Exploring BioPat:

an investigation tool for the analysis of industry evolution, technological paths and policy impact in the field of biofuels

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Presentation outline

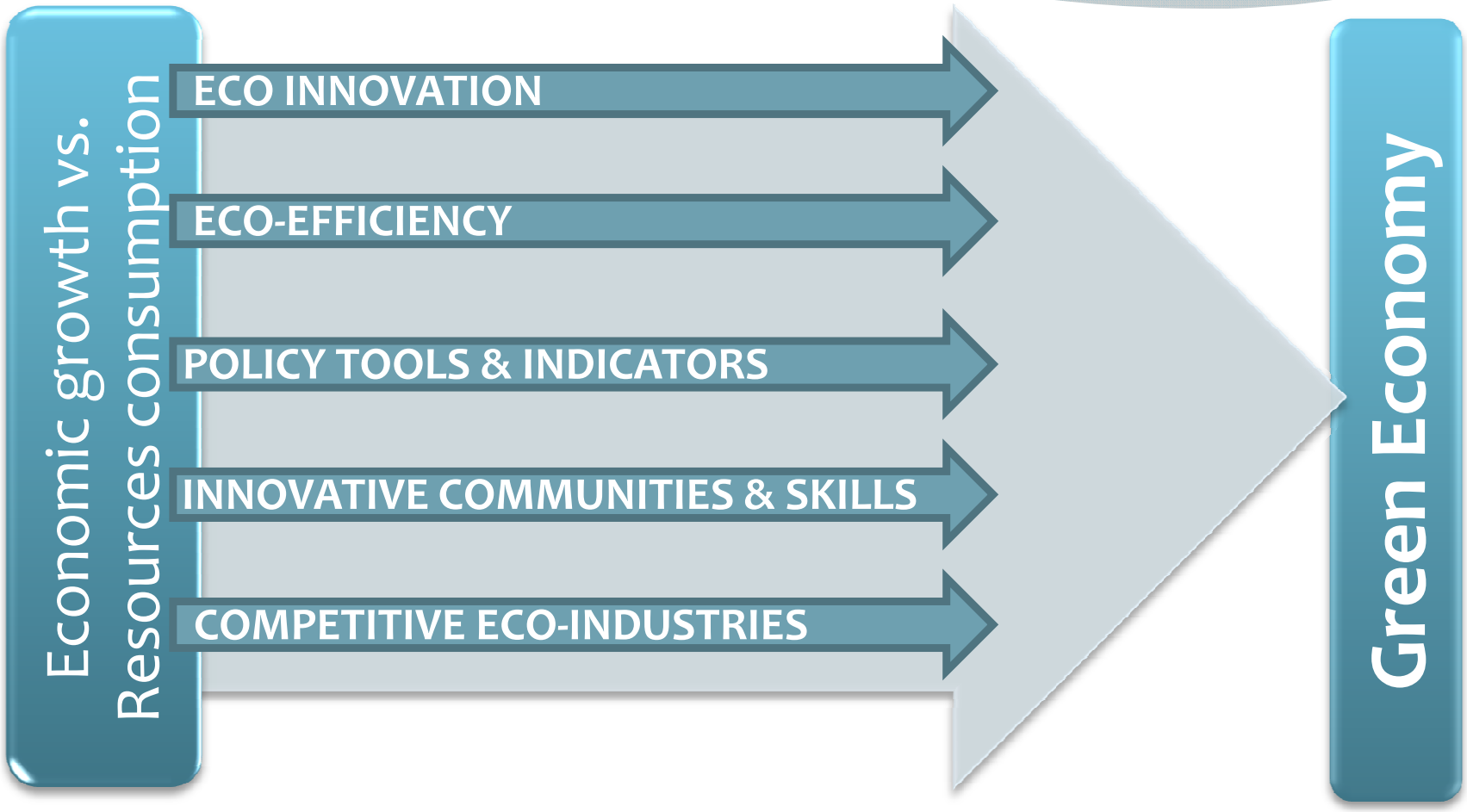
- Introduction on the Green Economy and Eco-Innovation: issues and policies.
- Collecting patent data in the biofuel sector: technical issues and the methodology adopted for this work.
- First evidence from the BioPat database.
- Preliminary findings relative to a first application to the inducement effects of environmental policies on innovation in the biofuels sector.

