Effects of environmental innovations on CO_2 emissions in Europe: an empirical analysis of panel data from an ARDL model

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Summary

1. Context and aim
2. Methodology and data
3. Empirical findings
4. Conclusion and policy implications

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1. Context and aim

Context

- Global warming of the planet
- International climate action is imperative for inclusive green growth
- But for many experts :

"No green growth without innovation"

(Aghion et al, 2009)

Definition

What is environmental innovation or eco-innovation?

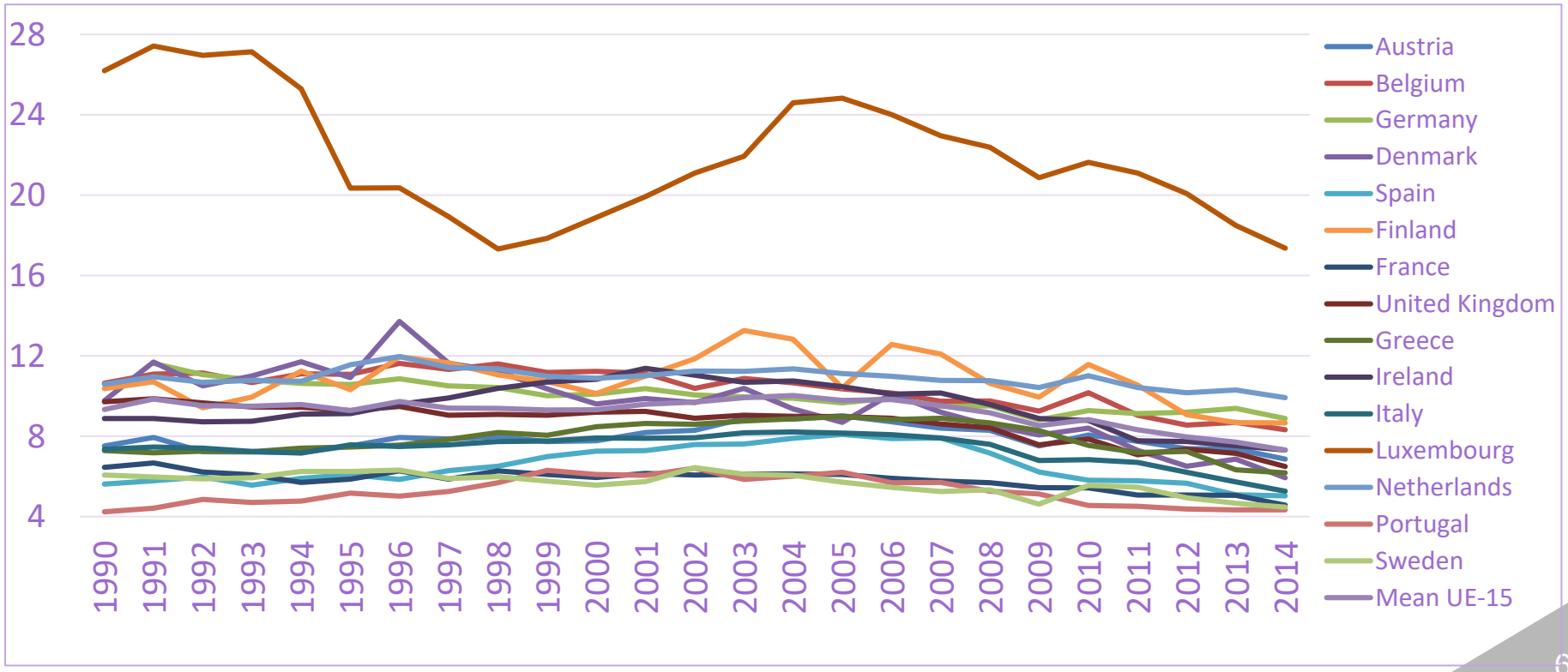
Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.

