Economics of Innovation

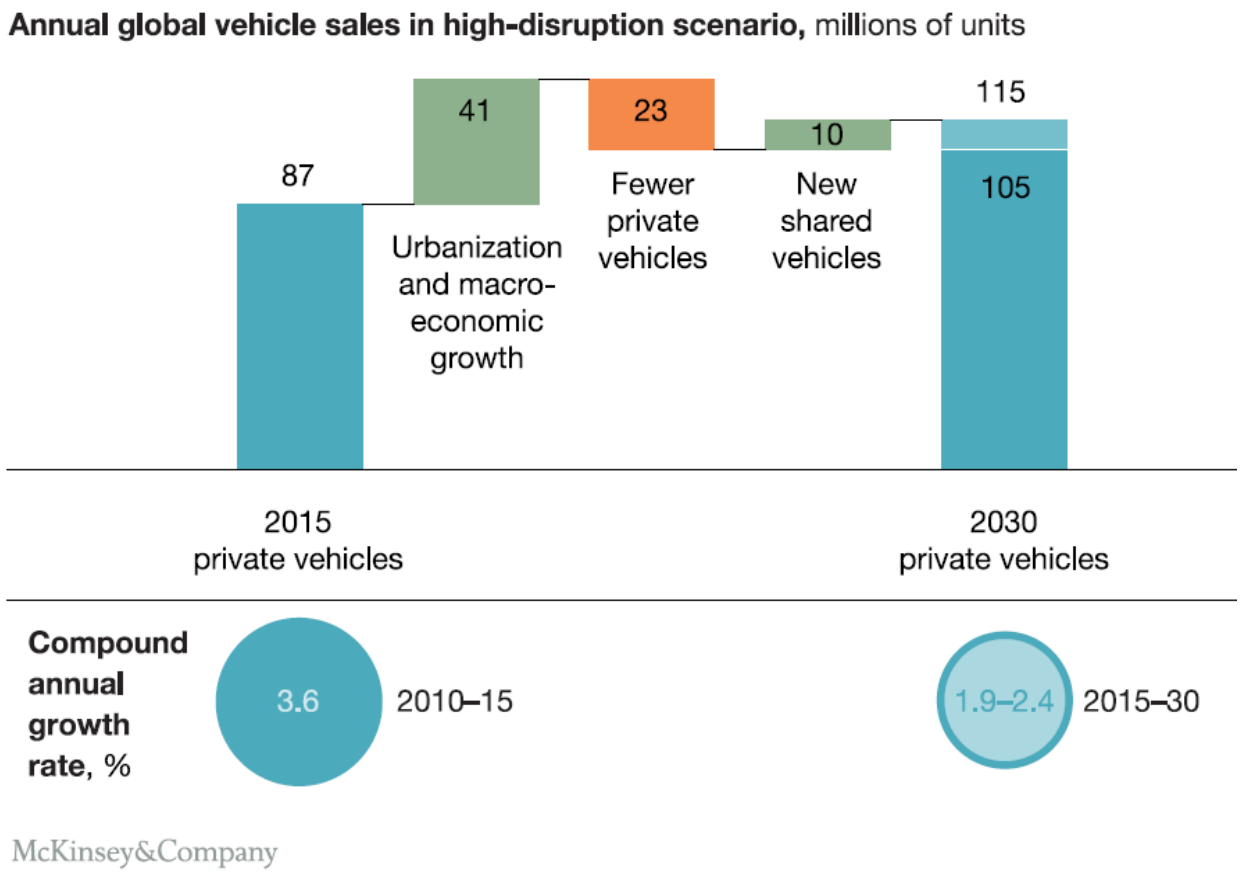
Introduction

- It is widely acknowledged that the effects of technological change on the economy are highly complex.
- Exploring these effects may unveil the mechanisms that need to be taken into account for policy implementation
- Innovation could work to compensate for economy scale effects, namely GDP and population growth, on emissions
- The role of innovation as a driver of long term productivity is a fact that goes back to the pillars of growth theory in economics, revitalized by the advent of sustainability policy oriented thinking that tries to synergically integrate the economy and the environment
- Innovation and the complementarity between different innovations are key stones to create the pre-conditions for achieving and integrating social, economic, environmental goals by 2020 and in the longer run

ICTs (Information & Communication Technologies)