Green growth is…

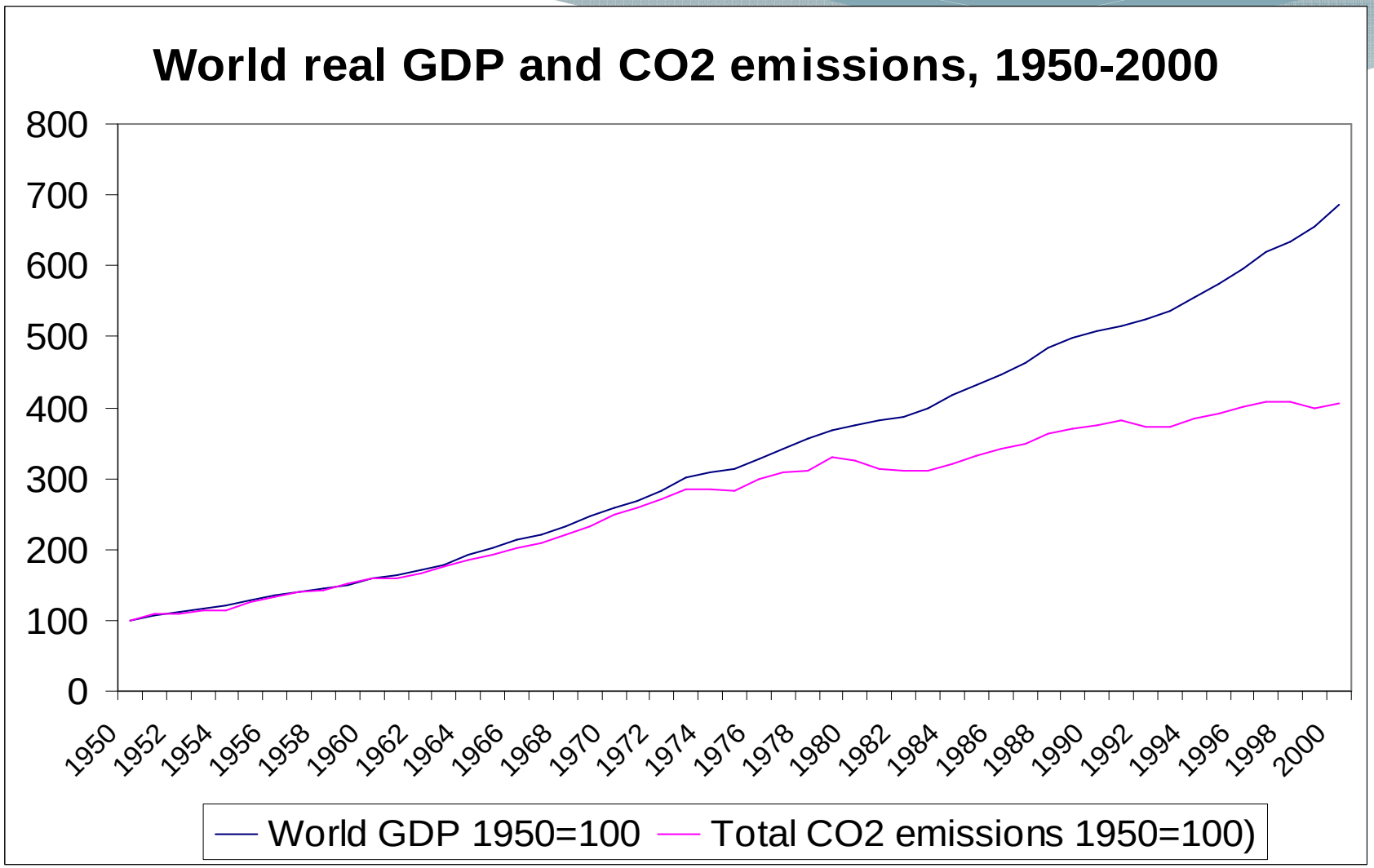
Sustainable consumption and production
(SCP key word in the new EU Resource efficiency roadmap)

