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Clustering environmental performances, energy efficiency and clean energy patterns
A comparative static approach across EU Countries

INTRODUCTION

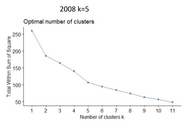
From its first steps, the European Union has strived to find a **common ground** of understanding among such a diverse historical, cultural and socioeconomic background of its Member States. The process of sustainability transition has always witnessed Europe as one of the most ambitious players in the global landscape. The EU has built a **comprehensive policy framework** encompassing all the significant areas of the **human-environment** relationship. The energy sector has always been the focus of the efforts tackling environmental pollution **(74% of GHGs released every year (IEA 2020))**. The power sector is also in the process of transitioning to a more efficient use of energy along with more **sustainable energy sources** (in 2008 renewables have outperformed fossil-fuel generation) (DG Energy 2020).

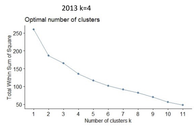
RQ: Is it possible to find homogeneous groups of Member States in terms of environmental performance and energy efficiency ?
RQ: What are the main characteristics of those groups?

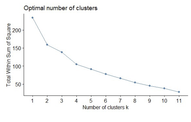
The IPAT relationship has been conceived to analyse the impact I (e.g., environmental pressure) as influenced by population P, affluence A and technology T (McNicoll 2015). In this work the IPAT will be the **analytical setting** through which identifying **common patterns** in terms of environmental performances. Data have been collected for the 27 EU Membe States plus UK and Norway from 2008 to 2018. For the **IPAT relationship** (Chertow, 2000): CO2 emissions, GDP per capita, Urbanization, Population, Industrialization (Eurostat, World Bank WDI). **Extensions:** Primary Energy Consumption, Share of renewables in energy consumption mix, Share of (solid-liquid) fossil fuels and renewables in electricity production (Eurostat).

To find groups in data **Partition Around Medoids – PAM** (k-medoids): attempt to minimize the distance between points labeled to be in a cluster and a point designated as the center of that cluster. The medoid of a cluster is defined as the object in the cluster whose average dissimilarity to all the objects in the cluster is minimal, that is, it is a most centrally located point in the cluster. For the choice of the stopping rule the **Elbow method** has been employed minimizing the **Total Within-sum of squares** (Kaufman and Rousseeuw 2005).

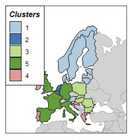
RESULTS





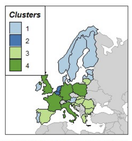


2008



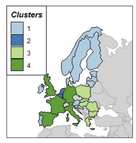
The different groups have been clustered using k-medoids.
Cluster 1: Austria, Denmark, Estonia, Finland, Lituania, Latvia, Norway, Sweden
Cluster 2: Belgium, Luxembourg, Netherlands
Cluster 3: Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia
Cluster 4: Croatia, Greece, Ireland, Portugal
Cluster 5:France, Germany, Italy, Spain, United Kingdom

2013



The different groups have been clustered using k-medoids.
Cluster 1: Austria, Denmark, Estonia, Finland, Ireland, Norway, Portugal, Sweden
Cluster 2: Belgium, Luxembourg, Netherlands
Cluster 3: Bulgaria, Croatia, Czech Republic, Greece, Hungary, Latvia, Lithuania, Romania, Slovakia, Slovenia, Spain
Cluster 4: France, Germany, Italy, Poland, United Kingdom

2018



The different groups have been clustered using k-medoids.
Cluster 1: Austria, Croatia, Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Norway, Portugal, Sweden
Cluster 2: Belgium, Luxembourg, Netherlands
Cluster 3: Bulgaria, Czech Republic, Greece, Hungary, Poland, Romania, Slovakia, Slovenia
Cluster 4: France, Germany, Italy, Spain, United Kingdom

CONCLUSIONS

Group 1: Austria, Denmark, Estonia, Finland,Norway, Sweden
Group 2: Belgium, Luxebourg, Netherlands
Group 3: Germany, France, Italy, United Kingdom, Spain
Group 4: Bulgaria, Czech Republic, Romania, Slovakia, Slovenia, Hungary, Greece
Group 5: Croatia, Latvia, Lithuania, Ireland, Portugal, Poland

Applying a **data-driven** approach this work tries to provide a new perspective on environmental policy analysis applying a **consolidated analytical framework** (e.g., IPAT). The analysis identified **three specific groups** with marked differences among each other from the ones with **higher performances** (Group 1, Group 2) in terms of clean energy, energy efficiency; wealthy countries with **poor environmental performances** (Group 3) opposed to relatively poorer countries with **promising environmental performances** (Group 4). Among those polarized clusters some countries have moved through clusters (Group 5).

Results could better address policymakers in terms of **convergence** of environmental policy implementing new measures to promote **emission reduction** with specific focus on energy efficiency for households (e.g., **heating and cooling**). Attention should be also paid to the energy mix in light of the transition towards renewables (e.g., **nuclear power**).

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