(Kemp & Pearson, 2007, p.7)

Context : Stylized Fact

Lower CO_2 emissions in Europe

Evolution of CO_2 emissions in EU-15 between 1990-2014 (metric tons per capita)



Source: Author's calculation, World Bank Data

Context: Stylized Fact

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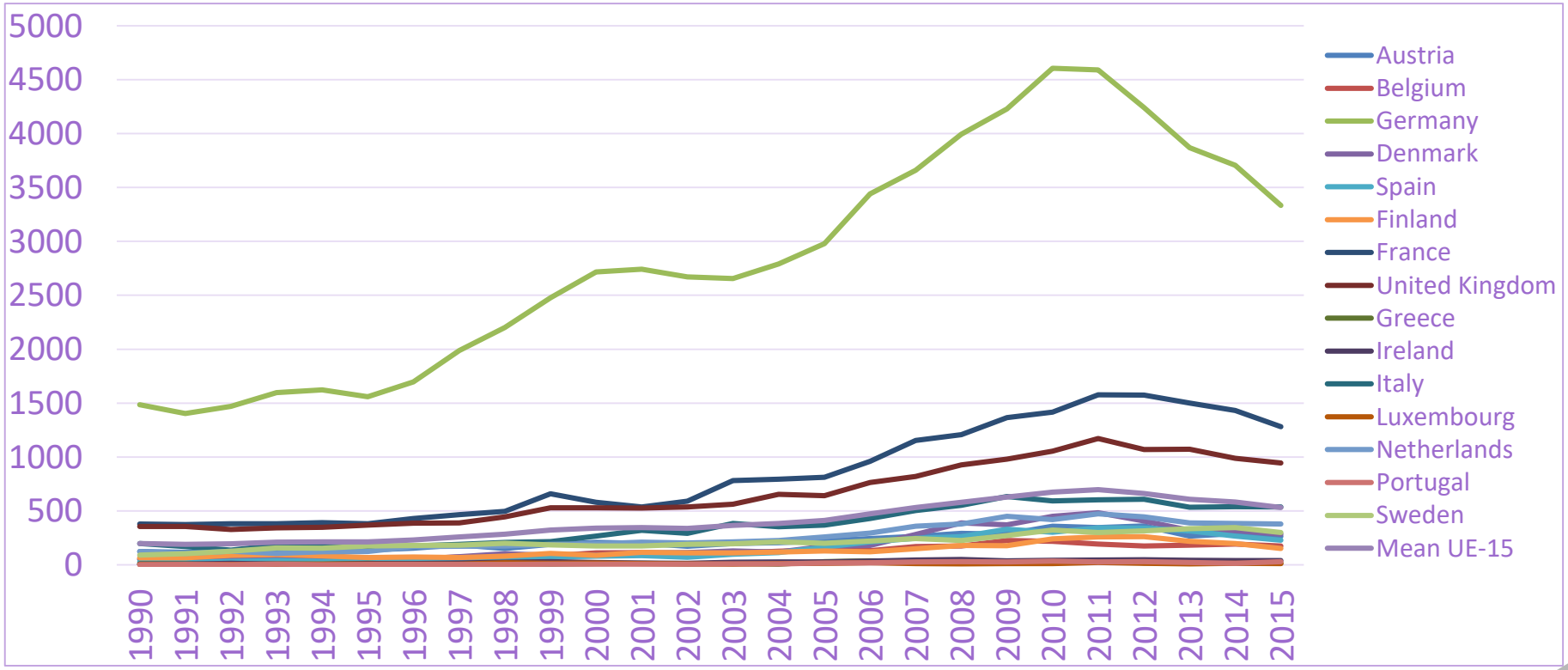
Increase in green patents

Evolution of Patents in « selected technologies related to the environment » between 1990-2014