- ICT as a General Purpose Technology (GPT) that can be applied in different domains to enable further technological development and innovations
- Development of ICT that reduces the environmental footprint of economic activities
  - ICTs have become essential to measure and model environmental processes, while also having an important role in improving the productivity of labour, capital and natural resources
  - The optimization of processes through ICTs is usually driven by the need to reduce costs, and in turn this also generates benefits for the environment
- ICTs, are also involved in all the technologies related to the sharing economy, namely an economic system in which services are shared among private individuals, either free or for a fee, typically by means of the Internet. Examples can be seen in the everyday life, such as car and bike sharing

Sharing mobility



McKinsey estimated that in 2016 the **car sharing** market valued 54 million dollars in three core regions (China, Europe and the United States) and that the growth rate is expected to increase in the future.

- an expansion of the sharing mobility sector will allow to decrease negative environmental pressures because of the lower number of individual vehicles and the reduced consumption of fossil fuels
- negative implication for the automotive sectors sales: McKinsey estimates that the loss in term of sales in the next 25 years will be around 10%→ Job losses, inequality growth

The advent of AV both in the public transportation sector and in the mobility on demand sector (e.g., taxis and services such as Uber) will rise by 7% by 2030 with the 87% of trips involving AV (World Economic Forum)

The consumer's perspective

- Implication of frontier technologies →issues concerning the taxation of both labour and capital (if not addressed, can hamper inequality among workers and among firms)
  - automation process → increase in inequality because of the loss of a considerable amount of jobs.
  - Present taxation system: a decrease in the cost of automation will lead to an increase in income inequality
- Solution to the problem depends on the country's preferences concerning the trade-off between higher output and equality→ **Policy channel**

The firm’s perspective

- The current profit taxation system establishes that companies’ profits has to be taxed in the country where they are physically present.
- Therefore, profits from digital firms are subject to a laxer taxation, → competitive advantage
- A revision of the current taxation system is thus fundamental to avoid hampering economic development and increasing income and wealth inequalities

The firm’s perspective

- the EU formalized two proposals to reform the current profit taxation system (March 2018)
  - volume of firm’s business as an indicator of where taxes has to be paid
  - what activity has to be taxed
- Cons:
  - giving a proper definition of digital company can be a thorny task in a world where digitalization is pervasive and not limited to one specific sectors
  - the digital economy is the economy itself so that it is increasingly difficult to think about it as a sector separated from the others
- OECD member states agreed to review tax rules related to the allocation of taxing rights between jurisdictions and to the determination of the share of profits to be taxed

Wrap up

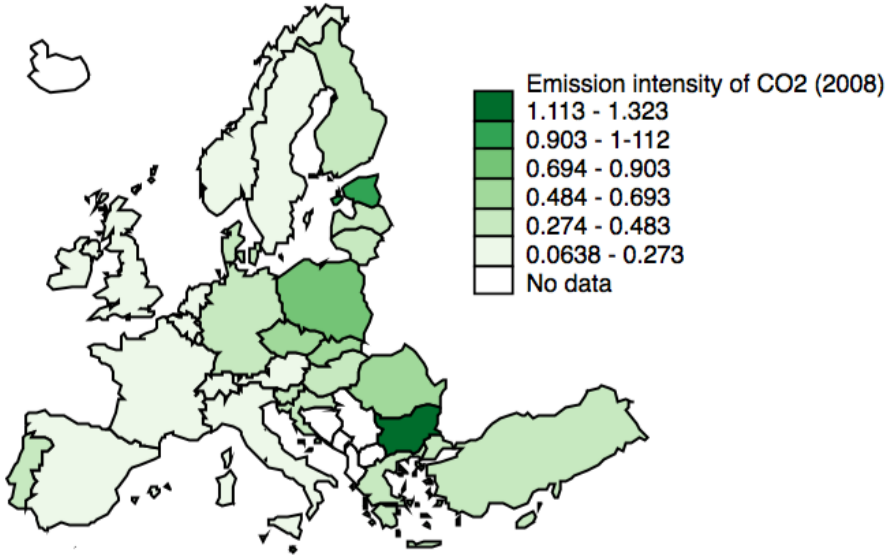
- Technological change poses new challenges for countries that needs to redesign their policy system in order to allow gains from innovation to be enjoyed as evenly as possible by all the different economic actors
- Support labour market through education and training of high skilled workers and through better redistributive measures
- Support firms by reforming taxation system, since the advent of digital economy made difficult to identify a clear tax base, and this situation could hinder the competitiveness of firms in the economy.
- Firms in some sectors need to rethink their business strategy to cope with new challenges brought about by frontier technologies that opened new markets such as in the case of the sharing economy

