Inducement effects in eco-innovation dynamics: the role of public policy design

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Knowledge dynamics, industry evolution, economic development, 5-11 July 2015, Nice

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- Eco-innovation

Public policies

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- The role of innovation policies
- Job effects, skills and the role of labour policies

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  - An example of radical vs. incremental innovation analysis
- Policy mix
  - The case of energy efficiency technologies in the residential sector
  - Policy mix design measurement
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Green Economy

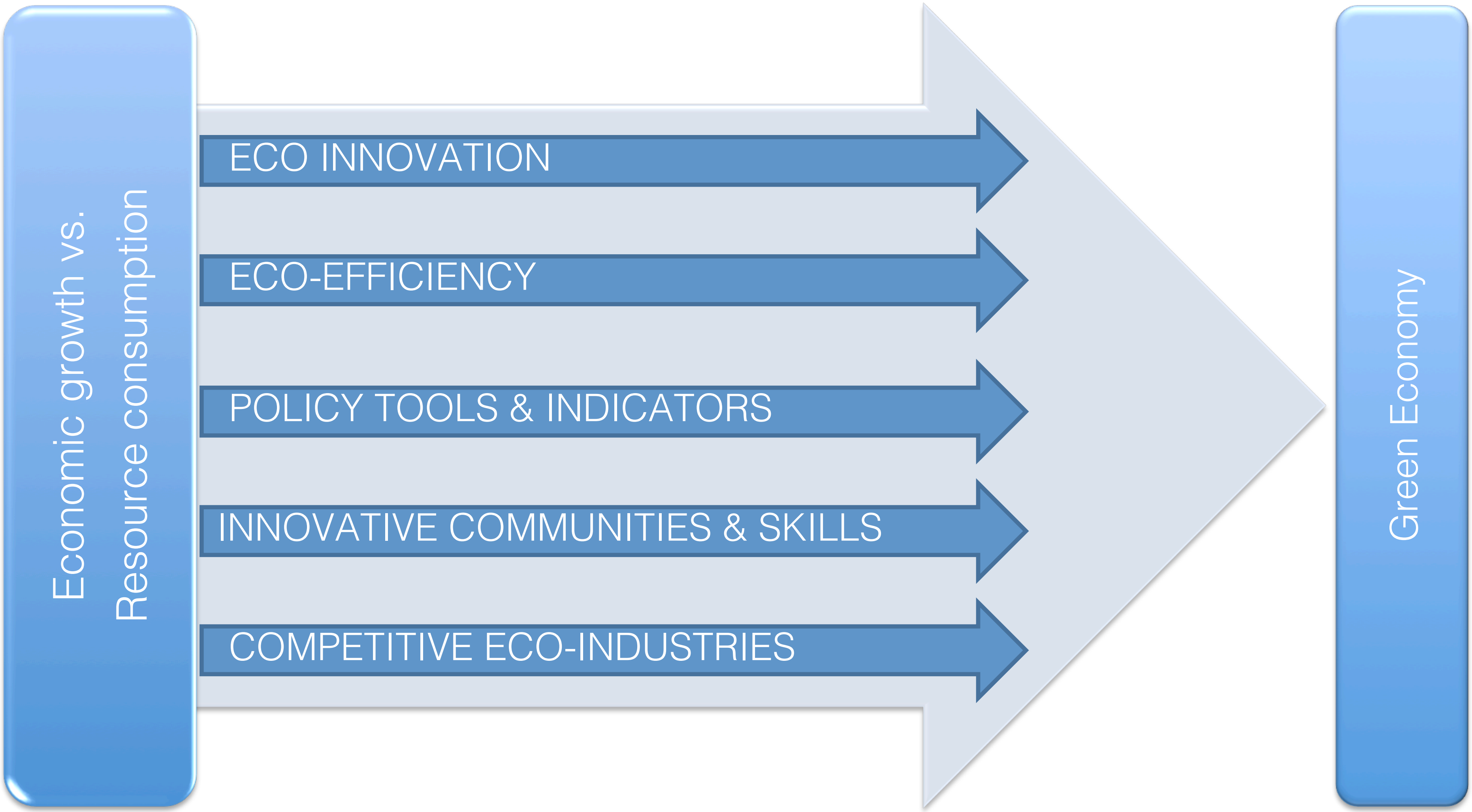
According to the UNEP definition, a green economy is

“one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is **low carbon, resource efficient and socially inclusive**”.

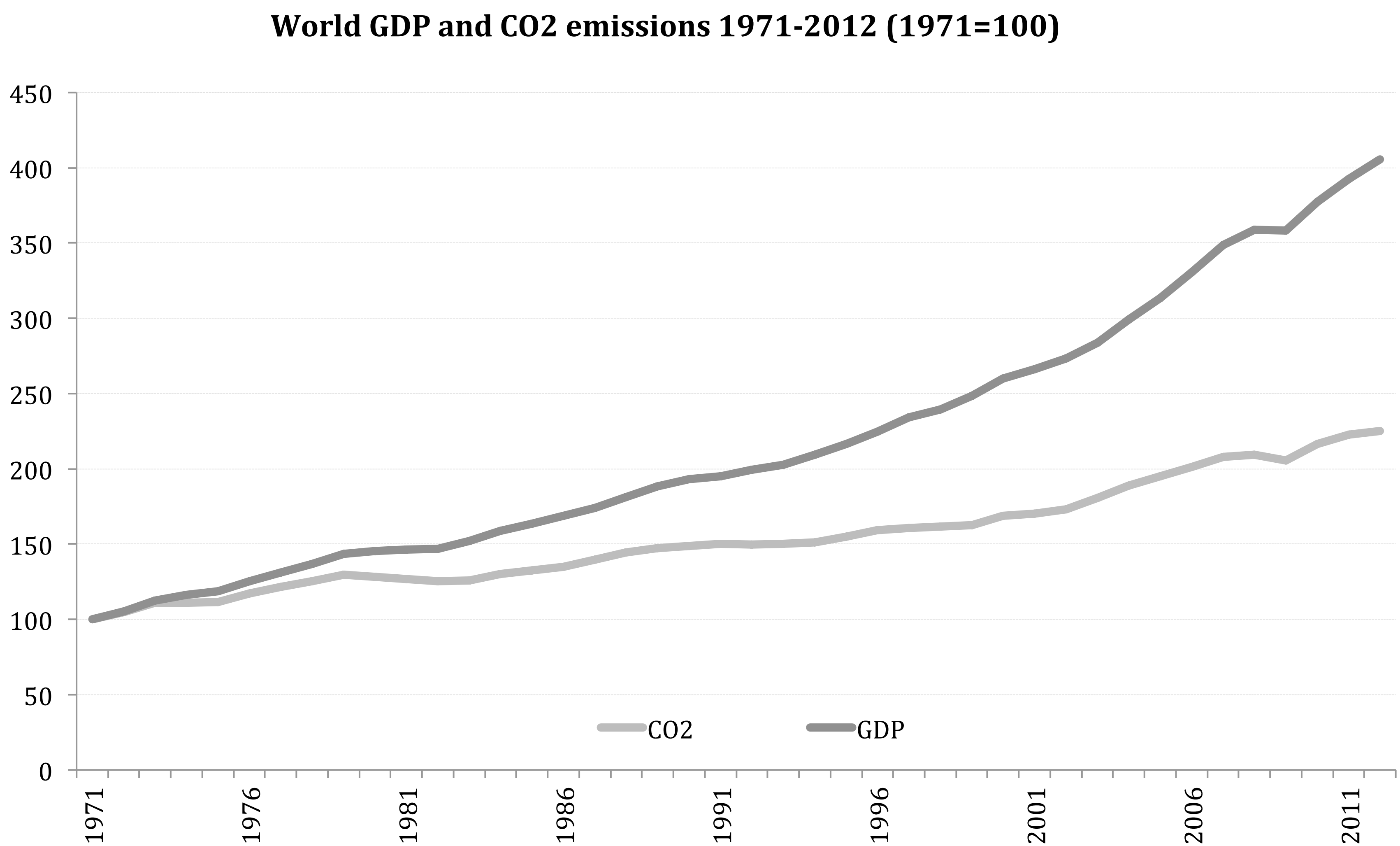
In an operational view, a green economy is

“one whose growth in income and employment is driven by **public and private investments that reduce carbon emissions and pollution**, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services. These **investments need to be catalyzed and supported by targeted public expenditure, policy reforms and regulation changes**”.