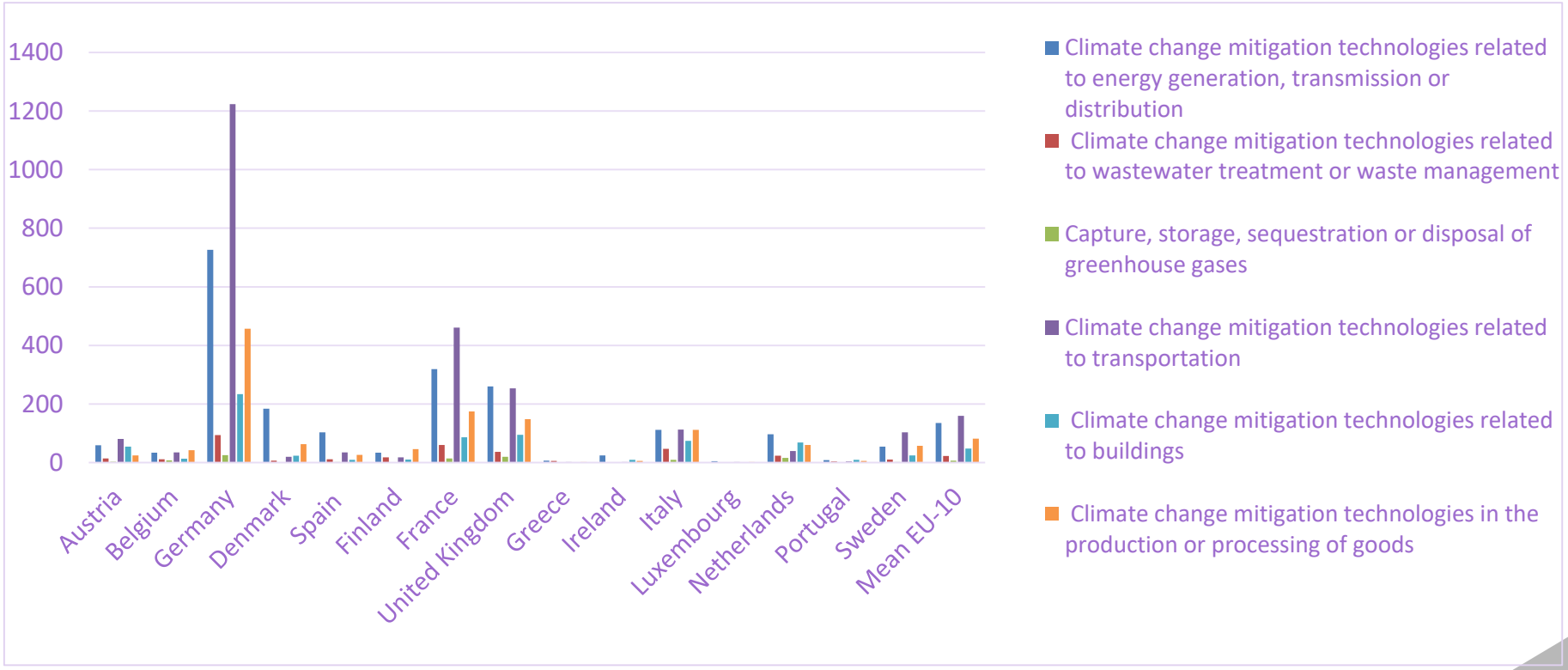


Source: Author's calculation, OECD data

Context: Stylized Fact

Increase in green patents

Types of Patents in « climate change mitigation » in 2015



Source: Author's calculation, OECD data

Questions

- Is there a co-integration relationship between CO_2 emissions and green patents?

- If so, what are the effects of green patents on CO_2 emissions in ST and LT ?

Context

- There are few empirical studies that analyze the effect of green technologies on CO_2 emissions (Cheng, Ren, Wang, & Yan, 2019).
  - **No consensus about the effects of green technologies**
    - Environmental innovations make a significant contribution to lowering CO2 emissions, especially in countries with a high level of income (Du et al., 2019)
    - No significant effect on reducing CO2 emissions in Italy (Weina et al., 2016)
    - Short-term rebound effect especially in the countries of the European Union (Font Vivanco et al., 2016; Herring & Sorrell, 2009; Sorrell, 2007)

- CO_2 emissions are usually explained by variables such as:
  - **international opening, rate of urbanization, GDP, technological innovation or the energy structure**
  - **However, these variables are not enough to understand the CO_2 emissions.**

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Aim

Analyse the effect of green technologies on CO_2 emissions at the European Union by using a Autoregressive Distributed Lag Model (ARDL)

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2. Methodology

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DATA

- ✓ With the exception of patent data*, all variables were extracted from the World Bank's Development Indicator Database.
- ✓ We use the annual data for the period 1990-2014 for the EU-15 countries
- ✓ Numerous studies on the determinants of CO_2 emissions
- ✓ The variables used in this study are carefully selected based on data availability and economic theory (Du et al., 2019; Su & Moaniba, 2017).

