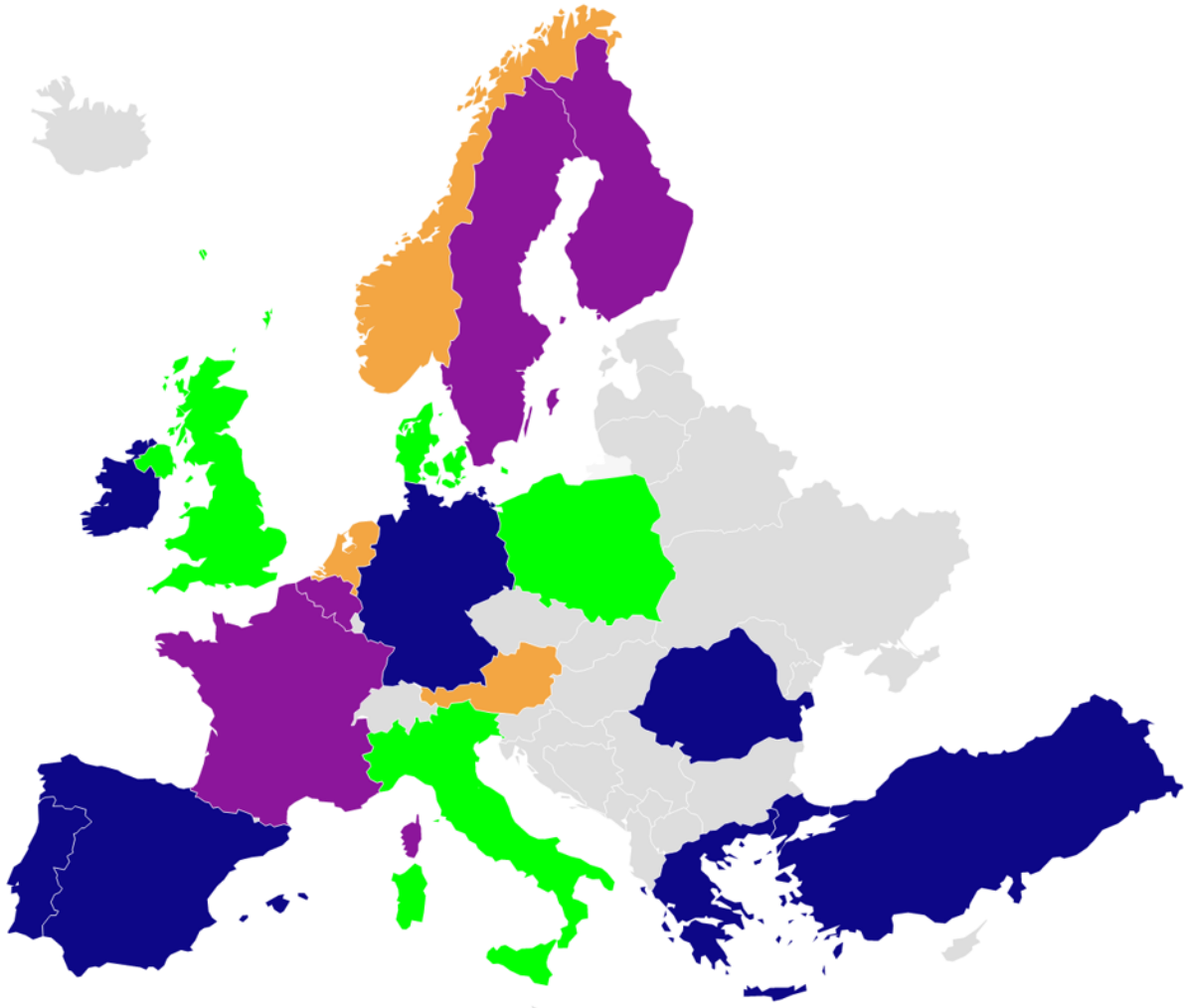
Results

Group 1: green, Group 2: orange, Group 3: violet



Results

Group 1: green, Group 2: orange, Group 3: violet, Group 4: blue.



Conclusions

- National policies strongly incentive renewables diffusion
- National actions limit coal consumption to decrease fossil fuels presence gradually
- An intense competition strongly affects the gas collapse, instead of collaboration that supports gas consumption keeping its trend stable
- Uncertainty after the events in Ukraine: we expect to encounter shocks in the coming years, but they are hardly predictable at this stage

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