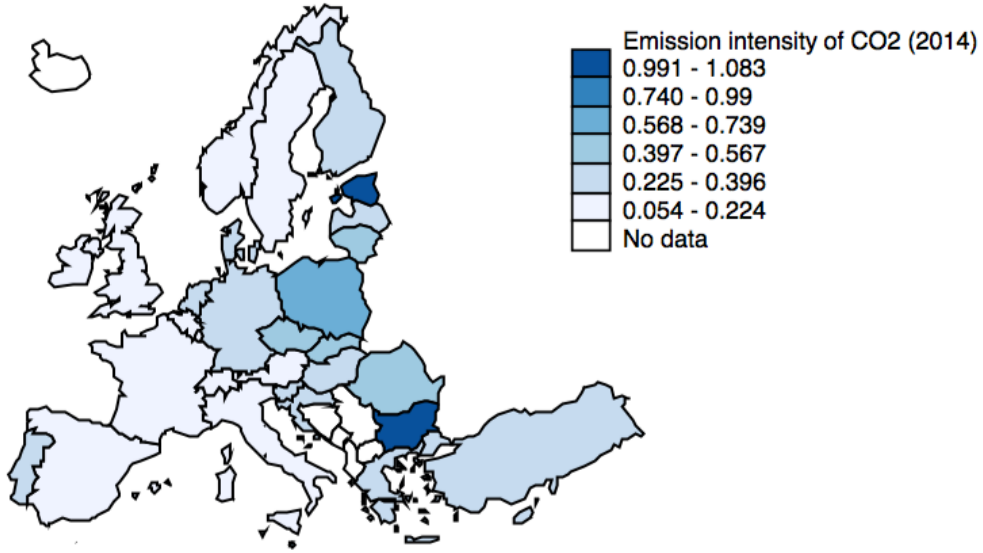
A closer look to environmental technologies

Overview

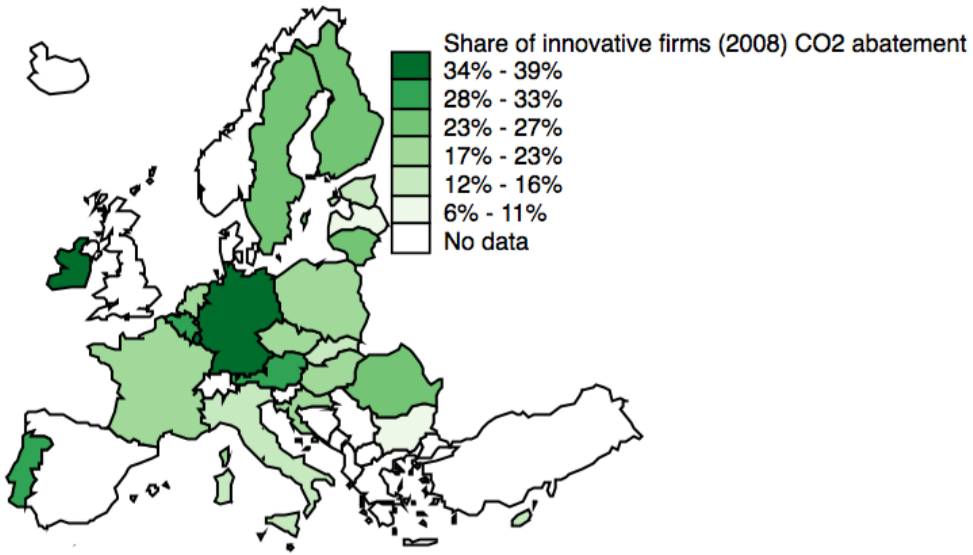
- To provide an overview about economic-environmental-innovation ‘performances’ at EU level
- EU performaces at sectorial level, holding attention to EI, changing specialization, economic-environmental performances
  - Overview on possible **win win dynamics**
- To give hints for further research
- Analyze if there is complementarity between different kind of innovations (product, process and organizational) and environmental innovation (EI) in the improvements of firm’s environmental performance.