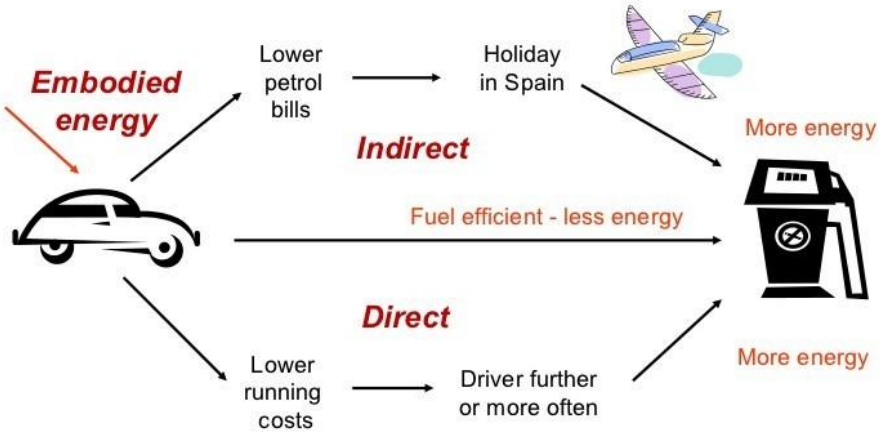
Variable	Definition
CO_2	CO_2 emissions (expressed in metric tons per capita) as a proxy for CO_2 emissions performance
INNOV	Patent data whose "selected technologies are related to the environment" -> OECD DATABASE
REC	Renewable energies (REC) and represents a composite variable of consumption of solar, hydroelectric, geothermal, biomass and wind energy in the total energy consumed.
GDP	Gross Domestic Product per capita (GDP) (US $)
OPEN	Measured as the sum between imports and exports as a % of GDP

Main hypothesis

The effect of environmental innovation depends on income level of countries and on the periodicity of impact

- ✓ **Long-term: green patents lead to lower CO_2 emissions**
- ✓ **In the short term: existence of a rebound effect**

Illustration of rebound effects



Empirical model and estimation procedure

The model takes the following form:

$$CO2 = f\ (\mathrm{INNOV}, \mathrm{REC}, \mathrm{GDP}, \mathrm{OPEN})\ \textbf{(1)}$$

The Eq. (1) can be rewritten in logarithmic form with a time series and panel form specification as follows:

$$LogCO2_{it} = \alpha_0 + \alpha_1 LogINNOV_{it} + \alpha_2 LogREC_{it} + \alpha_3 LogGDP_{it} + \alpha_4 LogOPEN_{it} + \varepsilon_{it}\ \textbf{(2)}$$

where the subscript i (i = 1, ..., N) denotes the country i in our sample, N being equal to 15. t (t = 1, ..., T) indicates the time period. Our panel has 15 countries and 25 years, so it has more years (T) than countries (N).

Pre-estimate : model choice

Table 1 : Unit root test

Variables	ADF		LLC		IPS	
	Level	First Diff.	Level	First Diff.	Level	First Diff.
Log CO_2	7,75	96,88***	4,93	-5,04***	5,33	-6,01***
LogINNOV	29,15	135,90***	-2,89***	-5,33***	0,28	-8,88***
LogREC	4,84	93,80***	5,20	-5,39***	7,74	-6,16***
LogOPEN	25,37	137,85***	-1,98**	-9,20***	1,03	-9,15***
LogGDP	22,97	90,61***	-4,24***	-6,12***	0,11	-5,87***

Notes : *** denotes significance at 1% level

The data are integrated in *I(0) or I(1).*

Table 1: Cointegration tests

Alternative hypothes is : common AR coefs. (within-dimension)

	Weighted			
	Statistic	Prob	Statistic	Prob
Panel v-Statistics	1,0242	0,1528	0,8068	0,2099
Panel rho-Statistics	-0,3632	0,3582	-1,2630	0,1033
Panel PP-Statistics	-4,1203***	0,0000	-5,4036***	0,0000
Panel ADF-Statistics	-1,6288**	0,0517	-1,2670	0,1026

Alternative hypothes is : individual AR coefs. (between-dimension)

	Statistic	Prob
Group rho-Statistics	0,2418	0,5956
Group PP-Statistics	-5,86470***	0.0000
Group ADF-Statistics	-0,7957	0.2131

Notes : *** denotes significance at 1% level

The results of the Pedroni's cointegration test confirm the existence of a cointegration relationship between the series under study

A panel ARDL model as proposed by (Pesaran & Smith, 1995) is more appropriate.