- green consumption
- greener industry
- greener industry mix

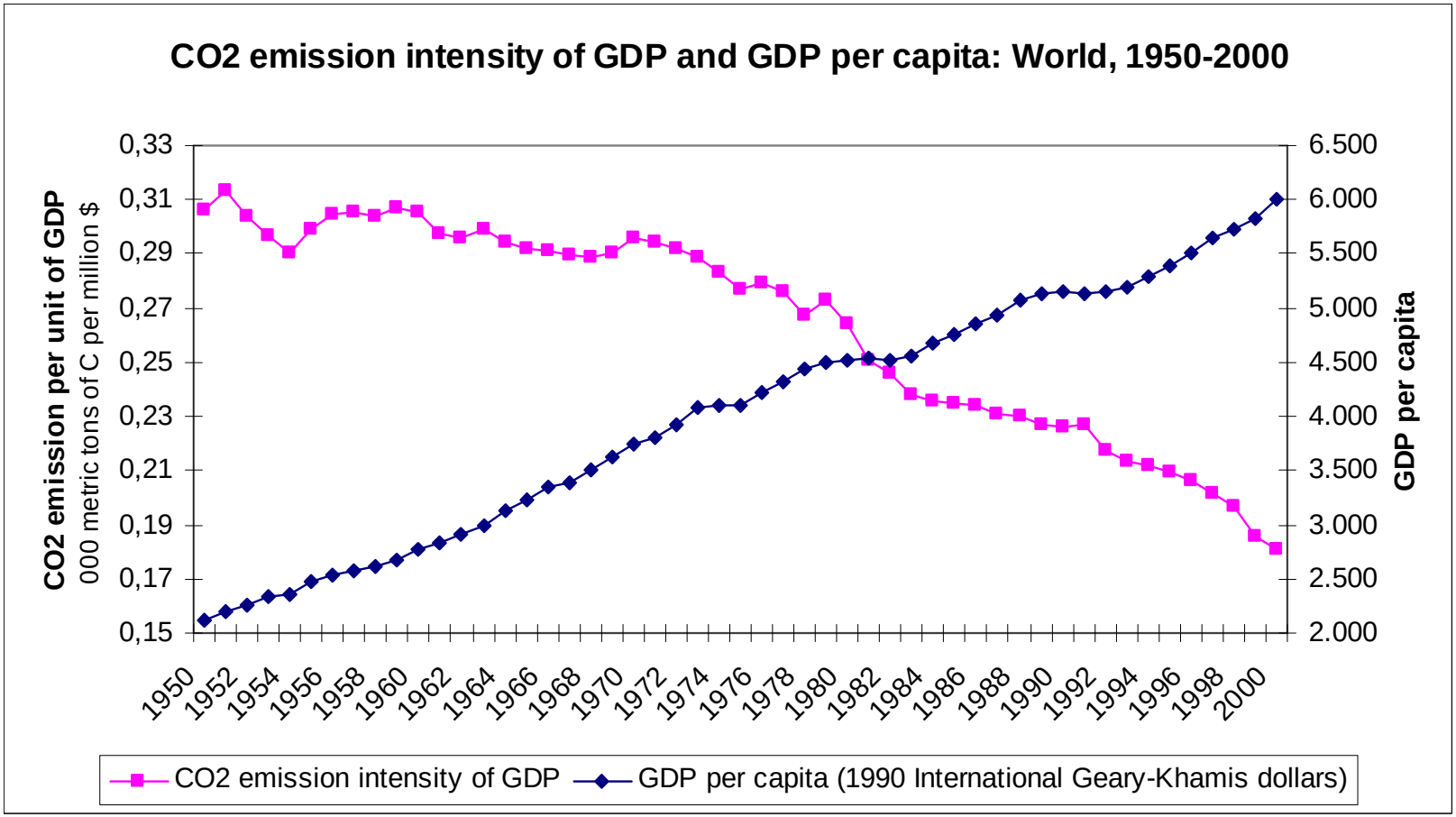
Green Economy



Background evidence: trends in GDP and CO_2 emissions



Background evidence: CO2/GDP intensity -42% over 1950-2000



Global challenges

- **Unsustainable use of natural resources**

  UN Millenium Assessment (2005): two thirds of necessary ecosystem services are in decline