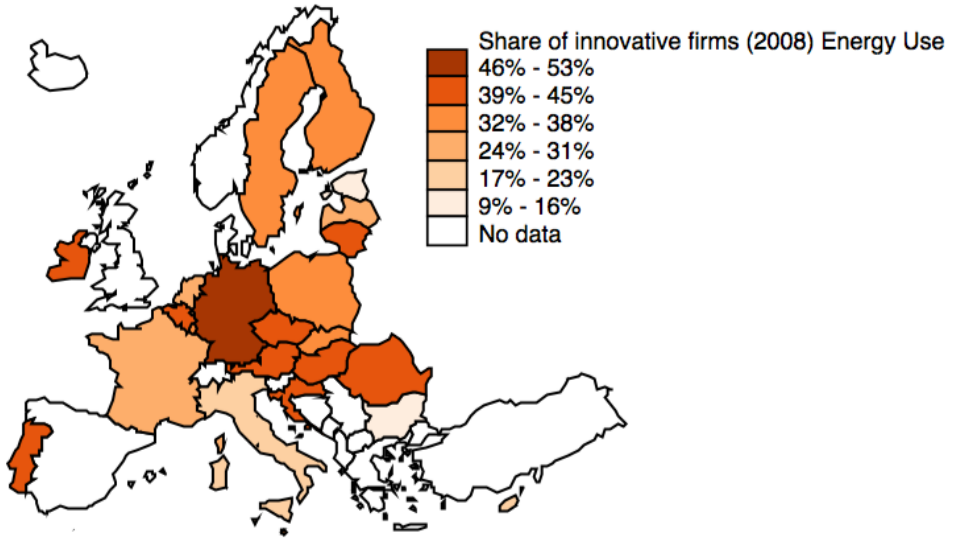
Emission intensity of GDP (CO2 emissions) in EU28



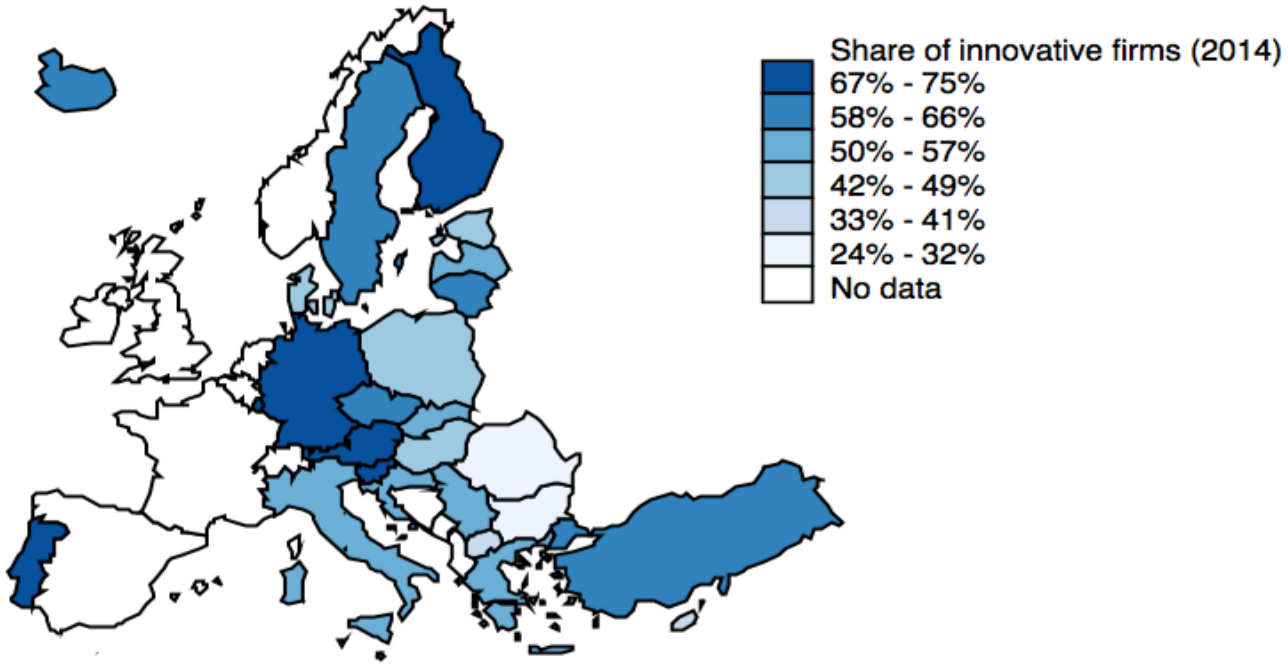


Adoption of innovation aimed to reduce CO2 footprint (left panel) and energy use (right panel) in EU countries in 2008