Green Economy

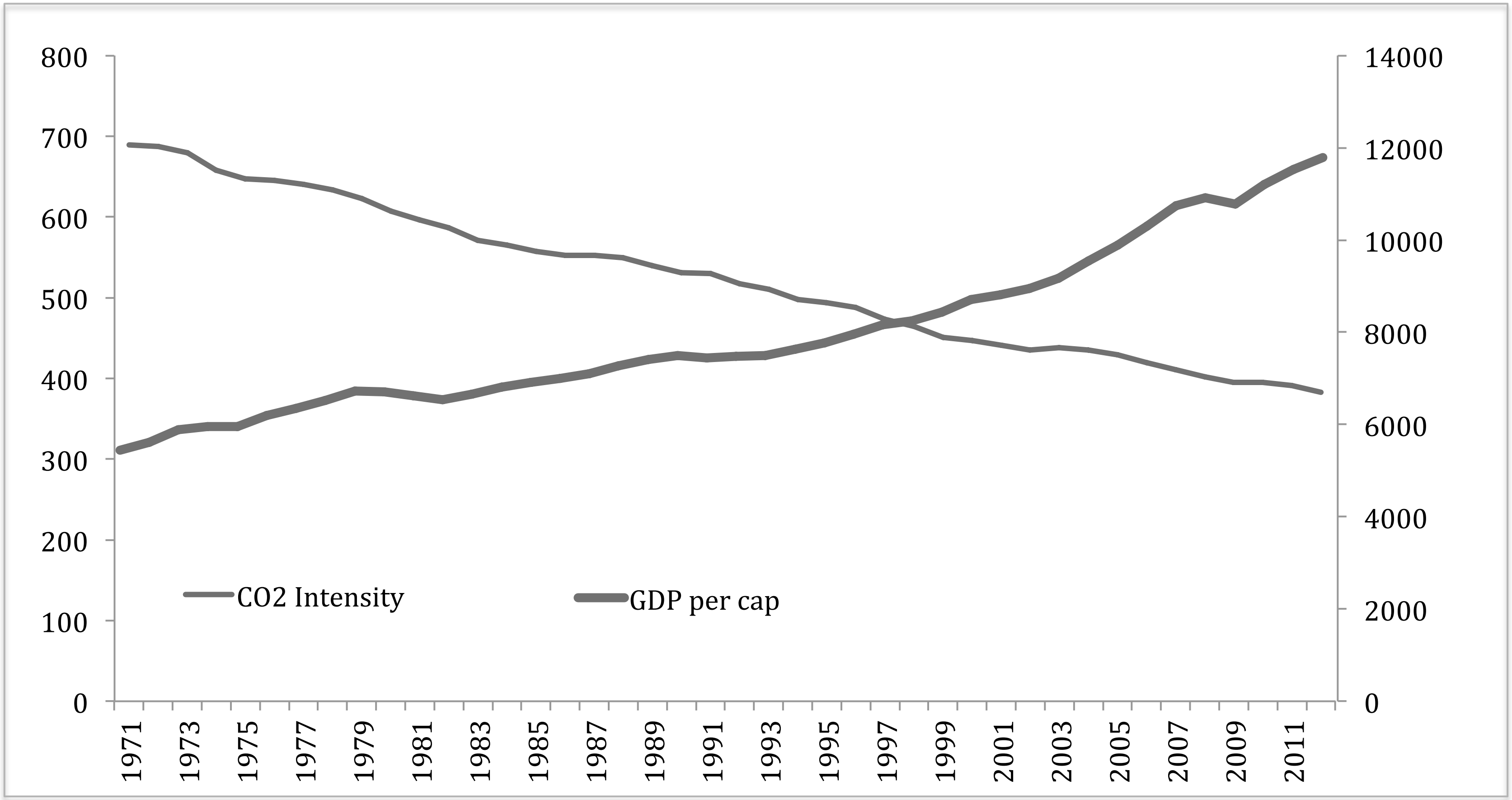


Background evidence



Background evidence

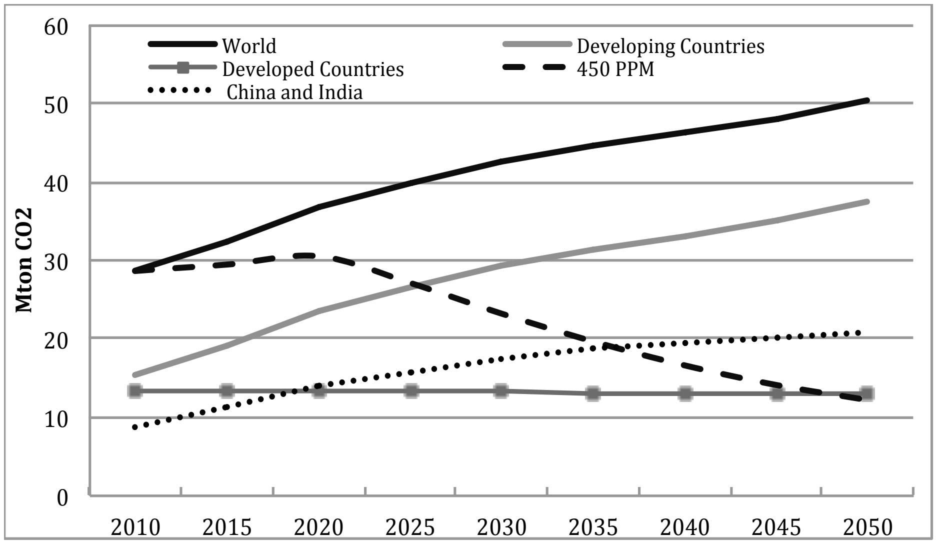
A clear decoupling effect emerged after year 2000, with increasing GDP per capita associated with a continuous reduction in CO2 intensity.

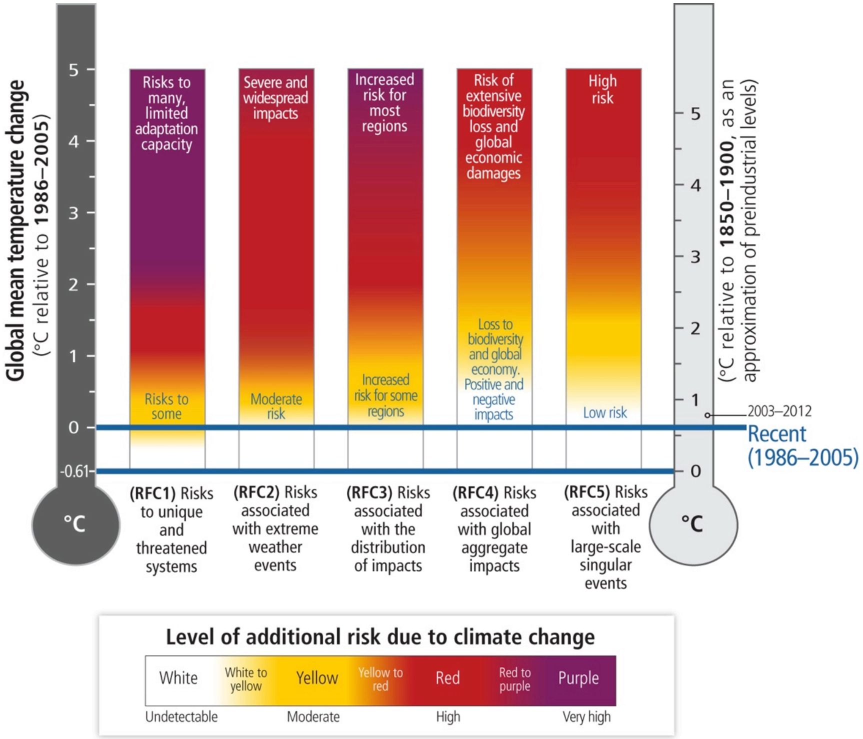


Background evidence

- Nonetheless, the projected economic growth patterns in emerging economies and developing countries are associated with increasing CO_2 emissions.
- According to the 5th IPCC Report, by 2050 the GHG emission levels might produce an increase in global temperature by 4-5° C, with a large risk of climate disasters.

CO_2 emissions projections 2010-2050





Global challenges

- Unsustainable use of natural resources
  - UN Millennium Assessment (2005): two thirds of necessary ecosystem services are in decline
  - Sustainable Development Goals (SGDs) as the future strategy for developing countries: environmental protection as a core action

- Climate change
  - Severe consequences and financial costs of inaction (Stern Report, 2006) – solutions exist

- Energy poverty
  - Access to electricity for rural areas and urban shanty towns as a means for achieving better life standards

- Water scarcity and poor quality
  - More than 1 billion people use unsafe sources of drinking; 2.6 billion do not have basic sanitation

Eco-innovation: definition

- Environmental technologies
  - All technologies preventing or treating pollution, managing resources or using them more cost-efficiently

- Eco-innovation
  - All forms of innovation (new products and services, production processes, business methods) benefiting to the environment

- Three broad categories of green technologies
  - **Energy efficiency** - energy conservation in buildings; fuel efficient vehicles; public transport and rail; improving electrical grid transmission
  - **Renewable energy** - geothermal, hydro, wind and solar, nuclear power, and carbon capture and sequestration
  - **Water, waste and pollution control** –water, waste and pollution management and control, including water conservation, treatment and supply

Eco-innovation: definition according to MEI project

	Indicator	Actual/Potential Data Source
	The Firm	
1	R&D expenditures for environmental protection in industry.	STATCAN currently collects this information
2	% of firms with EMAS or ISO14001	Numbers collected by German Federal Environmental Agency
3	% of firms with environmental mission statements and/or officers	Would need to survey for this.
4	Managers opinion of eco-innovation	Possibly for inclusion in CIS
	The Conditions	
5	'Green Tax' as a percentage of government budget	OECD data
6	Government expenditures on environmental R&D as: • % of total R&D expenditure • % of GDP	GBAORD data
7	Uptake of environmental subsidies for eco-innovative activity	Government data
8	Financial support for eco-innovation from public programmes	OECD data
9	Demand for eco-innovative products.	Measure demand using survey techniques.
10	Environmental expenditure in college/university research	National Science Foundation collect this for US. EU source unknown
11	Number of environmental graduates, MScs or PhDs	EIS & IRCE report
12	Waste management costs (landfill tariff, etc.)	Government data
13	Executive opinion on environmental regulation (Stringency and transparency).	For possible inclusion in CIS
14	Attitudes towards eco-innovation	Eurobarometer data

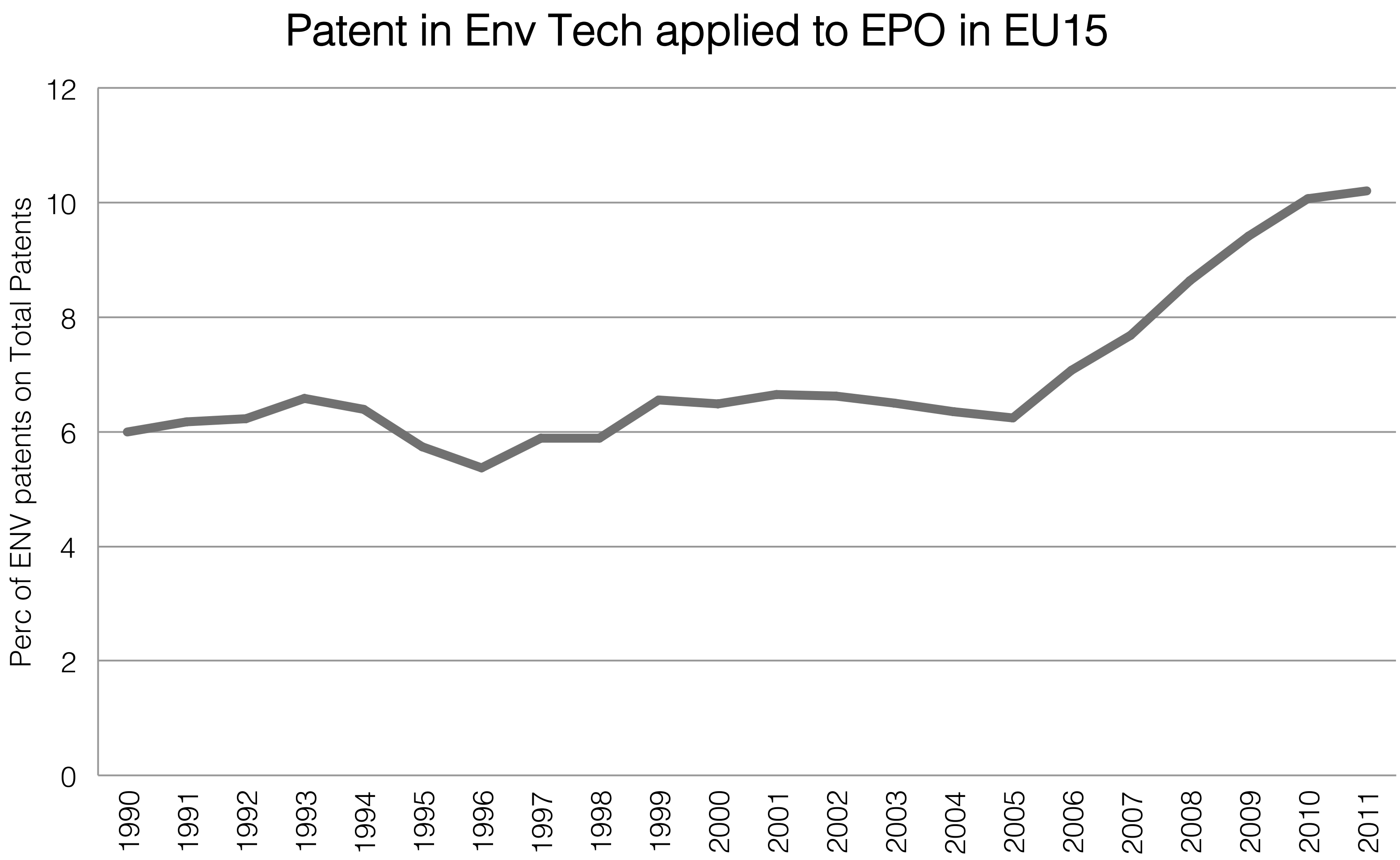
Eco-innovation: definition according to MEI project

	Overall performance indicators	
22	Eco-patents in triadic patent families per million population	US EU and Japan Patent offices
23	Material productivity of eco innovative firms (TMR per capita or GDP)	IRCE report
24	Share of eco-innovative firms as a percentage of all firms (may need to divide into manufacturing and services)	CIS. May need to be reanalysed.