- **Climate change**

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

- **Water scarcity**

  More than 1 billion people use unsafe sources of drinking; 2.6 billion do not have basic sanitation

Policy context: the EU rationale

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

Policy context: the EU rationale

- Environment is both a constraint and a 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
  - Already more than 2% of EU GDP and growing quickly
  - Clean technologies attract 10% of risk capital in Europe

Definition of Eco-Innovation (EI)

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

Definition of EI: the Measuring Eco-Innovation (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
	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

Definition of EI: three broad categories of green technologies

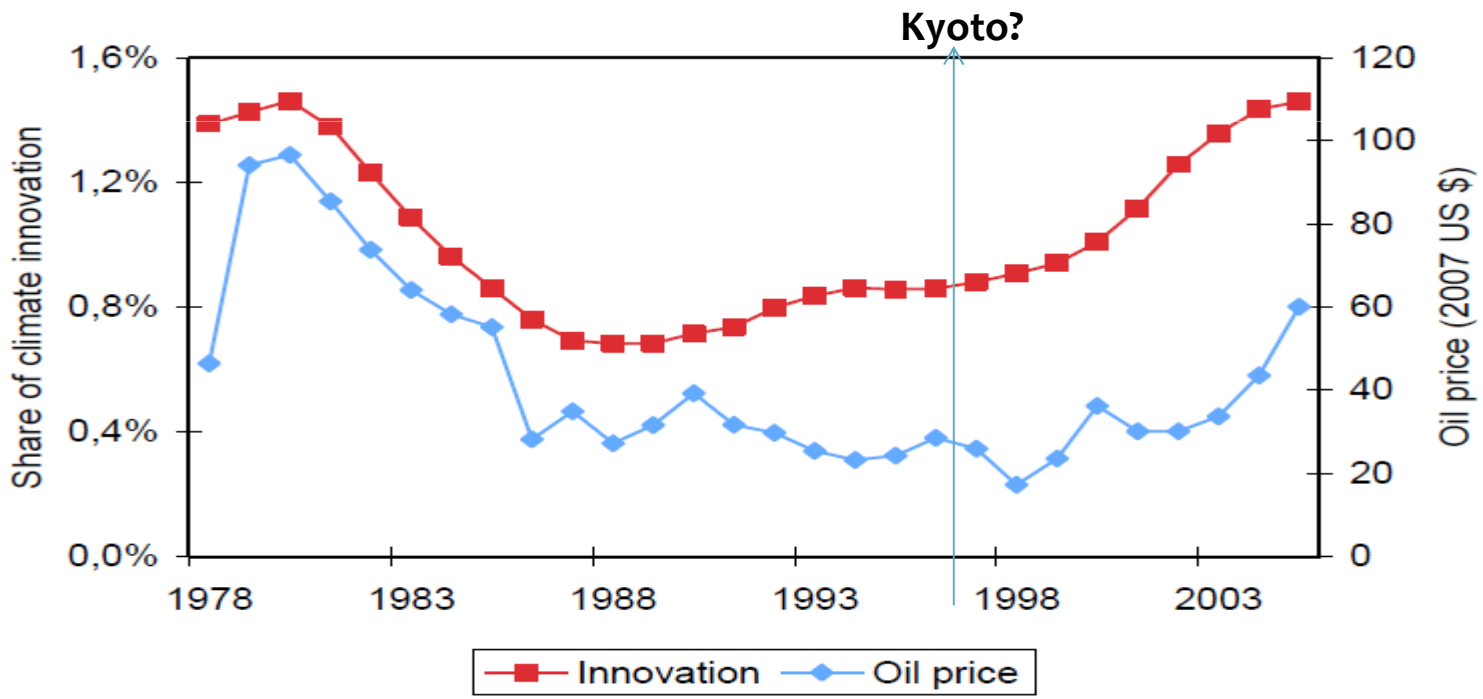
- **Energy efficiency** - energy conservation in buildings; fuel efficient vehicles; public transport and rail; improving electrical transmission (smart grid).

- **Renewable energy** - geothermal, hydro, wind and solar, nuclear power, and carbon capture and sequestration.