ARDL MODEL

The model estimated has a form of an ARDL (p, q, q…..q) model

$$\Delta LogCO2_{it} = \Phi_i \left(LogCO2_{i,t-1} - \beta'_i X_{i,t} \right) + \sum_{j=1}^{p-1} \alpha_{ij} \Delta LogCO2_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad \textbf{(3)}$$

Where :

- X is the vector of explanatory variables.
- Φ_i is the group-specific speed of adjustment coefficient (expected that $\Phi_i < 0$)
- β'_i are our vector of interest, which measures the long run impact of the explanatory variables on the CO_2 emissions.
- ECT = $[LogCO2_{i,t-1} - \beta'_i X_{i,t}]$ is the error correction term.
- α_{ij}, δ'_{ij} are the short run dynamic coefficients.
- p et q are optimal lag orders
- μ_i is the constant

Given the size of our sample, in our case the optimal model will be of the form ARDL (1, 1, 1, 1, 1)

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3. Empirical findings

The results of the ARDL model

➢ PMG estimator (Pesaran, Shin, & Smith, 1999)

Panel ARDL long-Run PMG estimation

Long-term equation			
Variables	Coefficient	t-Statistics	P-value
LogINNOV	-0,1242***	-5,8389	0,000
LogREC	-0,1326***	-12,89009	0,000
LogOPEN	0,2337***	9,9719	0,000
LogGDP	0,144***	2,61	0,009

Level of significance *** p<0.01, ** p<0.05, * p<0.1 and dependent variable D(log CO2)

Long term effect

- Environmental innovation (LogINNOV) and Renewable Energy Consumption (LogREC) has a significant and negative effect on CO_2 emissions : a 1% increase in green technologies contributes to a 0.12% decrease in CO_2 emissions
  - ✓ The result of (LogINNOV) is consistent with the findings of (Du et al., 2019) performed on a sample of 71 countries.
  - ✓ The result of (LogREC) is consistent with those of (Gozgor, 2018a) for the case of the United States and (Cerdeira Bento & Moutinho, 2016) for the case of Italy.

- International openness (LogOPEN) and GDP per capita (LogGDP) show significant and positive effects on CO2 emissions
  - ✓ The result of (LogOPEN) is in line with those of (Aklin, 2016; Ang, 2009; Dean, 2002; R. Kozul-Wright, 2012), which demonstrate that increased trade openness increases CO2 emissions. This result could be explained by the effect of scale and structure.
  - ✓ The result of GDP appears to be consistent with the theoretical analyzes of (Boyce, 1994; Magnani, 2000; Wilkinson & Pickett, 2010), which recognize that income inequality negatively affects the environment.

The results of the ARDL model

- PMG estimator (Pesaran, Shin, & Smith, 1999)

Panel ARDL Short-Run PMG estimation

Short-term equation			
Variables	Coefficient	t-Statistics	P-value
ECT	-0,3375***	-2,9126	0,0039
DLogINNOV	0,0395**	2,5104	0,0126
DLogREC	-0,2904***	-2,806	0,0054
DLogOPEN	0,0557	0,9804	0,3277
DLogGDP	0,5107***	2,7863	0,0057
Constant	0,221**	2,17	0,0304

Level of significance *** p<0.01, ** p<0.05, * p<0.1 and dependent variable D(log CO2)

Short term

- Environmental innovation (LogINNOV) has a significant and positif effect on CO2 emissions. In other words, in the short term, environmental innovation tends to increase CO2 emissions in the EU-15 countries.

Our main hypothesis is validated, and we can talk about rebound effect in the short term.