Adoption of innovation aimed to reduce CO2 footprint or energy use in EU countries in 2014



Sector level is important

- The role of **Meso** factors behind innovation and economic-environmental performances
- Economic specialization → economic environmental performances
- The role of (environmental) innovations

Data

WIOD

- The World Input-Output Database
- The database covers 27 EU countries and 13 other major countries in the world for the period from 1995 to 2009
- Data about value added, employment, CO2 and SOx emission
- Sectorial level data

EU CIS2008

- The Community Innovation Surveys *(CIS)* are a series of surveys executed by national statistical offices throughout the EU and in Norway and Iceland.
- The harmonized surveys are designed to give information on the innovativeness of different sectors and regions

Step 1: Static vs Dynamic

Static Analysis

Main sector are obtained as:

$$\frac{\text{Sectorial VA}}{\text{Total country VA}}$$

Dynamic Analysis

Expanding and Shrinking sectors are obtained as:

$$\Delta\text{Sectorial VA}$$

(2000-2007)

Main Sectors: Italy and Germany

Green higher than average, red lower than

Italy - Main Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
70							
7174							
J							
51					Not available	Not available	Not available
F							
Germany - Main Sectors							
70					Not available	Not available	Not available
7174							
51							
3033							
J							

Main Sectors: France and Netherlands

France - Main Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
7174							
70							
51							
J							
F							
Netherlands - Main Sectors							
7174							
51							
J							
70							
F							

Main Sectors: Sweden

Sweden - Main Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
3033							
7174							
70							
51		Not available	Not available				
J							

Top Expanding and Top Shrinking Sectors: Italy

Italy - Top Expanding Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
64							
J							
E					Not available	Not available	Not available
70							
Italy - Top Shrinking Sectors							
1718							
19							
62							
25							

Top Expanding and Top Shrinking Sectors: Germany

Germany - Top Expanding Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
61							
3033							
64							
63							
Germany - Top Shrinking Sectors							
20							
F					Not available	Not available	Not available
62							
23							

Top Expanding and Top Shrinking Sectors: France

France - Top Expanding Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
64							
62							
7174							
25							
France - Top Shrinking Sectors							
61							
1718							
3637							
19							

Top Expanding and Top Shrinking Sectors: Netherlands

Netherlands - Top Expanding Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
64							
23							
51							
J							
Netherlands - Top Shrinking Sectors							
2122							
19							
3033							
1718							

Top Expanding and Top Shrinking Sectors: Sweden

Sweden - Top Expanding Sectors							
Sector	VA/L	Sox/VA	CO2/VA	EN.INT	CIS EN.EFF	CIS CO2	CIS WASTE
23							
3033							
61							
64		Not available					
Sweden - Top Shrinking Sectors							
60							
2122							
62							
1718							

Step 2: Decomposition Analysis

- Decompose factors characterising different growth differential between a single country (or region) and a benchmark (Dunn, 1960, Garcia-Mila and Mc Guire, 1993 and Esteban, 2000)
  - This case a EU Member State vs. EU27
- X is the emission intensity index (where X=E/VA for EU27 and $X_{DE}=E_{DE}/VA_{DE}$ for Germany), and X^S is the sectorial emission intensity. In other term $X = \sum_s P^S X^S$; $X_{DE} = \sum_s P_{DE}^S X_{DE}^S$
- P^S is the sectorial value added and is define as $P^S=VA^S/VA$.
- We can decompose the emission efficiency differential between Germany and the EU27 average, which can be written as X_{DE}-X, in three different components (see Mazzanti and Montini, 2009):

Decomposition Analysis

- The structural factor (μ) or industry mix, which indicates the environmental efficiency share attributable to the particular industry mix of the country with respect to the EU average. This effect is given by:

$$\mu_{DE} = \sum_{S} X^{S}(P_{DE}^{S} - P^{S})$$

  - ➢ if positive (negative) the country is specialized in more (less) polluting sectors