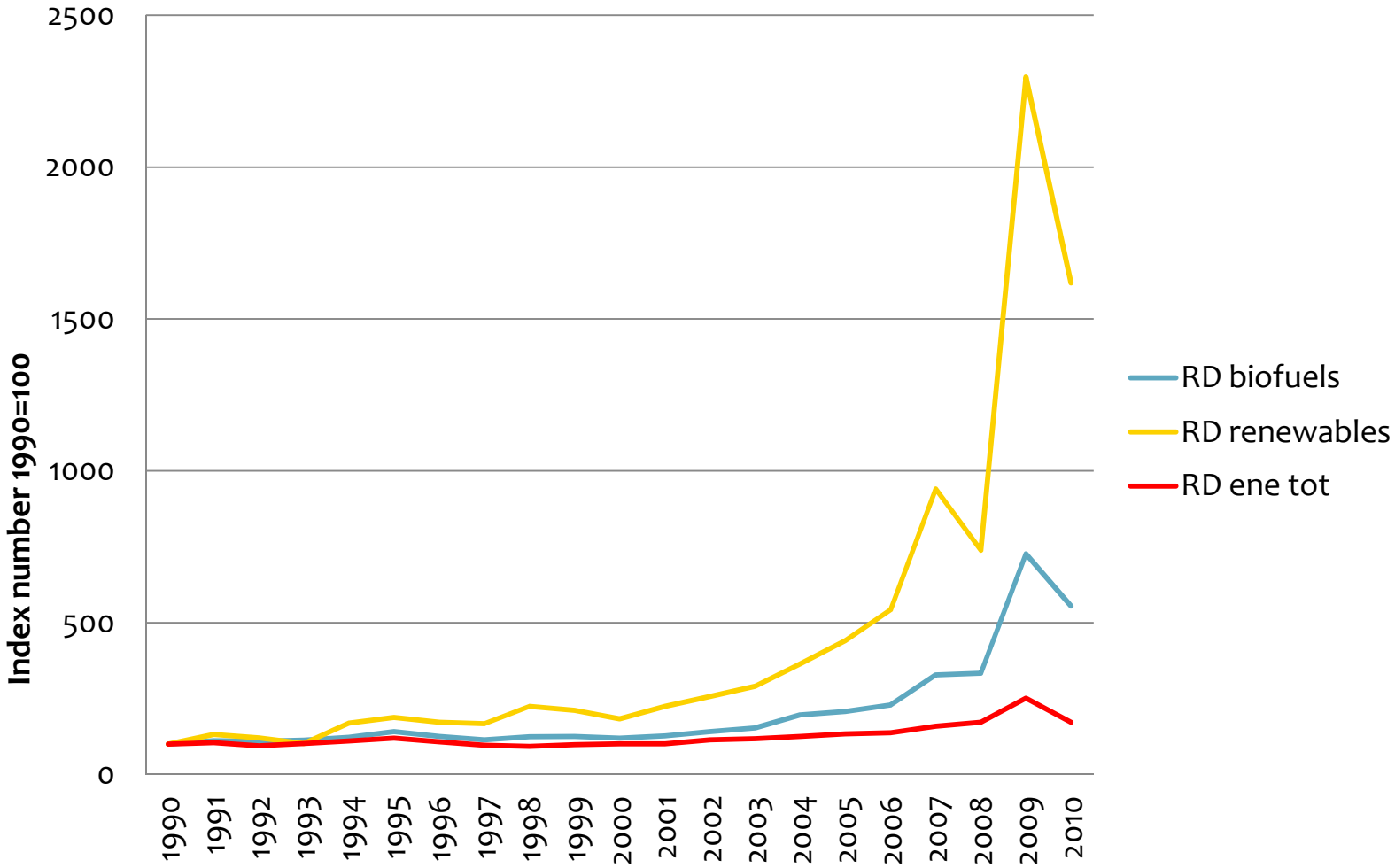
- **Water, waste and pollution control** –water, waste and pollution management and control, including water conservation, treatment and supply.