- Renewable Energy Consumption (LogREC) tends to reduce CO2 emissions
- International openness (LogOPEN) and GDP per capita (LogGDP) show significant and positive effects on CO2 emissions

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4. Conclusion and policy implication

Conclusion

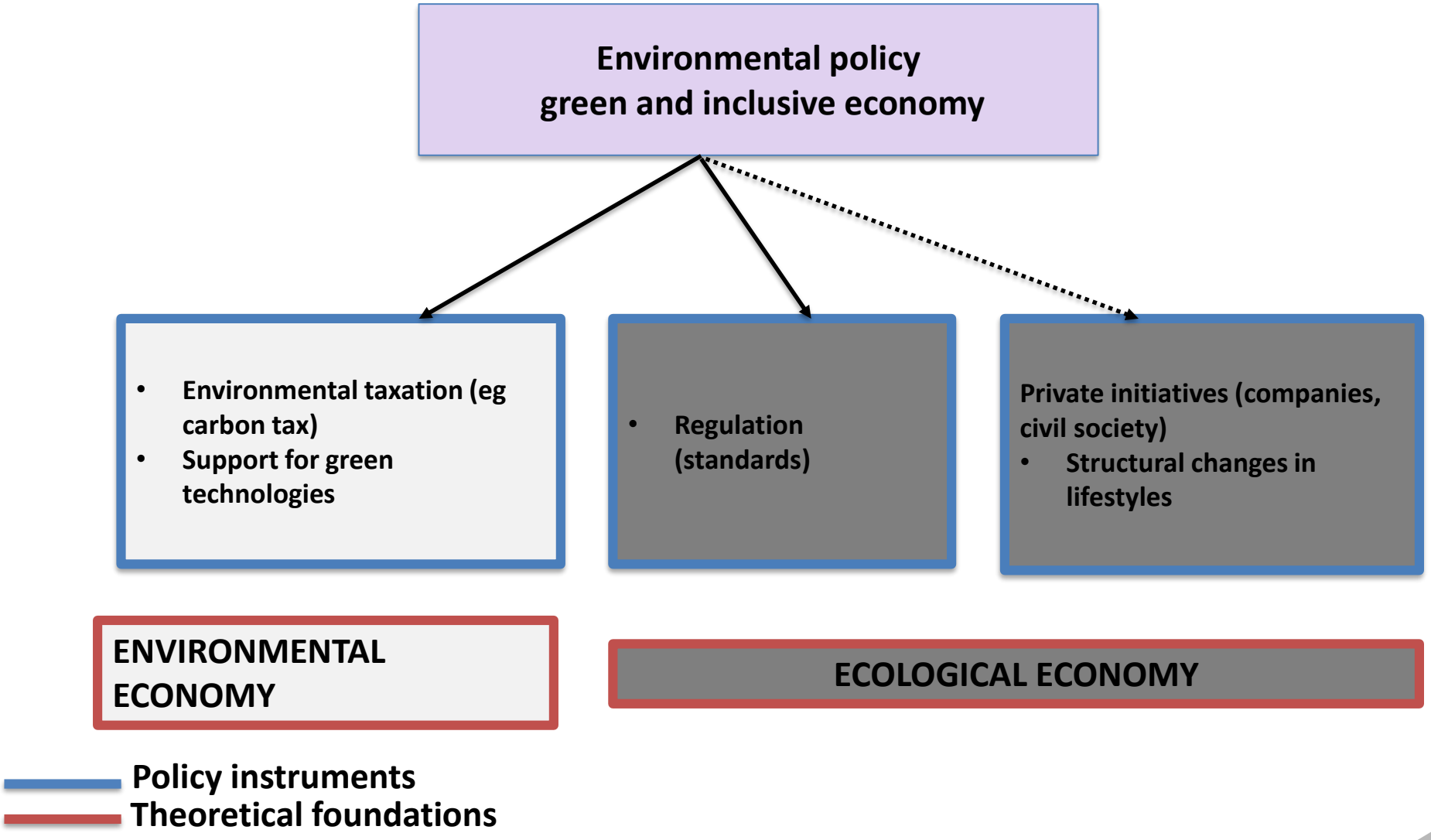
Our mains results over the period 1990-2014 show that:

1. **In the long term, environmental innovation tends to lower CO2 emissions whereas in the short term the observed effect is opposite, suggesting the existence of a rebound effect.**
2. **The renewable energy consumption (long-term and short-term) tends to lower CO2 emissions in Europe.**
3. **International openness (LogOPEN) and GDP per capita (LogGDP) have significant and positive effects on CO2 emissions.**

The limits of our results

1. **Country specificity analysis should be done at ST to better qualify the impact dynamics across countries**
2. **The rebound effect is not enough to explain the negative impact of green patents on ST. The specificity of energy / country policies can also be a cause of this effect.**

Policy implication



Source: author based on Abdelmaki and Mundler, 2010

Thank you for your attention

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