Green technologies and skills in Europe

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Climate Change, Green Technologies, and Innovation Dynamics

Global awareness and commitments:

- The **2015 Paris Agreement** set the goal of limiting global warming to **+2°C** above pre-industrial levels.
- The **costs of inaction** are high: pollution, biodiversity loss, and threats to human health and food security.

Role of green technologies:

- Central to strategies against climate change.
- **More complex and novel** than conventional technologies → require **targeted incentives** for development (Barbieri et al, 2022).
- Development capacity **varies across countries** depending on economic and knowledge structures.

Territorial factors in innovation:

- Innovation arises from the **recombination of existing ideas** (Romer, 1994).
- Dependent on the **diversity of local knowledge** and access to **social and material resources.**
- Regions with **heterogeneous knowledge bases** → **more complex and dynamic technologies.**

Skills, Green Innovation, and the Technological Life Cycle

Technological life cycle:

- **Emerging phase:** high variety and uncertainty of solutions.
- **Mature phase:** standardization and diffusion of knowledge.
- **Green technologies**—especially emerging ones—are strongly linked to **diverse knowledge bases** (Barbieri et al., 2020).

Research gap:

- The link between **workers' skills**, **green technology development**, and the **life cycle of innovation** remains underexplored, particularly in Europe.

Research objectives:

1. Identify **worker competencies** associated with green innovation.
2. Analyze how these competencies **evolve across the life cycle** of green technologies.

Methodology

Green technologies

- We use PATSTAT 2025 to follow the development of technologies
- We focus on Climate Change Adaptation and Mitigation Technologies (branch Y02)
- Inventors located in Europe at regional level

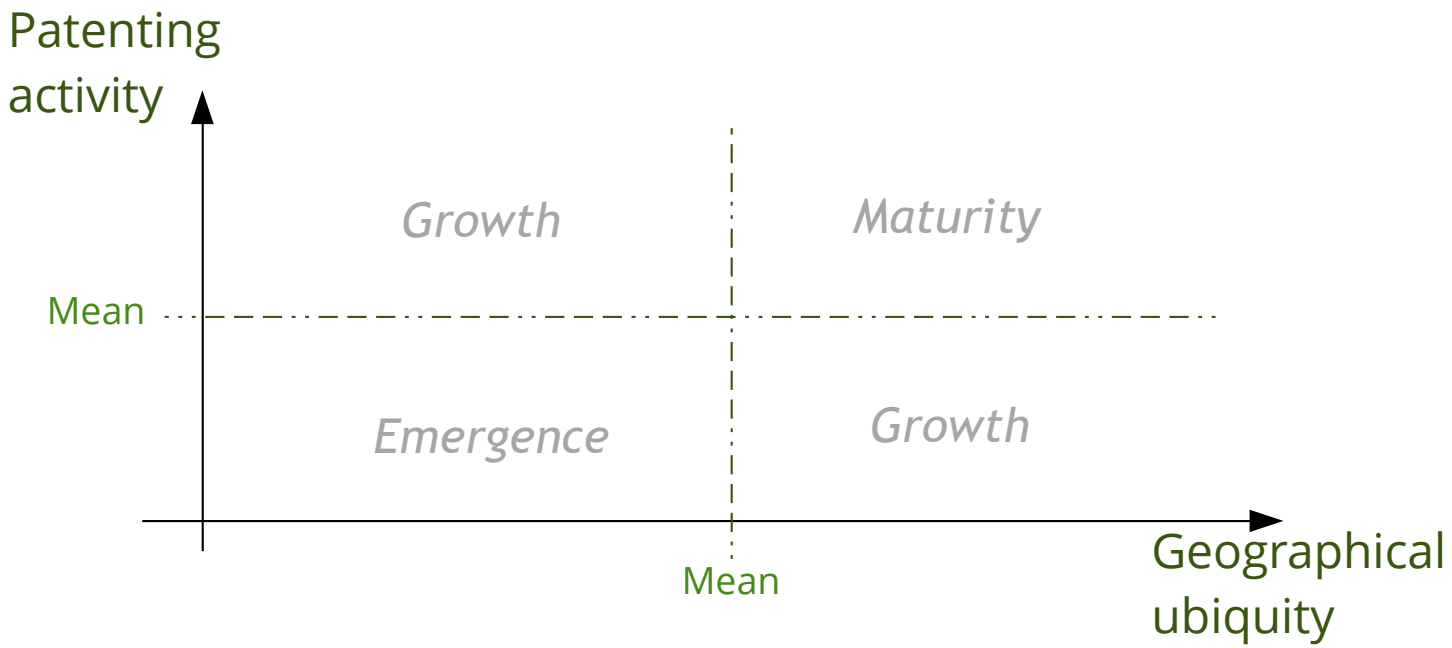
Regional labour market in Europe

- Source: Labour Force Survey at regional level
- ISCO at 1 digit level to identify occupations – all occupations except Armed forces (ISCO 6) and farming professionals (ISCO 0)
- Routine Task Intensity (RTI) index following Salomons (2015) → we compute an average RTI for each region / year.