- The differential factor (π), which measure that part of differential due to the country being more efficient in abating emissions than the EU average, which is derived as:

$$\pi_{DE} = \sum_{S} (X_{DE}^{S} - X^{S})P^{S}$$

  - ➢ If positive (negative) the region is less (more) emission efficient

Decomposition Analysis

- Finally, the last factor, called allocative (α), is given by the covariance between the previous two components, and represent the contribution to a country emission efficiency given by its specialisation in greener than average countries. It is calculated as:

$$\alpha_{DE} = \sum_{S} (X_{DE}^{S} - X^{S})(P_{DE}^{S} - P^{S})$$

  - If positive, the region is specialised in more polluting sectors in which emission efficiency is lower than the benchmark

Country	Pollutant	X_i-X	μ	π	α	Share of the Primary factor	Primary factor (%)
Germany	ET	-3.287	-3.856	**42.817**	-42.248	48%	π
	Co_2	-0.073	-0.037	**0.109**	-0.145	50%	α
	So_x	-0.524	**0.015**	-0.147	-0.392	71%	α
France	ET	-1.753	-0.524	-0.438	-0.791	45%	α
	Co_2	-0.206	-0.048	-0.169	**0.012**	74%	π
	So_x	-0.498	-0.204	-0.392	**0.098**	56%	π
Italy	ET	**0.689**	-1.402	**4.480**	-2.390	54%	π
	Co_2	**0.037**	**0.015**	**0.072**	-0.050	53%	π
	So_x	-0.333	-0.091	-0.032	-0.211	63%	α
Netherlands	ET	**3.698**	-1.006	**3.781**	**0.923**	66%	π
	Co_2	-0.027	-0.042	**0.014**	**0.001**	73%	μ
	So_x	-0.478	-0.131	-0.463	**0.115**	65%	π
Sweden	ET	-0.753	**10.424**	-1.456	-9.720	48%	μ
	Co_2	-0.217	-0.016	-0.186	-0.016	86%	π
	So_x	-0.458	**0.110**	-0.447	-0.121	66%	π

Germany

- Main sectors strong overall (still manufacturing is there)
- Innovation strenghts
- If Sweden and Denmark are omitted from the average, Germany presents a full economic-environmental-innovation performance in most sectors
- Diffuse strenghts in both expanding and shrinking sectors, in manufacturing and services

Italy

- Main sectors weak overall
- Real estate services expanding and best case that integrates higher than average performances
- Shrinking sectors with bad performances
- Textile and leather shrinking and bad
- Innovation weakness (highly confirmed)

Sweden

- In terms of productivity and emissions, performace are better than EU average, both in static and dynamic analysis
- The majority of the expanding sector belongs to the services industry, but…
- The most of EI is introduced in the manufacturing sector, even if it experience a reduction of the generated VA
- Sweden may be a case where win-win economic environmental perfomances jointly appear.

Complementarity

- Complementarity between two activities implemented by a firm exsists when doing more of one of them increases the attractiveness of doing more on the part of the other
- Systemic effects arises «with the whole being more than the sum of its part» (Roberts, 2006 p37).
- The literature shows that the issue of complementarity, in its various aspects, has gained momentum over the years. It is relevant to be explored given that management strategies and good practices have increasingly emphasized that competitiveness relies upon how different innovations are quantitatively and qualitatively combined more than on single investments.

Supermodularity

- Let the innovation practices set $\mathbb{I}$ be a set of elements that form a **lattice**
- In the presence of two innovation practices (EI and PI), we have two binary decision variables and the elements of the lattice $\mathbb{I}$ are 4 (that is 2^2):

$$\mathrm{I} = \{\{00\},\{01\},\{10\},\{11\}\}$$

- **Complementarity** among different innovation practices may be analysed by testing whether the environmental performances function below is supermodular in $\mathbb{I}$

$$EP_j = EP_j(EI, PI, \theta_j)$$

Supermodularity & complementarity

- We can assert that EI and PI are complements (so that EPj is supermodular) if and only if

$$EP_j(11,\theta_j) - EP_j(00,\theta_j) \geq \left[EP_j(10,\theta_j) - EP_j(00,\theta_j)\right] + \left[EP_j(01,\theta_j) - EP_j(00,\theta_j)\right]$$

- That is to say that changes in EP are brought about when both EI and process or product or organisational innovation increases together are more than the changes resulting from the sum of the separate increases of the two kind of innovation.
- θj may imply different degrees of complementarity. we are also interested in verifying whether the different sectors and geographical specificity may play a role in the exploitation of complementarity relationships between environmental innovations and other innovation practices.