Share of climate-related innovation in total innovation in comparison with oil prices

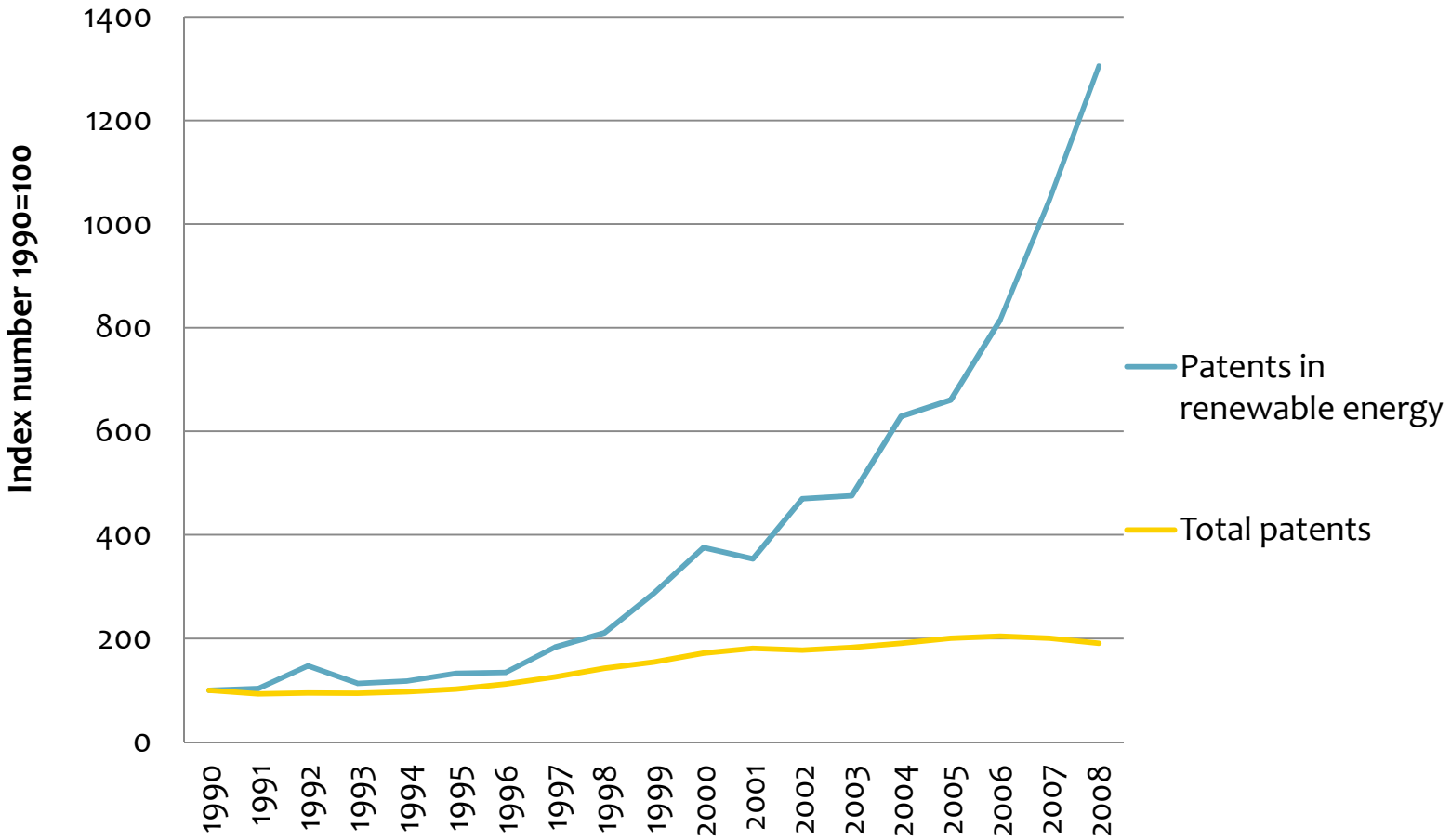
Source: Authors' calculations, based on PATSTAT data



Trends In public RD in energy sectors (IEA, 2012)



Trends in patents application, total and renewable energy (OECD-PATSTAT, 2012)