Additional data

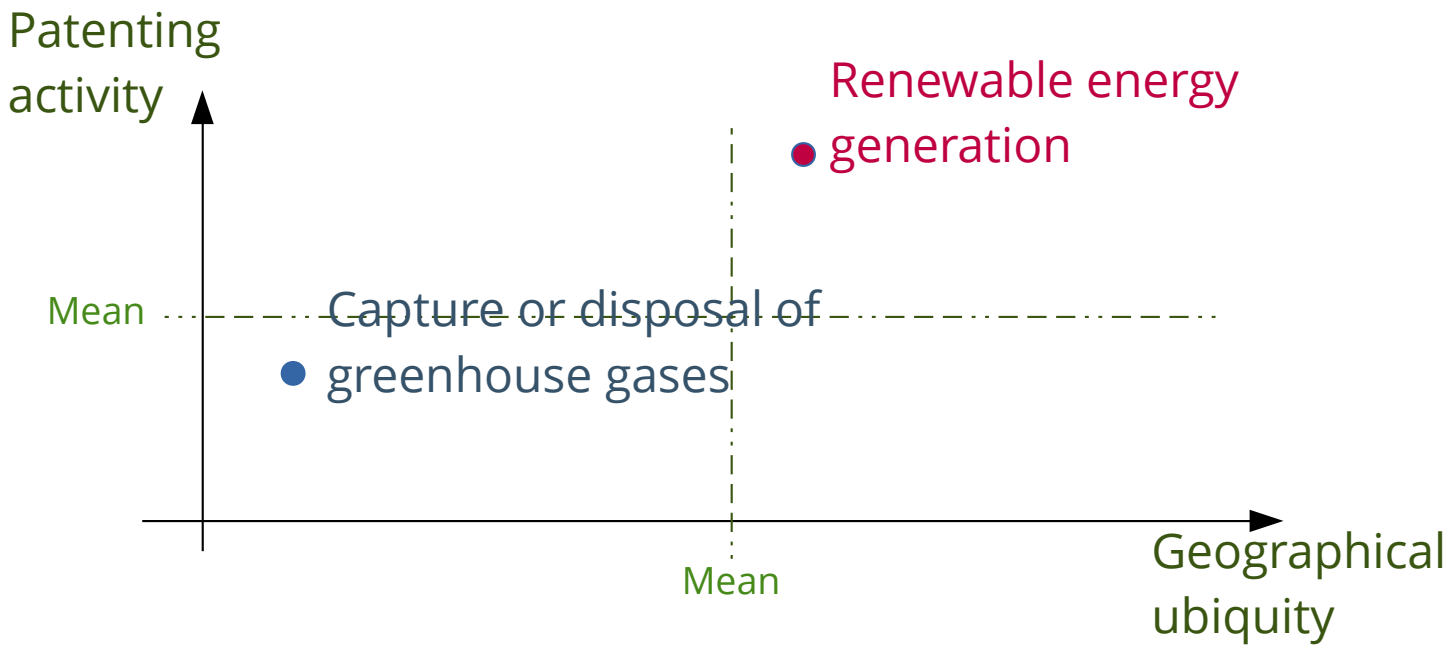
- OECD Regional database for population, GDP, employment / unemployment rate

Measuring the life cycle of technologies



- 2 dimensions
  - Pat. activity: Number of patent families
  - Geo. Ubiquity: Number of RTA per technology
- TLC stages computed for all green technologies worldwide
  - Using inventors' addresses
  - 5 years time period