Eco-innovation: the EU evidence

- Majority of EU companies do not eco-innovate
- Great majority of eco-innovators declare only incremental material efficiency improvements
- Strong eco-innovation performance does not automatically result in better environmental performance on the macro scale
- There is a high diversity of eco-innovation performance in the EU, both between countries and sectors
- There is an increased share of RD efforts invested by public institutions in environmental-friendly technologies
- There is an increased patenting activity by private firms in environmental technologies

Eco-innovation: the EU evidence

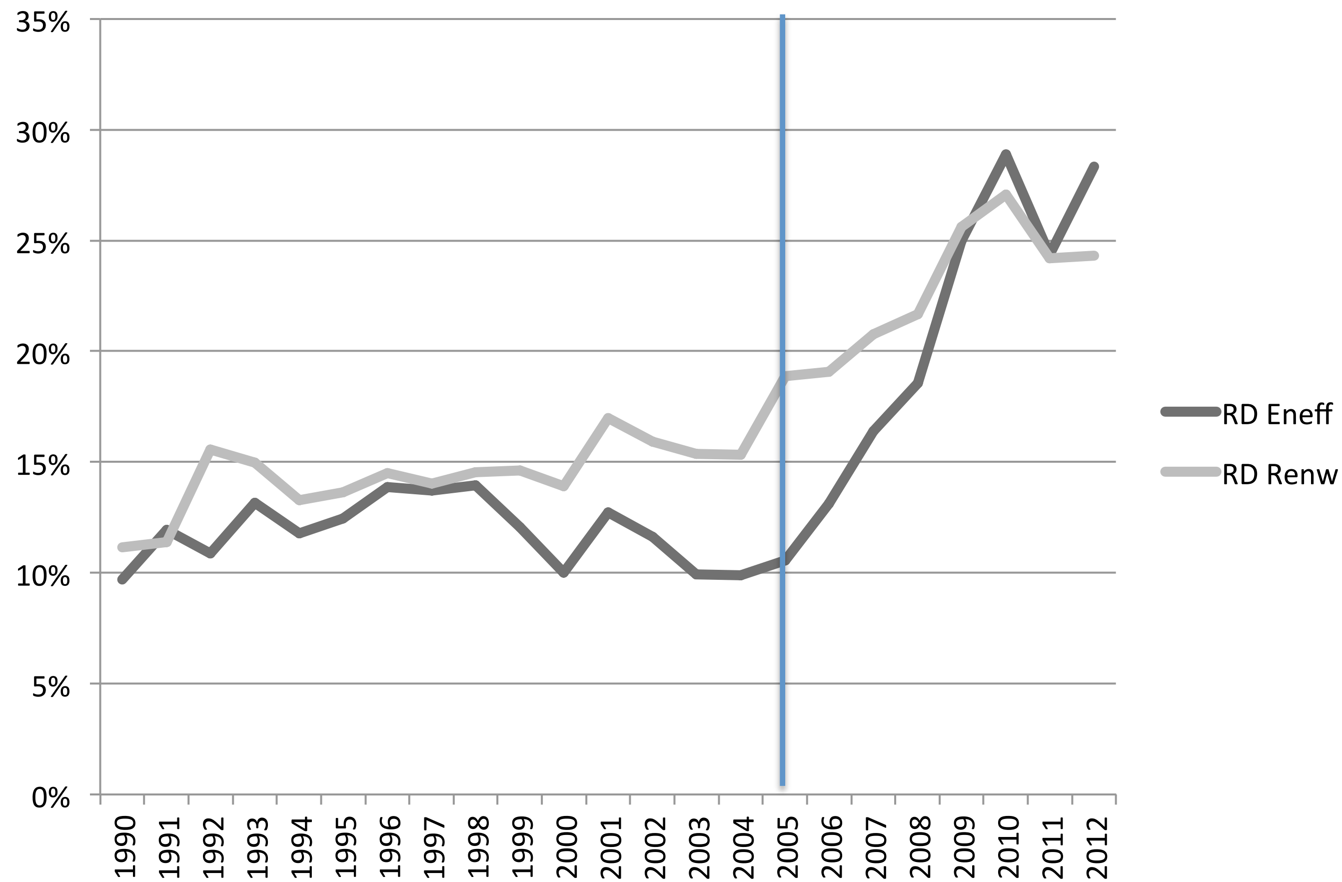


Eco-innovation: the EU policy context

- Goteborg Summit on Sustainable Development
  - Environmental technologies are a win-win solution for the environment and the economy (2001)
- Review of the Sustainable Development Strategy (2005)
  - EU to work with Member States to promote eco-innovation and to expand the market for eco-technologies
- Lisbon Strategy for growth and jobs
  - Knowledge and innovation for growth: Facilitate innovation, the uptake of ICT and the sustainable use of resources
- Communication 'Putting knowledge into practice' (2006) calls for lead markets in eco-innovation
- EU 2020 Strategy for low carbon emissions and clean energy technologies (2010)
- EU2030 climate strategy (2014)

Eco-innovation: the EU policy context

Share of public RD expenditure in Energy efficiency and Renewable energy w.r.t. to total public RD expenditure in the Energy sector (EU15 1990-2012)



Eco-innovation: the EU policy rationale

- Environment is both a constraint and source of opportunities
  - If not addressed, global challenges will act as a break on future growth and hinder prosperity
- Eco-innovation can contribute to economic growth while reducing its impact on the environment
  - New markets and business opportunities
- Climate change and resources management as innovation drivers: energy efficiency in building, hybrid cars, renewables
  - Eco-industries should be encouraged
- Clean technologies attract 10% of risk capital in Europe

Eco-innovation: Horizon 2020

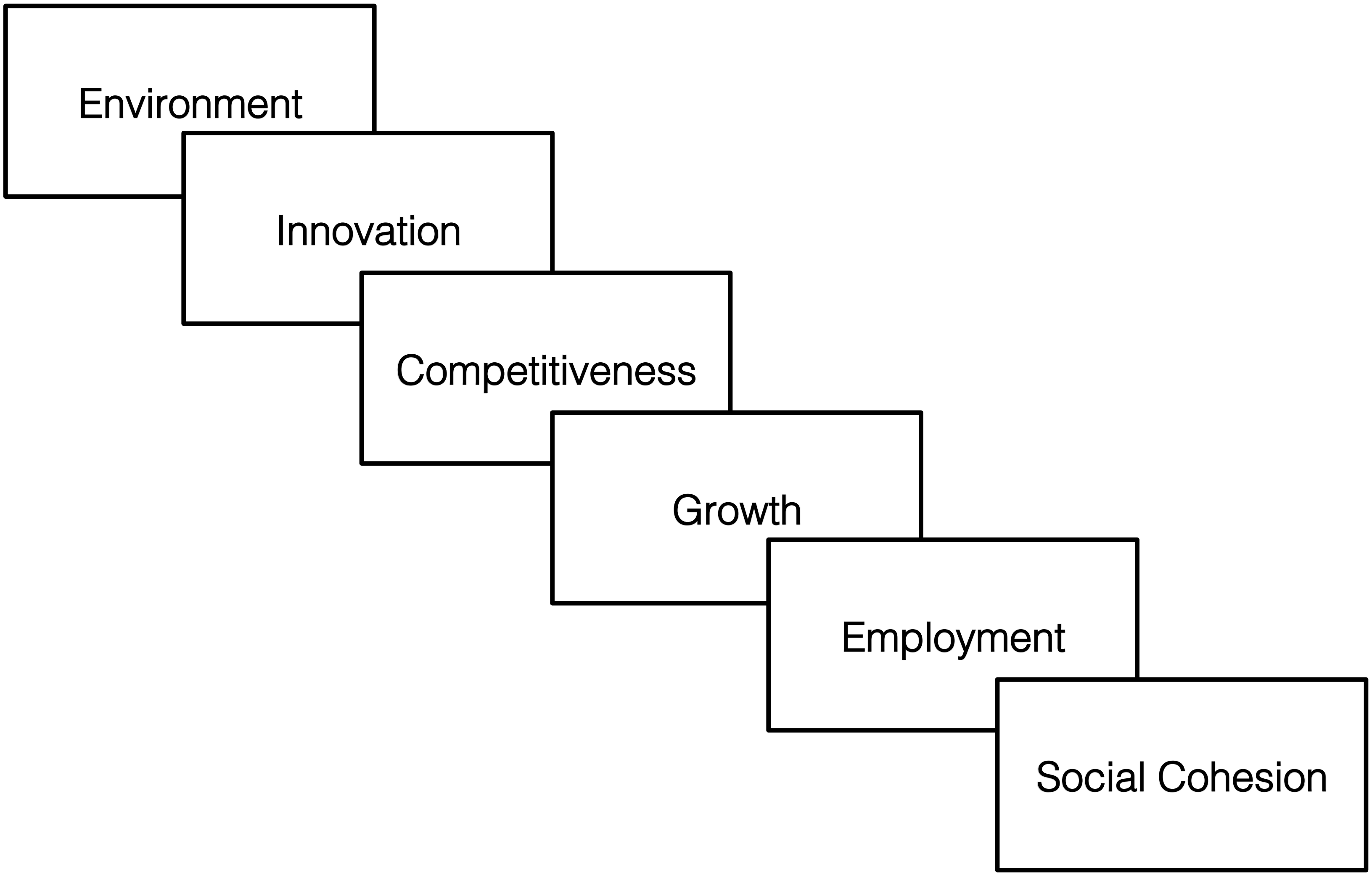
- The course for the EU economy for next 10 years and beyond and aims to support the transition towards a resource-efficient, low carbon economy
- Three thematic **priorities:**
  - **Smart growth:** developing an economy based on knowledge and innovation
  - **Sustainable growth:** promoting a more efficient, greener and more competitive economy
  - **Inclusive growth:** fostering a high-employment economy delivering social and territorial cohesion

- Environmental considerations integrated into economic policy
- **7 flagship initiatives: Innovation Union**, Youth on the move, A Digital Agenda for Europe, **Resource efficient Europe**, **An industrial policy for the globalization era**, **An Agenda for new skills and jobs**, European Platform against Poverty

Eco-innovation: the EU policy process

- Eco-innovation: Necessary contribution to achieve smart, sustainable and inclusive growth
- "Innovation Union": Addressing growing societal challenges like scarcity of resources, climate change, aging, etc through innovation
- "A resource efficient Europe": integrating resource efficiency and eco-innovation in the strategic initiatives of the EU ranging from energy, transport, construction, cohesion policy, agriculture, to climate change, water, biodiversity, as well as in the Multiannual Financial Framework and taxation
- "Industrial policy for a globalised era": identify development and deployment requirements for key environmental technologies, enhance coordination and cooperation in developing and deploying these technologies

Eco-innovation: the policy complexity



The policy complexity: market and system failures

- Market failures may limit the solution of environmental problems through new environmental technologies (Nelson, 1959; Arrow, 1962; Baumol and Oates, 1988).

- In a systemic setting, governments have to deal not only with ‘market failures’, but most importantly with ‘system failures’ (Metcalfe, 1995), namely with problems related to the interactive behaviour of agents operating in the system and the institutions designed for its governance (Edquist, 1997; Metcalfe, 2005).

- An inadequate understanding of policy complexity may erroneously lead to see policy co-ordination as the unproblematic outcome of a superior governance system, implicitly assuming a single level of governance managed by a fully rational policy maker (Flanagan et al., 2011; Kallis and van den Bergh, 2013)

- The analysis of interactions and trade-offs between policy instruments and their impacts on the ultimate policy objectives is crucial for fruitfully develop and operationalize the concepts of policy mix and policy coordination.