Research Hypothesis

- **[H1].** Complementarity between environmental innovations aimed at abating CO2 on the one hand, and product, process, and organizational innovation on the other hand is crucial to increasing environmental productivity.
- **[H2].** Manufacturing might present more evident signs of innovation complementarity given (i) the higher (compared to services) innovation intensity and (ii) since those sectors are pressed to find more radical solutions in order to remain both competitive and sustainable by regulatory tools that put a price on carbon.

	Obs	Mean	Description	Source
VA/CO2_09*	496	23.766	Environmental productivity in 2009	WIOD
VA/CO2_10*	496	21.970	Environmental productivity in 2010	WIOD
EI	528	0.271	Adoption of environmental innovation for CO2 abatement	CIS VI
Inno_org	528	0.436	Adoption of organizational innovation	CIS VI
Inno_prod	528	0.101	Adoption of product innovation	CIS VI
Inno_proc	528	0.125	Adoption of process innovation	CIS VI
L(vaemp)	500	84.589	Labour productivity (log)	WIOD
ICT	379	0.172	Percentage of adoption of information and communication technology	CIS VI
Manuf	528	0.542	Manufacturing sector dummy	-
Utility	528	0.042	Utility sector dummy	-
Other	528	0.3333	Other services sector dummy	-
EU_NC	528	0.227	Northern European dummy (Belgium, Germany, Netherlands, Finland, Sweden and France)	-
EU_SC	528	0.182	Southern European dummy (Cyprus, Malta, Italy and Portugal)	-

	EI/OI (11)	EI/OI (10)	EI/OI (01)	EI/OI (00)	EI/Prod Innov (11)	EI/Prod Innov (10)	EI/Prod Innov (01)	EI/Prod Innov (00)	EI/Process Innov (11)	EI/Process Innov (10)	EI/Process Innov (01)	EI/Process Innov (00)
Mining and quarring	3.91%	7.14%	3.61%	3.55%	0.97%	8.33%	1.61%	4.93%	3.23%	6.00%	4.05%	3.47%
Manufacturing	5.47%	4.29%	4.82%	5.67%	6.80%	3.57%	6.45%	5.63%	6.45%	4.00%	4.05%	6.25%
Food, beverage and tobacco	3.13%	8.57%	7.23%	3.55%	2.91%	7.14%	8.06%	3.52%	5.38%	4.00%	4.05%	5.56%
Textile and leather	4.69%	4.29%	4.82%	4.96%	5.83%	2.38%	1.61%	7.04%	6.45%	3.00%	4.05%	5.56%
Wood products	4.69%	5.71%	6.02%	3.55%	5.83%	4.76%	3.23%	4.93%	4.30%	6.00%	5.41%	4.17%
Paper products	6.25%	0.00%	3.61%	4.96%	3.88%	3.57%	4.84%	2.82%	4.30%	4.00%	6.76%	3.47%
Coke and petroleum	0.78%	4.29%	4.82%	2.13%	0.97%	2.38%	1.61%	2.82%	1.08%	2.00%	2.70%	1.39%
Chemical	4.69%	2.86%	6.02%	4.26%	3.88%	3.57%	6.45%	3.52%	3.23%	5.00%	4.05%	4.86%
Rubber and plastic	5.47%	2.86%	6.02%	4.26%	4.85%	4.76%	4.84%	4.93%	5.38%	4.00%	5.41%	4.86%
Non metallic mineral products	5.47%	5.71%	4.82%	4.96%	5.83%	5.95%	3.23%	4.93%	2.15%	9.00%	8.11%	3.47%
Metal and fabricated metal products	4.69%	5.71%	4.82%	5.67%	3.88%	5.95%	8.06%	4.93%	5.38%	5.00%	9.46%	3.47%
Computer and electrical equipment	4.69%	4.29%	6.02%	4.96%	3.88%	5.95%	9.68%	4.23%	4.30%	5.00%	2.70%	6.94%
Machinery and equipment	4.69%	4.29%	3.61%	6.38%	3.88%	5.95%	8.06%	4.23%	4.30%	5.00%	2.70%	6.25%
Motor vehicles and transport equipment	3.91%	2.86%	6.02%	5.67%	2.91%	3.57%	8.06%	5.63%	4.30%	3.00%	5.41%	6.25%
Other manufacturing	4.69%	5.71%	6.02%	4.26%	5.83%	4.76%	4.84%	4.93%	4.30%	6.00%	6.76%	4.17%
Waste, water and electricity	7.03%	5.71%	1.20%	4.96%	6.80%	7.14%	1.61%	4.93%	7.53%	6.00%	2.70%	4.17%
Construction	2.34%	0.00%	1.20%	3.55%	0.97%	1.19%	3.23%	2.82%	2.15%	1.00%	0.00%	4.17%
Wholesale and retail trade	3.91%	4.29%	2.41%	4.26%	2.91%	5.95%	1.61%	4.23%	4.30%	4.00%	4.05%	3.47%
Transport and storage	4.69%	8.57%	6.02%	3.55%	6.80%	4.76%	3.23%	3.52%	6.45%	5.00%	5.41%	4.17%
Accomodation and food	0.78%	1.43%	1.20%	0.71%	0.97%	1.19%	1.61%	0.70%	1.08%	1.00%	1.35%	0.69%
Information and communication	4.69%	0.00%	2.41%	4.96%	5.83%	0.00%	4.84%	4.23%	3.23%	3.00%	5.41%	3.47%
Financial activities	3.91%	8.57%	4.82%	4.26%	7.77%	3.57%	1.61%	5.63%	5.38%	5.00%	4.05%	4.86%
Real estate	0.78%	1.43%	2.41%	0.71%	0.97%	1.19%	1.61%	0.70%	1.08%	1.00%	1.35%	0.69%
Other professional activities	4.69%	1.43%	0.00%	4.26%	4.85%	2.38%	0.00%	4.23%	4.30%	3.00%	0.00%	4.17%