Measuring the life cycle of technologies - example

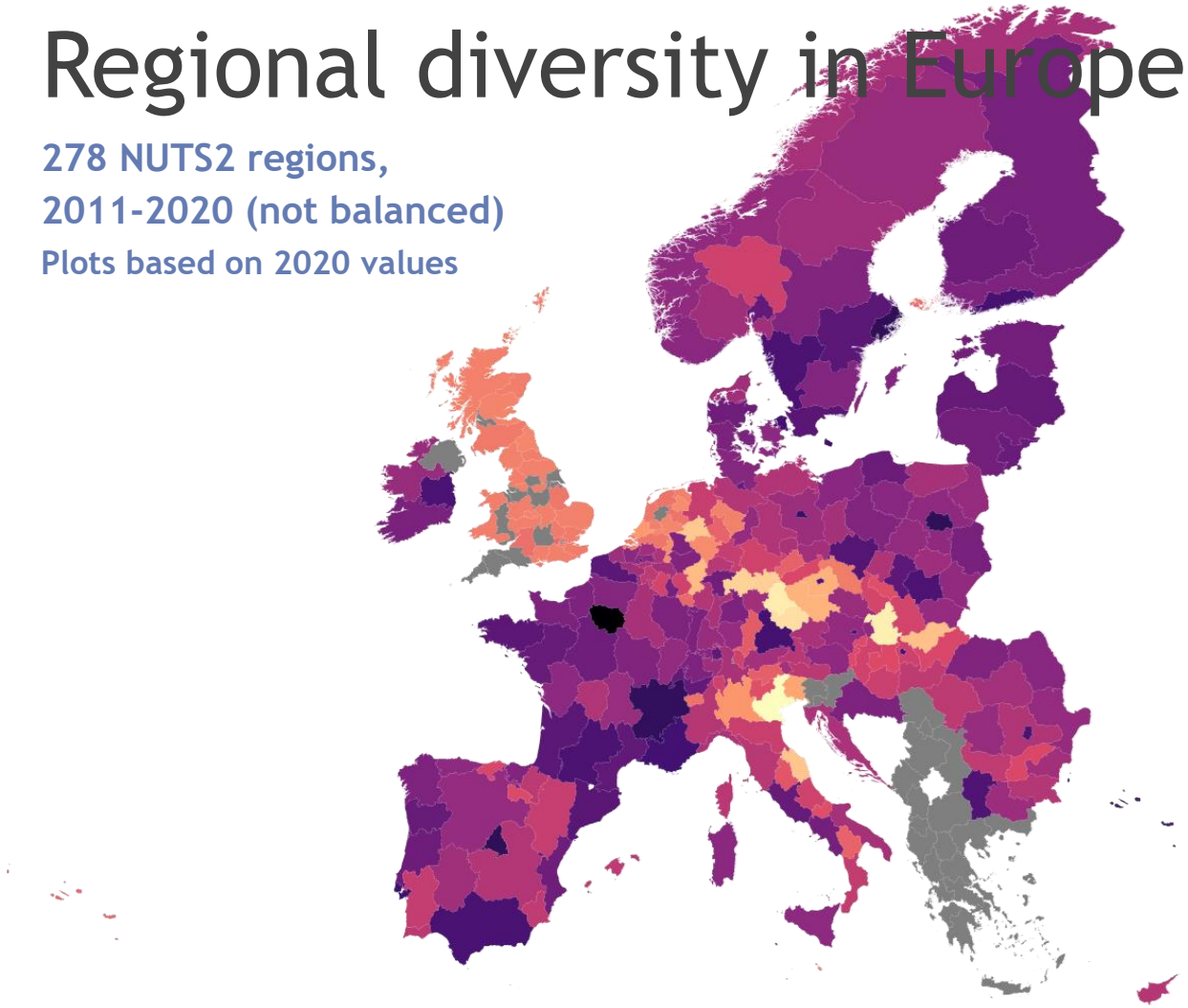


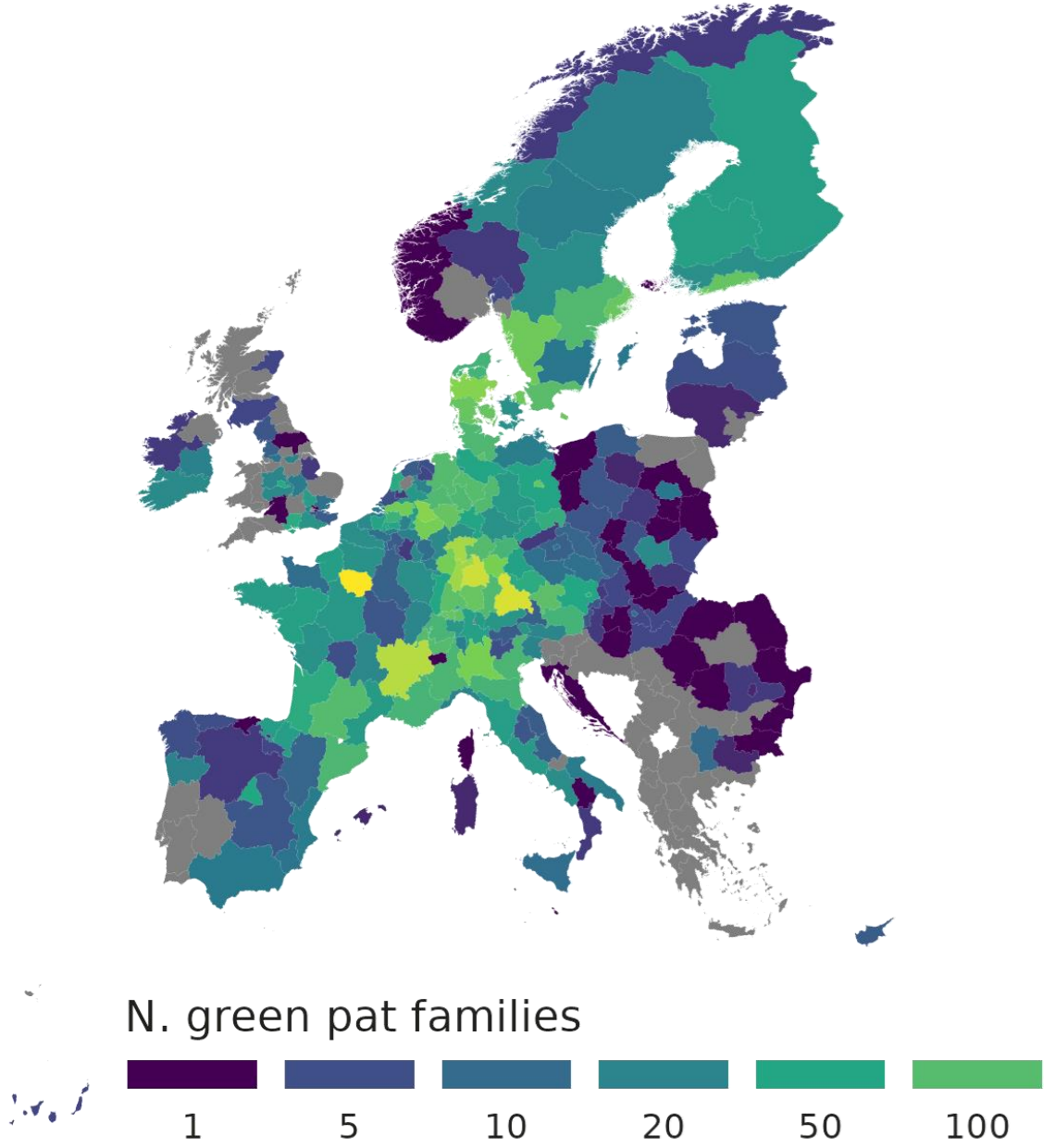
- *"Capture or disposal of greenhouse gases"* is in **emergence** phase
- *"Renewable energy generation"* is in **maturity** phase

Regional diversity in Europe

278 NUTS2 regions,
2011-2020 (not balanced)

Plots based on 2020 values





Preliminary results and discussion

- Different types of knowledge, and of knowledge connections, are relevant along the technology life cycle.
- In the **early phase**, the **RTI is negative and significant**: non-routine occupational structures favour exploration, and distant bits of know-how are more conducive to emerging GT inventive activity.
- In the **growth phase**, the **RTI turns positive**, although the effect is still limited: technologies are stabilising, and proximate knowledge starts supporting incremental improvement.
- In the **mature phase**, the **RTI is positive and significant**: routinisation becomes functional to exploitation and cumulative innovation.

Closing remarks

- Routinisation is not uniformly beneficial: its role depends on the stage of the technology life cycle.
- In early phases, GT growth is associated with a high concentration of knowledge-intensive activities.
- As technologies become mature, their development benefits from standardisation and cumulative knowledge.
- Policy implication: supporting diversity early and routinisation later is crucial to leverage green technologies' development path.
- Different types of knowledge, and of knowledge connections, are relevant to technology development along the life cycle:
  - Early stages: distant bits of know-how (experimentation);
  - Later stages: proximate know-how (stabilization);

Limitations and future avenues

Data

- Fill missing data / replace OECD source
- Improve NUTS continuity (in particular in France in 2016)
- Alternative source of data for skills ?
- Improve geolocation of inventors

Exploration

- Differences between green tech / non-green tech
- Explore connections between certain technologies / occupations / time periods
- Use alternative patent family definition, green technology classification – delve into environmental management technologies

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