The policy complexity: potential negative interactions

The case of energy sector

- In the energy sector, there is a strong need for regulatory strategies to force technological regime shifts
- Coexistence of several different public policies that aim to escape the carbon lock-in
- In the absence of strong coordination between different public policies implemented in the energy sector, contrasting forces and impacts can negatively affect the final outcome of the adopted policy mix
  - Policies that target renewables may not be helpful for the achievement of objectives in terms of increasing energy efficiency
  - Instruments other than the Emission Trading Scheme (ETS) have been found to frequently negatively interact with ETS as they are not aligned to it (Borghesi, 2011)

The policy complexity: potential negative interactions

The case of the employment effects of eco-innovation

- The transition to the low-carbon economy is expected to impact the quantity and the quality of employment
- However, the employment impact of flows of environmental innovations induced by policy actions is far to be clear(Fankhauser et al., 2008) (Horbach, 2010; Gagliardi et al., 2014)
  - Firm-level studies *vs* sectoral level studies (Pianta 2001, 2005)
  - Process vs product innovation (Horbach and Rennings, 2012)

- Dedicated skills are needed for green transition:
  - Potential skill bias and wage polarisation effects (Chennells and Van Reenen, 2002; Acemoglu, 2002; Pianta, 2005; Croci Angelini et al., 2009)
  - The speeding up of transition processes may contrast with important social challenges such as reducing inequalities and promoting inclusive growth

Environmental, innovation and labour policy domains

Macro categories	Simple categories	Differentiated categories
Environmental domain	Market/price-based Regulation/command-and-control Soft instruments	• Environmental taxes or subsidies, cap and trade systems • Environmental Standards • Information & education • Voluntary approaches
Innovation domain	Supply-side measures/ technology push Demand-side measures/ demand pull	• Financial support • Stimulation of cooperation and networks • Provision of public goods • Provision of property rights • Public procurement • Diffusion policies
Labour domain	Supply side measures Demand side measures/macro and sectoral	• Labour market reforms • Education and training policies • Tax incentives • Aggregate demand stimuli • Public procurement • Sectoral incentives, niche strategies

Policy implications

- Need to take into account the complexity associated with the design of an appropriate policy mix and the inherent difficulties related to coordination activities aiming at reaching a satisfactory level of policy coherence

- Interactions between agents, institutions and policies shape system performances

- Importance of activating learning and adaptive mechanisms involving private agents, stakeholders, policy makers and scholars interested and involved in the transition process

Demand-pull and technology-push policies

The biofuels case

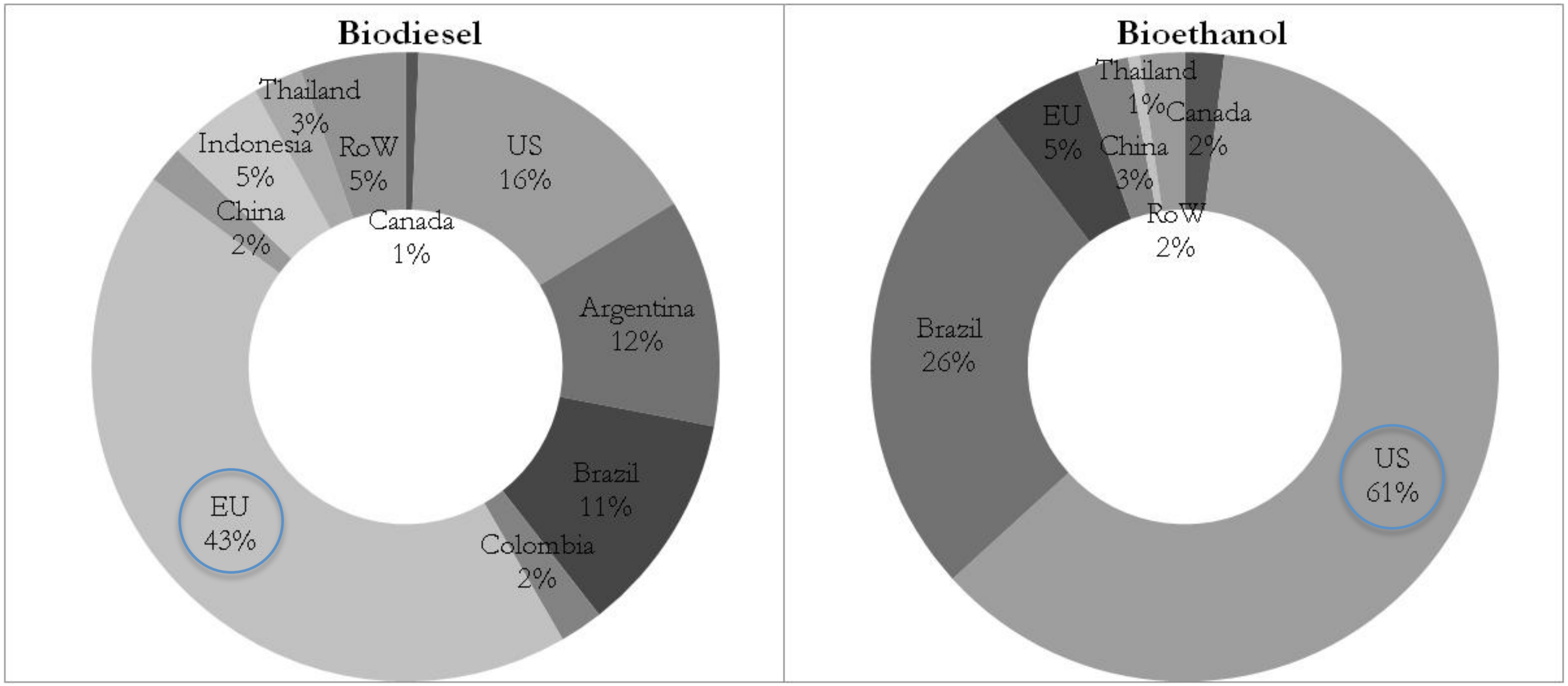
Application 1: Stylized facts

- Although in 2010 total emissions in the EU were 10% smaller than the 1990 level, transport emissions were 20% higher (EEA, 2012)
- 94% of transport emissions were related to road transport
- In recent years, a dramatic increase in oil prices volatility is observable

- The global production of biofuels was in 2011 more than 6 times the value in 2000 (IEA, 2012), with the United States (US) being the major producer (44%), followed by Brazil (27%) and the EU (18%)
- Three controversial aspects
  - real competitiveness and policy pervasiveness
  - conflict between energy and food production
  - transition towards new technological domains (next generations biofuels)

Application 1: Stylized facts

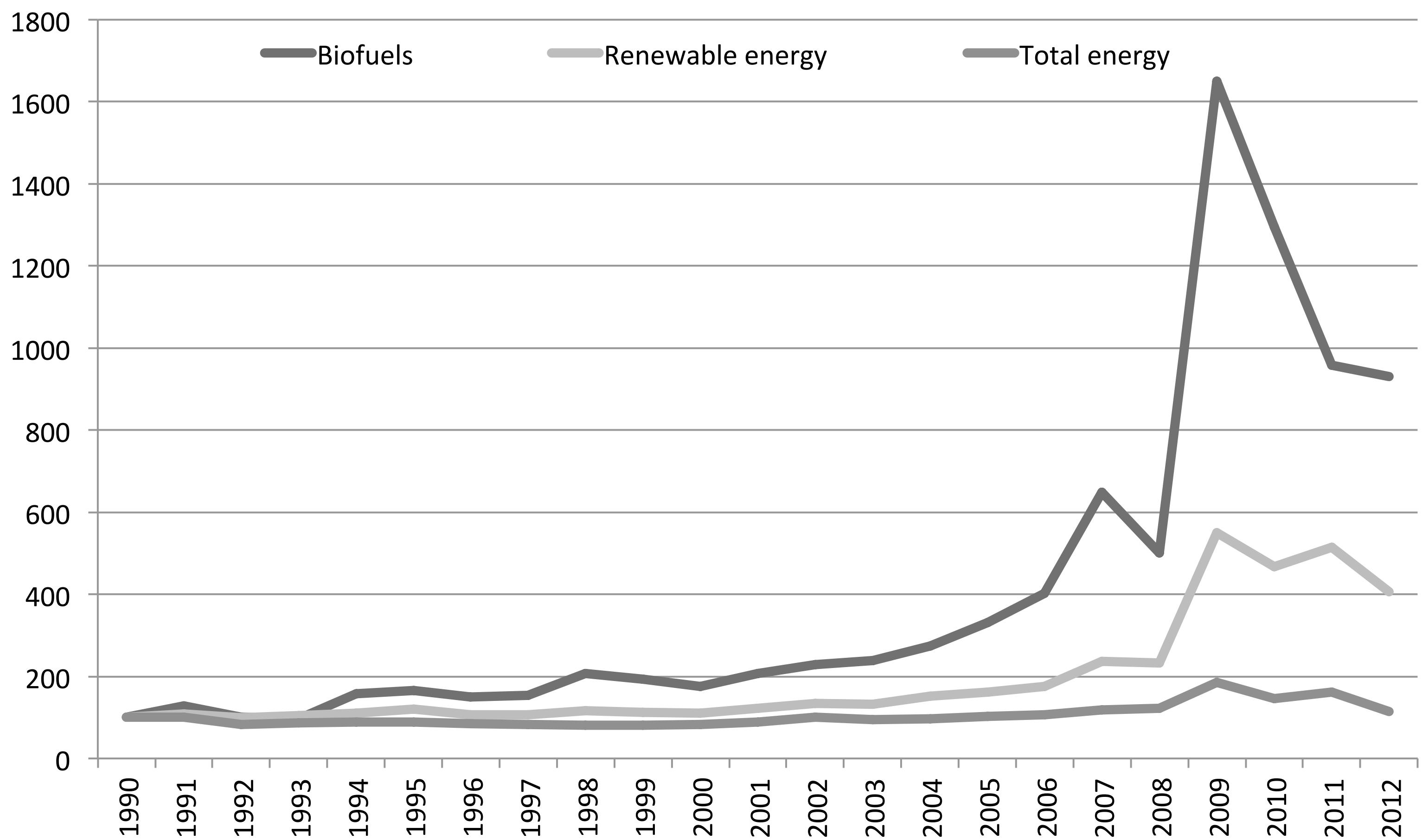
Biodiesel and bioethanol production distribution (2011)



Source: own elaboration on BP (2012) and EIA-DOE (2013)