Model and testing

- The regression we test (cross section):
- $\frac{VA_t}{CO_{2t}} = \beta_0 + \beta_1 l(vaemp_{2008}) + \beta_2 ICT_{2008} + \beta_3 EIPI_{11_{2008}} + \beta_4 EIPI_{10_{2008}} + \beta_5 EIPI_{01_{2008}} + \beta_6 EIPI_{00_{2008}} + \varepsilon$
  Where the subscript t in VA/CO2 stands for either 2009 or 2010.
- **Wald test** (to test if a given set of parameters is statistically significant) on the following:
- $\beta_3 EIPI_{11_{2008}} + \beta_6 EIPI_{00_{2008}} = \beta_4 EIPI_{10_{2008}} + \beta_5 EIPI_{01_{2008}}$
  If the null is rejected, then complementarity is present

Results

All sectors					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.13	≤0	0.16	≥0
EI	Process Innovation	0.17	≥0	0.10	≥0
EI	Product Innovation	2.45	≥0	2.61	≥0

Manufacturing					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	1.44	≥0	1.60	≥0
EI	Process Innovation	2.57	≥0	2.10	≥0
EI	Product Innovation	2.70	≥0	3.12*	≥0

Results II

All sectors NORTHERN COUNTRIES					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.79	≥0	0.91	≥0
EI	Process Innovation	0.13	≤0	0.17	≤0
EI	Product Innovation	0.08	≥0	0.10	≥0

Manufacturing NORTHERN COUNTRIES					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	1.25	≥0	1.42	≥0
EI	Process Innovation	1.55	≥0	1.78	≥0
EI	Product Innovation	0.16	≥0	0.18	≥0

Results III

All sectors SOUTHERN COUNTRIES					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.31	≥0	0.72	≥0
EI	Process Innovation	0.03	≥0	0.04	≥0
EI	Product Innovation	0.46	≥0	0.72	≥0

Manufacturing SOUTHERN COUNTRIES					
Innovation Practice Variables		VACO2_09		VACO2_10	
		Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)	Wald Test	Sign of the linear combination (b11+b00)+(-b10-b01)
EI	Organisational Innovation	0.46	≥0	0.46	≥0
EI	Process Innovation	0.27	≤0	0.23	≤0
EI	Product Innovation	0.00	≥0	0.01	≥0

About innovation complementarities…

- Complementarity is a rare fact in the real world of innovation adoption
- Complementarity is not characterizing the eu economy for what concerns the use of EI as a driver on environmental productivity in the carbon dioxide realm
- A slight increase in significance is present in manufacturing sector, which are heavier and subject to more stringent regulation with respect to the services sector
- The pair of complements which results significant are EI and product innovation→ EI aimed at cutting emissions + product innovation has the higher output in terms of VA creation
- Innovation capacity of the manufacturing sector is crucial to enhance the EU climate change performances