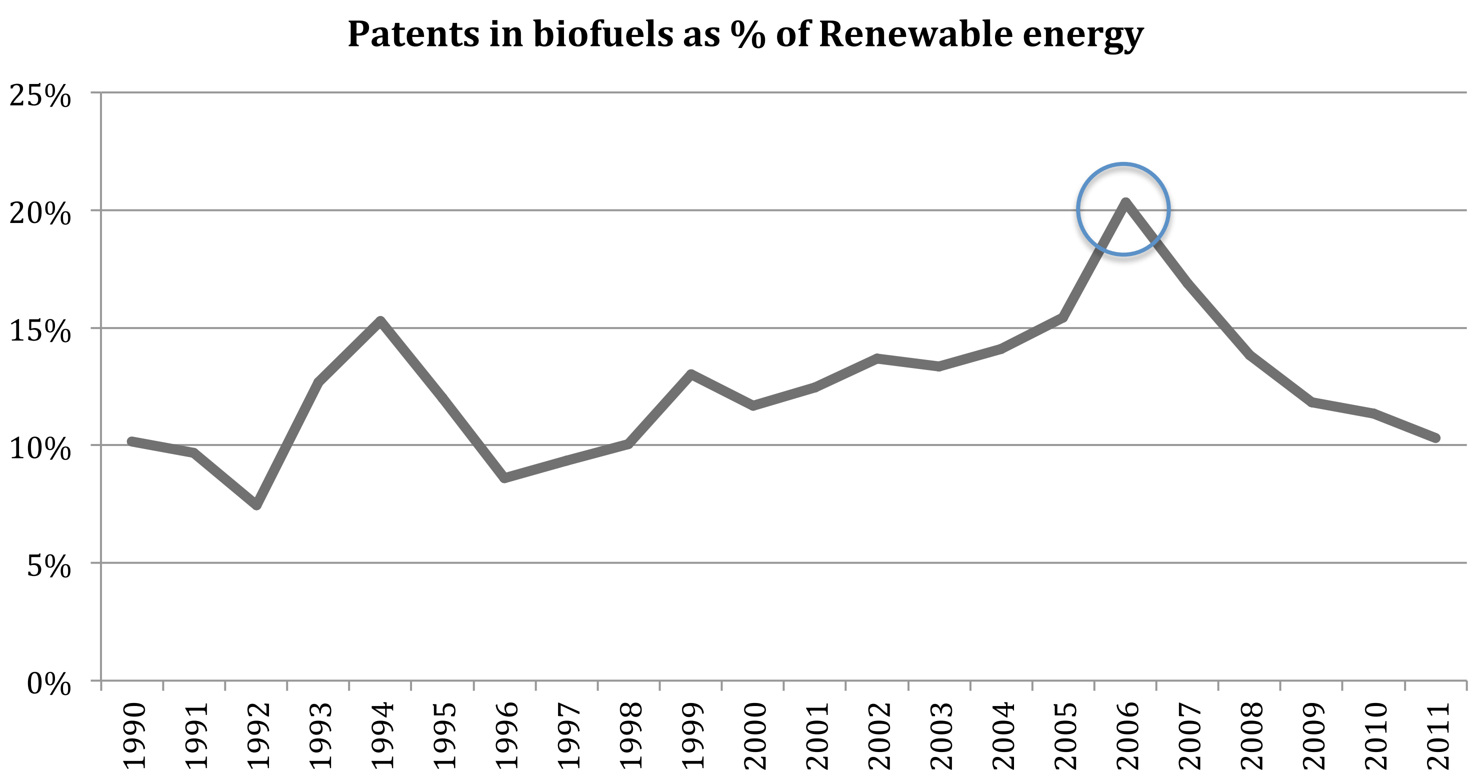
Application 1: Stylized facts

Public R&D expenditures – selected energy sectors, index number 1990=100 (OECD, 1990-2012)



Application 1: Stylized facts

Biofuels patents application – % of total renewables (OECD, 1990-2011)



Source: our elab. on OECD Stat data

Application 1: Background

Demand-pull and technology-push policy instruments

- Relevant environmental policy instruments are conventionally classified in the two broad categories of demand-pull and technology-push instruments (e.g. Horbach et al., 2012; Peters et al., 2012; Rennings, 2000)

- Both kinds of instruments have been found to be relevant in spurring innovation in environmental technologies

- Differentiated impact of these instruments on the diverse types of innovative activities
  - incremental or radical innovations (Nemet, 2009)
  - technological exploitation or exploration (Hoppmann et al., 2013)

Application 1: Background

Policy impact: demand-pull policies

- Importance of understanding the mechanisms linking public policies and innovation incentives in order to inform policy makers on the possible consequences of adopting alternative policy mixes in terms of the balance between demand-pull or technology-push forces

- Demand-pull policies may not be suited to stimulate non-incremental innovations

- The prevalent use of deployment policies, may reduce firms' exploration activities and favour technological exploitation of mature technologies, (eg. renewable energies for power generation)

Application 1: Background

Demand-pull: quantity based vs. price-based instruments

- Within policy instruments designed to enlarge the markets for new environmental technologies, it is possible to distinguish between
- quantity-based (such as quotas and targets) and
- price-based support policies (such as feed in tariffs and tax exemptions)

  - Quantity-based instruments produce declining innovation incentives when the standards tend to become non-binding
  - Price-based policies allow producer's surplus to increase with technical progress (Jaffe et al., 1995; Menanteau et al., 2003). They provide a permanent incentive to introduce innovations

Application 1: Background

Policy impact: technology-push

- On the supply-technology side, the role of public policy in shaping the pace of innovation in environmental technologies is also important (Costantini and Crespi, 2013)

- Technology-push policies are better suited to spur technology exploration activities

- Advanced generation biofuels originate from science-based technologies and require technological exploration activities, technology-push instruments are of crucial importance for their development (Hoekman, 2009; Panoutsou et al., 2013)

- However, a pure R&D-driven strategy can be ineffective in the absence of market formation activities as it forms a critical barrier to the development of advanced generation technologies (Hekkert et al., 2007; Suurs and Hekkert, 2009a,b)

Application 1: Background

Technology-push: quantity based vs. price-based instruments

- Price-based tools might be more effective in supporting innovation in energy technologies whose cost is not close to traditional energy technologies, by offering a longer-term perspective that may favour explorative activities (Finon and Menanteau, 2003; Johnstone et al., 2010; Schmidt et al., 2012)

- Quantity-based policies are suited for enhancing the development of biofuel-related technologies that are closer to being competitive with traditional energy sources

Application 1: Research strategy - hypotheses

- HP1: Demand-pull and technology-push policies are relevant drivers of eco-innovation
- HP2: Price-based instruments display a greater impact on innovation activities than quantity-based instruments
- HP3: In mature technologies demand-pull policies have a greater impact on innovation dynamics than technology-push instruments
- HP4: In less mature technologies innovation is spurred by both demand-pull and technology-push instruments
- HP5: In less mature technologies price-based instruments are more effective in fostering innovation activities than quantity-based instruments

Application 1: Research strategy – innovation measure

- The complex technological biofuels domain is analysed by using patents as an innovation measure
- The sector-specific patent database BioPat is used (Costantini et al., 2012, 2015)
- The main advantage of BioPat is that it is based on a co-word analysis, carried out after selecting several keywords validated with the help of research experts in the biofuels sector
- Patents included in BioPat have been used in order to calculate patent counts, allowing to identify all biofuels-related applications
- Policies related to biofuels sector have been mapped

Application 1: Research strategy - econometrics

- Many empirical contributions estimate the drivers of eco-innovation using patent count data as dependant variable

- Count variables (nonnegative integer values) should be dealt with econometric models like the Poisson Regression Model (PRM) and Negative Binomial Regression Model (NBRM)

- Our dependent variables are strongly overdispersed (variance greater than the mean) and have the 25% of zeros

- The PRM may be biased by an excess in zeros and an overdispersion problem

- The NBRM is used since it addresses the failure of the PRM by introducing unobserved heterogeneity across the Poisson means

- Robustness for endogeneity using GMM

Application 1: Research strategy - model

$$Y_{i,t} = \alpha_i + \beta_o + \beta_1(InnSys_{i,t-p}) + \beta_2(EnvSys_{i,t-p}) + \beta_3(BiofPol_{i,t-p}) + \beta_4(EneSys_{i,t-p}) + \beta_5(Controls_{i,t-p}) + \varepsilon_{i,t}$$

where i=1,…,35 indexes country

t=1990,…,2008 indexes time

αi are country fixed effects

The dependent variable is given by the **number of patents in each year for each single country**

Three different typologies of explanatory variables are used: total biofuels patents, advanced generation biofuels, first generation biofuels

Application 1: Research strategy – dataset 1

Variable name	Definition	Source
	Dependent variables	
Patent count BioPat	Patent count selected by keywords or technological domain in BioPat	EPO via Thompson Innovation
	Regressors	
GERD % GDP	Gross domestic expenditure on R&D as % of GDP	OECD (2012)
Total patents per capita	Total number of patent application by applicant per 1000 inhabitants	(WDI) Online database (World Bank, 2013)
Specific patent stock	Stock of past applied patents (calculated on past values of the dependent variable as eq. (5), decay rate = 0.15 (Table 1)	EPO via Thompson Innovation

Application 1: Research strategy – dataset 2

Variable name	Definition	Source
Carbon intensity	Ratio between CO_2 emissions (kt) and GDP in PPP (current international $)	WDI
Energy consumption	Total energy used including petroleum products, natural gas, electricity and combustible renewable and waste as % of GDP in PPP (current international $)	WDI
Road energy consumption	Total energy used in the road sector including petroleum products, natural gas, electricity and combustible renewable and waste as % of GDP in PPP (current international $)	WDI
Export %GDP	Total export value as % of GDP in PPP (current international $)	WDI

Application 1: Research strategy – dataset 3

Variable name	Definition	Source
Excise exemption (biofuels)	Average ratio between value of excise tax reductions for bioethanol and biodiesel (US $ per litre) and energy tax (US $ per litre) weighted by specific fuel consumption	(GSI, 2008), IEA (energy taxes), OECD
Excise exemption (bioethanol)	Ratio between value of excise tax reductions for bioethanol (US $ per litre) and energy tax (US $ per litre) weighted by total gasoline consumption	GSI, IEA (2011b), OECD
Excise exemption (biodiesel)	Ratio between value of excise tax reductions for biodiesel (US $ per litre) and energy tax (US $ per litre) weighted by total diesel consumption	GSI, IEA, OECD
Fuel mandate	Mandates for blending targets for ethanol and biodiesel consumption on gasoline and diesel (% of total fuel consumption)	GSI
Policy count in renewables	Number of already existing policies with the aim of fostering renewable energies production, adoption and diffusion	IEA-IRENA
RD bioenergy	Public R&D expenditures in Bioenergy as % of GDP	IEA RD&D Online Data Service

Application 1: Results – the baseline model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GERD % GDP	1.158***			1.141***					
	(7.57)			(7.77)					
Total patents per capita		0.245***			0.269***		0.284***	0.272***	0.286***
		(5.07)			(5.59)		(5.83)	(5.56)	(5.77)
Patent stock in BioPat			0.629***			0.603***			
			(10.50)			(12.24)			
Export % GDP	0.878***	1.084***	0.833***	0.789***	0.896***	0.881***	0.855***	0.850***	0.809***
	(4.54)	(6.63)	(5.43)	(4.93)	(5.80)	(6.32)	(5.48)	(5.27)	(4.95)
Energy consumption	0.106	0.369***	-0.081						
	(0.73)	(2.96)	(-0.70)						
Road energy consumption				0.376	0.623**	0.024	0.597**	0.586**	0.557**
				(1.26)	(2.46)	(0.11)	(2.31)	(2.23)	(2.08)
Carbon intensity							-0.697*		-0.668*
							(-1.77)		(-1.68)
Policy count in renewables								-0.095	-0.093
								(-1.55)	(-1.52)
Country specialization dummy in biodiesel	0.767**	0.986***	-0.375	0.789**	0.745**	-0.241	0.646**	0.735**	0.642**
	(2.25)	(3.07)	(-1.08)	(2.47)	(2.42)	(-0.81)	(2.04)	(2.34)	(1.99)

Application 1: Results – the role of public policies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total patents per capita$_{(t-1)}$	0.487***	0.490***	0.493***	0.486***	0.480***	0.468***	0.511***	0.471***
	(6.10)	(5.94)	(6.19)	(6.09)	(6.03)	(5.68)	(6.28)	(5.61)
Carbon intensity$_{(t-1)}$	-1.269***		-1.257***	-1.253***	-1.313***	-1.090**	-1.084**	-1.094**
	(-3.01)		(-2.98)	(-2.97)	(-3.14)	(-2.45)	(-2.42)	(-2.49)
Policy count in renewables$_{(t-1)}$		-0.074	-0.070					
		(-1.20)	(-1.15)					
Excise exemption (biofuels)$_{(t-1)}$	0.567***	0.644***	0.579***				0.528***	0.527***
	(3.14)	(3.53)	(3.22)				(2.91)	(2.94)
Excise exemption (bioethanol)$_{(t-1)}$				0.497***				
				(3.08)				
Excise exemption (biodiesel)$_{(t-1)}$					0.576***			
					(2.95)			
Fuel mandate$_{(t-1)}$						7.038	5.022	5.380
						(1.63)	(1.22)	(1.31)
Public R&D (bioenergy)$_{(t-1)}$								0.067**
								(2.42)
Export % GDP$_{(t-1)}$	0.994***	1.008***	0.941***	0.956***	1.036***	0.984***	1.001***	1.104***
	(5.74)	(5.62)	(5.22)	(5.50)	(5.92)	(5.61)	(5.96)	(6.51)
Road energy consumption$_{(t-1)}$	2.744***	1.026***	0.923***	0.982***	0.910***	0.863***	0.928***	1.025***
	(5.42)	(3.21)	(2.77)	(2.94)	(2.72)	(2.57)	(2.81)	(3.12)
Country dummy in biodiesel	1.141**	1.404***	1.142**	1.140**	1.123**	1.225**	1.286***	1.261***
	(2.40)	(3.15)	(2.42)	(2.38)	(2.38)	(2.54)	(2.67)	(2.63)

Application 1: Results – the role of public policies

Different technology generations

	First generation			Second generation		
	(1)	(2)	(3)	(4)	(5)	(6)
Total patents per capita$_{(t-1)}$	0.535***	0.544***	0.597***	0.340**	0.315**	0.360**
	(5.38)	(5.26)	(5.79)	(2.30)	(2.11)	(2.44)
Carbon intensity$_{(t-1)}$	-1.445***	-1.291**	-1.132**	-1.611*	-1.510*	-1.297
	(-2.57)	(-2.29)	(-1.96)	(-1.79)	(-1.68)	(-1.42)
Excise exemption (biofuels) $_{(t-1)}$	0.789***		0.701***	0.769**		0.697*
	(3.17)		(2.83)	(2.01)		(1.81)
Fuel mandate$_{(t-1)}$		14.160**	11.407**		10.492	8.202
		(2.56)	(2.13)		(1.41)	(1.12)
Public R&D (bioenergy) $_{(t-1)}$	0.020	0.018	0.020	0.137**	0.128**	0.134**
	(0.50)	(0.46)	(0.53)	(2.14)	(2.05)	(2.10)
Export % GDP$_{(t-1)}$	0.861***	0.833***	0.922***	0.213	0.173	0.253
	(3.50)	(3.50)	(3.97)	(0.70)	(0.58)	(0.86)
Road energy consumption$_{(t-1)}$	0.015	-0.244	-0.102	1.653**	1.555**	1.607**
	(0.03)	(-0.51)	(-0.22)	(2.21)	(2.07)	(2.18)
Country dummy in biodiesel	0.426	0.496	0.550	1.186	1.468*	1.408*
	(0.85)	(1.02)	(1.12)	(1.34)	(1.83)	(1.74)

Application 1: Results – robustness check

Potential endogeneity of policy variables (GMM estimator for count variables)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total patents per capita$_{(t-1)}$	-0.189	-0.246	-0.135	-0.154	-0.206	-0.231	-0.174	-0.209
	(-0.59)	(-0.76)	(-0.41)	(-0.50)	(-0.66)	(-0.86)	(-0.61)	(-0.77)
Carbon intensity$_{(t-1)}$	-1.90**		-1.819**	-1.791**	-2.242***	-2.234***	-1.988***	-1.910**
	(-2.29)		(-2.24)	(-2.19)	(-2.67)	(-2.85)	(-2.63)	(-2.32)
Policy count in renewables$_{(t-1)}$		-0.053	-0.038					
		(-1.44)	(-1.07)					
Excise exemption (biofuels)$_{(t-1)}$	0.782*	1.053***	0.825**				0.830**	0.904***
	(1.95)	(2.58)	(2.23)				(2.85)	(2.58)
Excise exemptic (bioethanol)$_{(t-1)}$				0.834***				
				(2.84)				
Excise exemption (biodiesel)$_{(t-1)}$					0.436			
					(0.81)			
Fuel mandate$_{(t-1)}$						4.466	-1.672	-1.463
						(0.50)	(-0.26)	(-0.24)
Public R&D (bioenergy) 1)								0.108***
								(2.57)
Export % GDP$_{(t-1)}$	1.543***	1.605***	1.529***	1.505***	1.469***	1.414***	1.519***	1.596***
	(4.31)	(3.70)	(4.17)	(4.85)	(3.37)	(3.35)	(4.04)	(4.22)
Road energy consumption$_{(t-1)}$	2.744***	2.568***	2.562***	2.876***	2.527***	2.380***	2.769***	2.771***
	(5.42)	(5.54)	(4.95)	(5.97)	(4.52)	(4.37)	(5.60)	(5.85)

Application 1: Conclusions

- By looking at the general innovation performance in the biofuels sector, both demand-pull and technology-push instruments are relevant in shaping the speed of technological change
- At a general level price-based deployment instruments display a greater impact on innovation activities with regard to quantity-based instruments
- When we distinguish between first and advanced technological generations within the biofuels domain, in the former case innovation activities mainly respond to demand-pull instruments, both price and quantity-based
- In the case of (less-mature) advanced generation technologies, these are found to be influenced by both demand-pull and technology-push public supports, with price-based instruments displaying a greater innovation inducement effect than quantity-based tools
- Detailed analyses of the mechanisms linking demand-pull and technology-push policies with the rate, type and direction of innovation activities in environmental technologies are highly reccommended

Application 1: Main lessons and further research

- Importance of working on the design of policy mix in order to foster sustainable transition by providing appropriate incentives to favour technology exploration activities and avoid the system to be locked-in within the dominant technology design

- Further research is certainly needed to study how policy instruments, both on the demand and the supply-side, may interact and affect the intensity and the direction of technical change in environmental domains

- Difficulties in designing the policy mix increases as the number of policy domains and policy instruments increase

The analysis of policy mix characteristics

The case of energy efficiency technologies in the residential sector

Application 2: Stylized facts

Definition of energy efficiency

- Energy Saving (ES) is only an absolute decrease of energy consumption
- ES can be obtained *via* energy efficiency (EE) gains, hence ES is a broader concept (Linares and Labandeira, 2010)
- EE is defined as useful output of a process given a fix amount of energy input (Patterson, 1996)
- The reduction of energy demand can be thought as a function of the level of EE, which in turns depends on the invention and adoption of new EE technologies

Application 2: Stylized facts

- Energy-growth decoupling occurred in the last 30 years, since the oil crisis (1973, 1979)

- Economic implications: IEA estimates that with no EE gains, energy consumption between 1973 and 2006 would have been much higher (around 60%, IEA, 2010)

- Most of the EE efforts in industrial sectors, but nowadays residential sector adsorbs 1/3 of electricity consumptions (IEA, 2012)

  - Modern lifestyle depends heavily on the availability of devices, systems and equipment fuelled by electricity

  - Electricity use grew rapidly in OECD countries, because of the increased penetration of many different appliances

Application 2: Stylized facts

- The reduction of energy demand can be thought as a function of the EE levels, which depends on the availability of new EE technologies, being these latter a specific eco-innovation domain

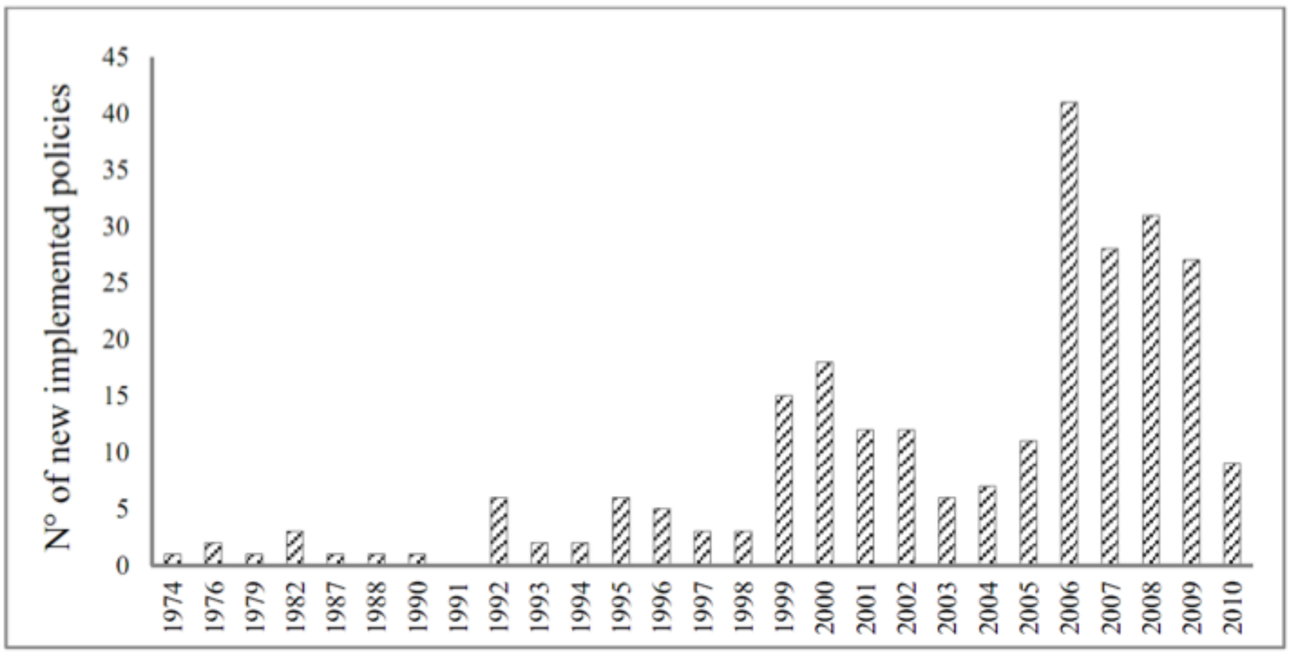
- The development of eco-innovations constitutes an important part of energy and environmental policy strategies. Among all, EE is defined as the most cost effective and relatively easy to be implemented (EC, 2011; IEA, 2010; 2012)

- Decreasing dynamics in energy and carbon intensity may be detected in almost all economic sectors with the exception of the residential one. Some other countries have reduced efforts to improve EE in the residential sector, other countries obtained EE gains especially in this sector (Costantini et al., 2013; 2014)

Application 2: Stylized facts

- Reasons behind these divergences may be detected in several directions. The most important explanation can be found in the different national policy strategies during the last two decades (Del Rìo and Hernandez, 2007)

- Policy intervention for residential EE has been different both in size and quality among OECD countries



Residential EE policies in high-income OECD countries (1974–2010). Source: Costantini et al., 2014.

Application 2: Background

- A large number of economic studies have been devoted to identifying the determinants of eco-innovations, analysing the different elements that contribute to triggering firms' eco-innovation activities (del Rìo, 2009; Foxon, 2003; Horbach, 2008; OECD, 2011)
- The two broad categories of demand-pull and technology-push policy instruments have benne already emphasized. While technology-push instruments act to increase the supply of new knowledge, demand-pull instruments affect the size of the market demand for new technologies (see, among others, Costantini et al., 2015; Hoppmann et al., 2013; Horbach et al., 2012; Nemet, 2009; Rennings, 2000)
- Recent analyses of innovation dynamics, in particular when eco-innovation processes are under scrutiny, focus on the role of systemic instruments designed to influence the overall socio-economic and technology system to allow for adaptive strategies within institutional and technological contexts, (Kemp, 2011; Wieczorek and Hekkert, 2011; Nill and Kemp, 2009; Smith et al., 2010)

Application 2: Background

- While there is a quite unanimous consensus on the positive inducement effect played by public policies on eco-innovation dynamics, there is still space for investigating how the type and the combination of different policy instruments influence innovation trajectories
- A well designed policy scheme should take into account several elements such as credibility, flexibility and ability of policies to learn from mistakes and successes. These features can determine the success or failure of a given policy framework (Mowery et al., 2010)
- Neither the term “policy mix”, nor the intuition that different innovation policy instruments can interact, are new to the economic literature. Early studies attempt to investigate the complementarity mechanisms as well as the substitution or compensation effects among coexisting instruments (see Branscomb and Florida, 1998; Howlett, 2005; Smith, 1994; Sorrell and Sijm, 2003)

Application 2: Background

- According to Flanagan et al. (2011), the tools employed in a single policy setting should be designed in order to respect at least three characteristics
    1. the overall policy mix needs to be comprehensive, ensuring the extensiveness and exhaustiveness of its elements
    2. instruments should be synergic in order to maximize and exploit potential complementary effects among different policy elements (consistency)
    3. there must be coherence between the different in force policy tools where the objective of each instrument should be in line with the others
- In addition, a proper policy mix should be formed by instruments able to
    1. stimulate and allow the participation of various actors, including users
    2. prevent lock-in and stimulate creative destruction
    3. prevent institutions that are too weak and too stringent
    4. stimulate physical and knowledge infrastructures (Smits and Kuhlmann, 2004; Wieczorek and Hekkert, 2011)
- Finally, Borras and Edquist (2013) emphasize the need to map and categorize the set of policy instruments so far employed at global level, which is growing in complexity and heterogeneity, since several so-called “soft instruments” (such as voluntary and non-coercive measures) are increasingly employed to complement more traditional market-based and command-and-control measures

Application 2: Research strategy – hypotheses HP1

- We try to evaluate the role played by the **comprehensiveness** of the policy mix, meaning how extensive the use of different policy instruments is, including not only standard demand-pull and technology-push tools but also, for instance, soft instruments such as voluntary and non-coercive measures (Rogge and Reichart, 2013)
- The inherent complexity of a policy framework aimed at enhancing energy efficiency suggests that a large range of instruments has to be implemented at the same time (Crespi, 2015)
- Complementary or supplementary tools are in fact often needed to control for side effects or to reinforce the efficacy of the main instruments employed (del Río and Howlett, 2013). Hence we expect that:

➢ **HP1. A more comprehensive policy mix positively influences innovation performance in EE technologies**

Application 2: Research strategy – hypotheses HP2

- However, the positive impact of comprehensiveness may be somewhat reduced if an excessive number of different policies is settled
- Trade-offs that are detrimental to the innovation system (e.g., a perception from economic agents of increasing costs in being compliant with different regulatory frameworks, the dispersion of economic resources across small and ineffective public support interventions, the greater likelihood of potential conflicts in final objectives of different tools), can emerge when a disproportionate variety of policy tools are jointly implemented
- This may lead to instrument mix **inconsistency**, which is related to the presence of negative interactions and contradictions between different instruments (del Río, 2009b). As stressed by Arundel and Kemp (2009), when the portfolio of policy options is unclear or too detailed, it may also act as a barrier to innovation

➢ **HP2. An excessive variety of policy tools may lead to an instrument mix that is inconsistent and over-dispersed, resulting in negative effects for innovation dynamics in EE technologies**

Application 2: Research strategy – hypotheses HP3

- The different, simultaneous instruments forming the policy setting should also be balanced in terms of the intensity with which different tools are implemented
- An unbalanced structure of public budgets favouring specific policies may result in a strong orientation of the policy framework that can indeed produce serious consequences in terms of technological and environmental achievements and in terms of a reduced variety of alternative technologies, leading to a possible lock-in effect in inferior technologies
- The **balanced availability of public resources and policy intervention** on an array of different instruments may signal a more stable commitment and long-term strategic view, aimed at achieving synergies between the different policy elements
- In this context, the whole innovation system may positively react to lower uncertainty and reduced risk perception (del Río, 2009a; Schmidt et al., 2012)

➢ **HP3. A more balanced policy mix, ceteris paribus, has a positive influence on innovation dynamics in EE (internal balance)**

Application 2: Research strategy – hypotheses HP4

- Decisions and policy strategies adopted by other countries are likely to influence internal innovation performance
- The issue addressed here is if and to what extent the relation between domestic and foreign policy setting influences countries' innovation patterns
- We expect that the higher the alignment of the domestic policy framework with those adopted by foreign countries (**external balance**), the higher the potential synergies between policy and innovation efforts between the domestic sector and those of other countries

➢ **HP4. The higher the balance of the domestic policy mix with the policy setting adopted by other countries (external balance), the higher the capacity of domestic policy strategy to foster innovation in EE**

Application 2: Research strategy – econometrics

- The use of patent data as proxies of the innovative activity implies that we have to deal with count variables, that is, variables with non-negative integer values
- Econometric models specifically designed for this kind of variable are the Poisson Regression Model (PRM) and the Negative Binomial Regression Model (NBRM)
- Given that our dependent variables are strongly overdispersed and do not have an excessive number of zeros, a fixed effects NBRM model is used
- The Hausman test points out that the fixed effects estimator is more appropriate than the random effects estimator, since it assumes a value equal to 185.64
- In order to test the validity of alternative lag structures, we have performed a Bayesian information criterion (BIC) testing for p assuming value 1, 2, 3 (p=1)

- Robustness check for endogeneity is carried by applying a GMM estimator for count variables

Application 2: Research strategy – the model

$$Y_{i,t} = \alpha_i + \beta_o + \beta_1\left(EEPol_{i,t-p}\right) + \beta_2\left(IntPolMix_{i,t-p}\right) + \beta_3\left(ExtPolMix_{i,t-p}\right) +$$
$$+\beta_4\left(InnSys_{i,t-p}\right) + \beta_5\left(EneSys_{i,t-p}\right) + \varepsilon_{i,t}$$

Yi,t indicates the innovation performance measure in the EE residential sector

i=1,…,N indexes countries (23 OECD)

t=1990,…,2010 indexes time

αi are country-specific unobserved time invariant effects

p stands for eventual lag structure

εi,t are stochastic errors

The dependent variable measuring EE innovation

In this work, innovation in the EE domain is represented by the count of patent applications filed at EPO by 23 OECD countries over the period 1990-2010

The patent database here adopted gathers the Y02 Cooperative Patent Classification (CPC) based on patent classes for green technologies, with the work by Noailly and Batrakova (2010) mapping EE technologies in the building sub-sector, and the analysis on the electrical appliances by Costantini et al. (2014)

Application 2: Dataset – the dependent variable

Main domain	Sub-domain	CPC Class	Sub-classes	Keywords
Insulation	Heat Saving	E06B	3/24, 3/64, 3/66, 3/67	
		E06B	3	high perform+ OR insulat+ OR low energy
		C03C	17/00, 17/36	low e
		E06B	3/67F	vacuum
		E06B		aerogel
		E06B	3/20	
		E06B	1/32, 3/26	thermal break
		E04B	1/74, 1/76	
		E04B		Polyurethane OR PUR OR polystyrene OR EPS OR XPS OR heavy gas+ OR pentane OR insulat+
		E04B		Flax OR straw OR (sheep+ AND wool)
		E04F	15/18	
		E04F		Sea shell
		E04D	11	Insulat+
		E04D	11	Green roof
		E04D	11, 9	thatch+
		F16L	59/14	
	Water saving	F24H		Water AND (sav+ OR recover+)
		F16K	1	Water AND (sav+ OR recover+)
		E03C	1	Water AND (sav+ OR recover+)
	Cooling reduction	E04F	10	
		C03		Glass AND (reflect+ OR sunproof OR heat resist+)
		E06B	3	Glass AND (reflect+ OR sunproof OR heat resist+)
		B32B	17	Glass AND (reflect+ OR sunproof OR heat resist+)
High-efficiency boilers	HE-boilers	F23D	14	Low
		F24D	1	
		F24D	3, 17	
		F24H, excluding F24H7		

Application 2: Dataset – the dependent variable

Main domain	Sub-domain	CPC Class	Sub-classes	Keywords
Heat and cold distribution and CHP	Heating system	F24D	5, 7, 9, 10, 11, 13, 15, 19	
	Storage heaters	F24H	7	
	Heat exchange	F28F	21	
	Cooling	F25B	1, 3, 5, 6, 7, 9, 11, 13, 15, 17	
	Combined heating and refrigeration systems	F25B29		
	Heat pumps	F25B30		
	CHP	X11-C04		
		R24H240/04 (ICO		
Ventilation	Ventilation	F24F	7+	
Solar energy and other RES	Solar energy	F24J	2	
		H01L	31/042, 31/058	
		H02N	6	
	Biomass	F24B		Wood+
	Geothermal	F24J	3	
Building materials	Construction structures	E04B	1	Building+ or house+
	Materials	C09K	5	Building+ or house+
Climate control systems	Temperature control	G05D	23/02	
	Electric heating devices	H05B	1	
Lighting	Lighting	F21S		Not vehicle, not aircraft
		F21K	2	Not vehicle, not aircraft
		H01J	61	Not vehicle, not aircraft
		F21V	7	House or home or building
	LED	H01L	33	Light and LED
		H05B	33	Light and LED

Application 2: Dataset – the dependent variable

CPC general Class related to each appliance		**Technologies aimed at improving efficiency of home appliances**	**Description**
Refrigerators and freezers	F25D See http://www.cooperativepatentclassification.org/cpc/scheme/F/scheme-F25D.pdf	Y02B 40/32	Motor speed control of compressors or fans
		Y02B 40/32	Thermal insulation
Dish-washers	A47L 15/00 See http://www.cooperativepatentclassification.org/cpc/scheme/A/scheme-A47L.pdf	Y02B 40/42	Motor speed control of pumps
		Y02B 40/44	Heat recovery e.g. of washing water
Washing-machines	D06F (excluding D06F31/00, D06F43/00, D06F47/00, D06F58/12, D06F67/04, D06F71/00, D06F89/00, D06F93/00, D06F95/00 as well as their subgroups). See http://www.cooperativepatentclassification.org/cpc/definition/D/definition-D06F.pdf	Y02B 40/52	Motor speed control of drum or pumps
		Y02B 40/54	Heat recovery, e.g. of washing water
		Y02B 40/56	Optimization of water quantity
		Y02B 40/58	Solar heating

Application 2: Dataset – the independent variables

The EE domestic policy setting formed by three policy domains

1. quantitative demand-pull policies
2. quantitative supply-push policies
3. qualitative measures of different instruments based on their different application (regulatory/ compulsory vs. information/voluntary approaches)

$$Tax\_bundle_{i,t} = \frac{\sum_{n=1}^{3}\left(tax_{i,t}^{n} \cdot ener\_cons_{i,t}^{n}\right)}{\sum_{n=1}^{3}\left(price_{i,t}^{n} \cdot ener\_cons_{i,t}^{n}\right)}$$

$$RD_{EE}Ratio_{i,t} = \frac{RD_{EE,i,t}}{RD_{TOTEN,i,t}}$$

$$KPOL_{i,t}^{q} = \sum_{s=1}^{t}\left(POL_{i,s}^{q}\right)$$

Application 2: Dataset – the independent variables

Policy Type	Instrument
Economic Instruments	Direct investment Fiscal/Financial incentives Market-based instruments
Information and Education	Advice/Aid in implementation Information provision Performance label Professional training and qualification
Policy Support	Institutional creation Strategic planning
Regulatory Instruments	Auditing Codes and standards Monitoring schemes Obligation schemes Other mandatory requirements
Research, Development and Deployment (RD&D)	Demonstration projects Research programmes
Voluntary Approaches	Negotiated agreements Public voluntary schemes Unilateral commitments

Application 2: Dataset – the independent variables

The characteristics of the domestic policy mix

Comprehensiveness of the policy mix (**HP1**)

$$POL_{Tot_{i,t}} = \sum_{q=1}^{6} \left(KPOL_{i,t}^{q}\right)$$

Inconsistency of the policy mix (**HP2**)

$$POL_{Incons1_{i,t}} = \left(\sum_{q=1}^{6} \left(KPOL_{i,t}^{q}\right)\right)^{2}$$

$$POL_{Incons2_{i,t}} = \sum_{q=1}^{6} \left(KPOL_{i,t}^{q}\right) \cdot \left[1 \Big/ \sum_{q=1}^{6} \left(\frac{KPOL_{i,t}^{q}}{KPOL_{Tot_{i,t}}}\right)^{2}\right]$$

Application 2: Dataset – the independent variables

Internal balance (**HP3**)

$$POL_{Bal}{}_{i,t}^{d} = \left[\frac{\left|POL_{dom}{}_{i,t}^{f} - POL_{dom}{}_{i,t}^{g}\right|}{\sqrt[2]{POL_{dom}{}_{i,t}^{f} + POL_{dom}{}_{i,t}^{g}}}\right]^{-1} \qquad \forall f \neq g$$

$$POL_{dom}{}_{i,t}^{f,g} \in \left[Tax\_bundle_{i,t}, RD_{EE}Ratio_{i,t}, POL_{Tot_{i,t}}\right]$$

$$Tot\_POL_{Bal\,i,t} = \sqrt{\frac{\sum_{d=1}^{3}\left(POL_{Bal}{}_{i,t}^{d} - \frac{\sum_{d=1}^{3} POL_{Bal}{}_{i,t}^{d}}{3}\right)^{2}}{3}}^{\,-1}$$

The closer the similarity between each couple of policy domains, the greater the coherence between them, and the lower the standard deviation among the three couple-based similarity measures, the higher the global balance across all the policy spheres considered here

Application 2: Dataset – the independent variables

External balance (**HP4**)

A measure of policy spillover

defined here as the policy strength adopted by foreign countries weighted by the bilateral export flows in energy intensive manufacturing sectors Xir,t from country i to country r taken from UN-COMTRADE database

$$POL\_Spill_{i,t}^{f} = \sum_{r=1}^{N} X_{ir,t} \cdot POL_{dom}{}_{r,t}^{f} \ \ \forall r \neq i \ \ N = 22$$

$$Tot\_POL\_Spill_{i,t} = \sum_{r=1}^{N} X_{ir,t} \cdot \sum_{f=1}^{3} POL_{dom}{}_{r,t}^{f} \ \ \forall r \neq i \ \ N = 22$$

Application 2: Dataset – the independent variables

External balance (**HP4**)

The interaction with the domestic policy mix

- We are interested in understanding to what extent the foreign policy setting influences the capacity of the domestic policy mix to enhance innovation dynamics
- According to HP4, we aim to evaluate if and to what extent a greater balance between the domestic and the external policy strategy reinforces the inducement effect on innovation dynamics produced by domestic policies
- The external balance is measured by constructing an indicator based on the co-existence of similar policy efforts in force at time t for country i compared with all other countries (r) for each policy domain (f)

➢ Step 1: bilateral single policy domain similarity index

$$Bil\_POL_{Bal}{}_{ir,t}^{f} = \left[\left(\frac{\left| POL_{dom}{}_{i,t}^{f} - POL_{dom}{}_{r,t}^{f} \right|}{\sqrt[2]{POL_{dom}{}_{i,t}^{f} + POL_{dom}{}_{r,t}^{f}}} \right)^{-1} \right] \forall r \neq i \; N = 22$$

Application 2: Dataset – the independent variables

External balance (**HP4**)
The interaction with the domestic policy mix

- Step 2: an aggregate measure of external balance for each single policy domain by adopting as a weighting criterion the value of export flows in energy intensive commodities from each reporting partner i towards each partner r Xir,t

$$WExt\_POL_{Bal\,i,t}^{\;f} = \sum_{r=1}^{N}\left(Bil\_POL_{Bal\,ir,t}^{\;f} \cdot X_{ir,t}\right)\ \forall r \neq i\ N = 22$$

- Step 3: an overall measure of policy mix external balance by considering all policy domains, applying the same criterion as developed for the internal balance

$$Tot_{Ext_{POL_{Bal\,i,t}}} = \sum_{r=1}^{N}\left(\sqrt{\frac{\sum_{f=1}^{3}\left(Bil_{POL_{Bal\,ir,t}^{\;f}} - \frac{\sum_{f=1}^{3} Bil_{POL_{Bal\,ir,t}^{\;f}}}{3}\right)^{2}}{3}}^{\,-1} \cdot X_{ir,t}\right)\ \forall r \neq i\ N = 22$$

Application 2: Results – the domestic EE policy domains

	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Stock of GERD	0.693***	0.762***	0.684***	0.683***	0.693***	0.638***	0.739***	0.750***
	(13.77)	(15.91)	(13.24)	(13.26)	(13.40)	(12.09)	(14.84)	(14.90)
Energy tax (demand-pull)	0.523***		0.359***	0.310***	0.374***	0.358***	0.381***	0.342***
	(6.56)		(4.33)	(3.85)	(4.58)	(4.30)	(4.68)	(4.27)
RD in EE (technology-push)		0.242***	0.087***	0.103***	0.146***	0.096***	0.153***	0.168***
		(8.31)	(2.60)	(3.14)	(4.38)	(2.78)	(4.67)	(5.24)
Econ. instruments			0.203***					
			(7.19)					
Info. & edu.				0.226***				
				(7.46)				
Policy support					0.190***			
					(5.24)			
Reg. instruments						0.241***		
						(7.49)		
RD&D support							0.191***	
							(4.67)	
Vol. app.								0.171***
								(4.11)
Energy intensity	-0.275***	-0.134*	-0.210***	-0.188***	-0.172**	-0.216***	-0.186***	-0.169**
	(-4.19)	(-1.95)	(-3.09)	(-2.74)	(-2.52)	(-3.13)	(-2.72)	(-2.49)
N	460	460	460	460	460	460	460	460
chi2	223.08	322.43	571.05	550.20	468.82	514.60	446.75	429.68

Application 2: Results – the internal policy mix

	(1)	(2)	(3)	(4)	(5)
Stock of GERD	0.633***	0.666***	0.679***	0.624***	0.664***
	(11.99)	(12.37)	(12.57)	(11.75)	(12.36)
Energy tax (demand-pull)	0.322***	0.261***	0.299***	0.326***	0.263***
	(3.94)	(3.17)	(3.70)	(3.98)	(3.23)
RD in EE (technology-push)	0.056*	0.072**	0.072**	0.037	0.053
	(1.69)	(2.24)	(2.22)	(1.03)	(1.54)
EE policy stock (comprehensiveness)	0.206***	0.418***	0.444***	0.217***	0.430***
	(9.02)	(7.91)	(6.90)	(9.06)	(8.17)
EE policy stock sq. (inconsistency)		-0.070***			-0.071***
		(-4.49)			(-4.59)
EE policy stock (dispersion)			-0.156***		
			(-3.97)		
Internal Policy Balance				0.052*	0.054**
				(1.88)	(2.02)
Energy intensity	-0.217***	-0.227***	-0.240***	-0.224***	-0.228***
	(-3.13)	(-3.19)	(-3.45)	(-3.22)	(-3.21)
Constant	-7.032***	-7.552***	-7.769***	-6.914***	-7.540***
	(-8.40)	(-8.87)	(-9.12)	(-8.26)	(-8.95)
N	460	460	460	460	460
chi2	625.208	612.905	633.680	621.173	607.557

Application 2: Results – external balance and spillovers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stock of GERD	0.427***	0.536***	0.535***	0.501***	0.611***	0.651***	0.660***	0.577***
	(6.29)	(7.42)	(7.74)	(8.14)	(10.86)	(11.68)	(11.69)	(9.57)
Energy tax (demand-pull)	0.077	0.175**	0.166**	0.116	0.305***	0.274***	0.264***	0.258***
	(0.92)	(2.04)	(1.99)	(1.39)	(3.66)	(3.28)	(3.19)	(3.12)
RD in EE (technology-push)	0.108***	0.076**	0.075**	0.121***	0.078**	0.074**	0.071**	0.087***
	(3.57)	(2.42)	(2.45)	(3.97)	(2.40)	(2.29)	(2.22)	(2.64)
EE policy stock (comprehensiveness)	0.223***	0.372***	0.350***	0.197***	0.336***	0.409***	0.417***	0.307***
	(4.09)	(6.81)	(6.43)	(3.60)	(5.87)	(7.63)	(7.86)	(5.01)
EE policy stock sq. (inconsistency)	-0.059***	-0.064***	-0.060***	-0.065***	-0.053***	-0.068***	-0.070***	-0.050***
	(-3.93)	(-4.06)	(-3.89)	(-4.28)	(-3.23)	(-4.30)	(-4.46)	(-2.93)
General policy spillovers	0.314***							
	(8.05)							
Energy tax spillovers		0.194***						
		(2.91)						
RD in EE spillovers			0.212***					
			(3.63)					
EE policy stock spillovers				0.167***				
				(8.72)				
External Policy Balance					0.049***			
					(3.55)			
Energy tax External Balance						0.019		
						(1.08)		
RD in EE External Balance							0.005	
							(0.37)	
EE policy stock External Balance								0.085***
								(3.56)
Energy intensity	-0.253***	-0.231***	-0.275***	-0.225***	-0.224***	-0.234***	-0.228***	-0.268***
	(-3.41)	(-3.27)	(-3.8)	(-2.96)	(-3.17)	(-3.29)	(-3.20)	(-3.64)
Constant	-8.712***	-8.804***	-8.969***	-7.273***	-7.526***	-7.698***	-7.563***	-7.636***
	(-10.30)	(-9.31)	(-9.63)	(-8.47)	(-9.11)	(-8.93)	(-8.90)	(-9.33)
N	460	460	460	460	460	460	460	460
Chi2	738.394	643.777	665.821	743.245	640.367	614.922	613.759	635.872

Conclusions

- Different policy types, including the soft instruments represented here by information and education, policy and RD&D support and voluntary approaches, are effective in influencing innovation dynamics in the energy efficiency domain
- A more comprehensive policy mix is able to enhance innovation activities in the domain of EE technologies
- However, the simple addition of an indiscriminate number of simultaneous policy instruments may create inconsistencies
- Coordination problems, in terms of potential conflicting effects determined by the co-existence of too many policy instruments, potentially reduce the innovation inducement capacity of the overall policy effort
- A well-balanced use of different policy instruments seems to be a good policy strategy to be adopted to positively influence innovation dynamics
- The policies adopted by foreign countries influence innovation patterns by interacting with the internal policy mix
- The inducement effects of domestic policies are reinforced when the external balance of the policy mix design is higher
- This effect is detected for complementary qualitative instruments which seem to amplify their potential role when they are aligned with similar accompanying policies adopted by other countries

Overall conclusions: need of a global perspective

- Need to develop a coherent policy framework, avoiding the great divide between economic, energy, environment and technology pillars
- Environment/energy/technology policies should fuel the green transformation of economies but should also help achieving more and better jobs
- Public policies should be designed in order to prevent lock-in in inferior technologies
- For a green recovery employment policies should take into account the major transformation needed to move to greener jobs and assure the availability of adequate skills
- Rationale for coordinated actions
- Use part of resources from green taxes and other financial schemes
  - To support policies/programmes
  - To support capacity building
- Foster technology transfer to developing countries
- Ensure that environment-friendly technologies are available and affordable for all

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Thank you

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