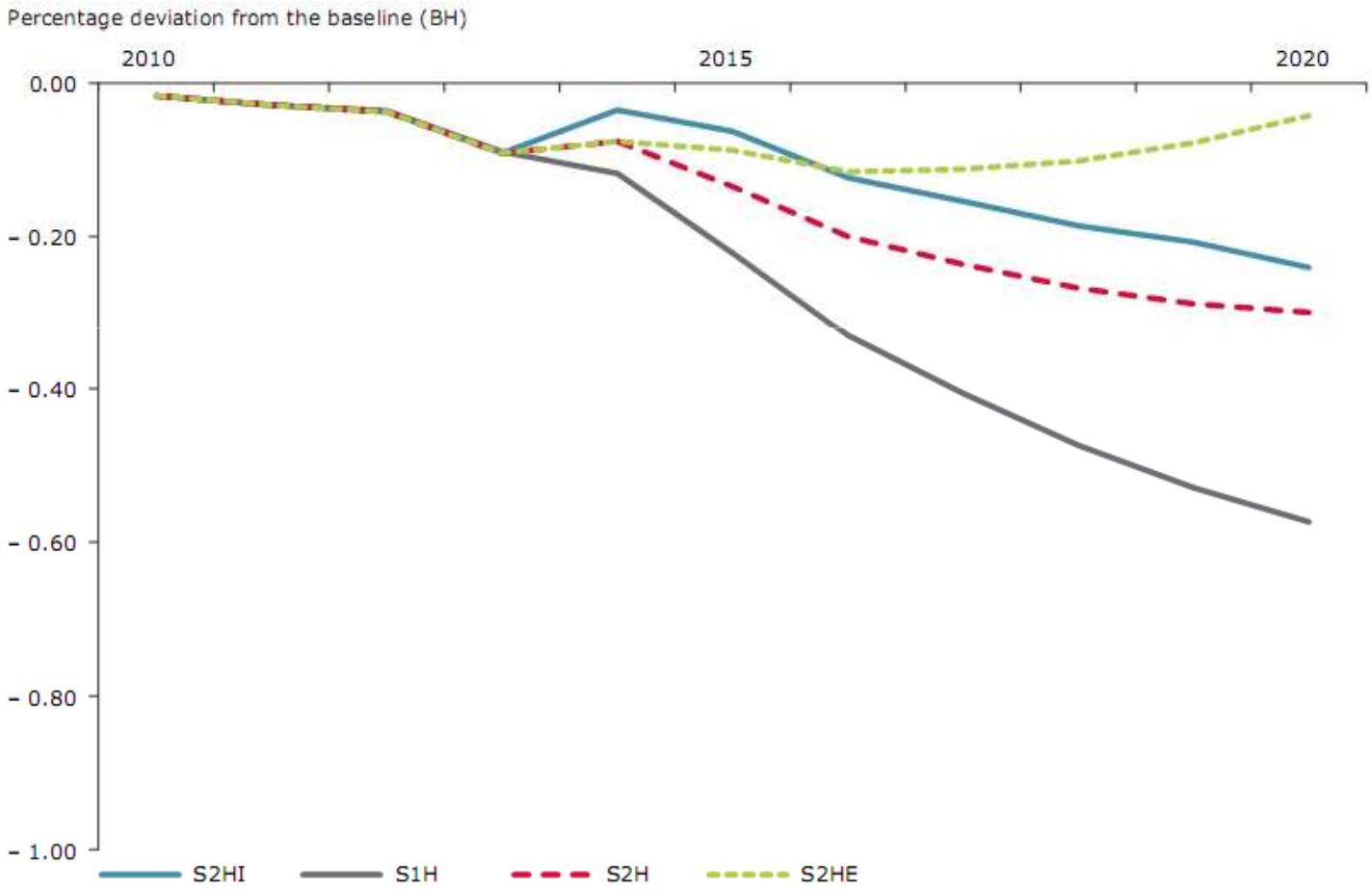


Definition of EI: the EU evidence

- **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**
- **Environmental tax reform in Europe: opportunities for eco-innovation (EEA Technical report No 17/2011).**
- **Revision of the Energy Tax Directive 2003/96/EC** (introducing a direct carbon tax on CO_2 emissions it must give a big push to the use of renewable energy and encourage more efficient technologies in the use of carbon fuels)

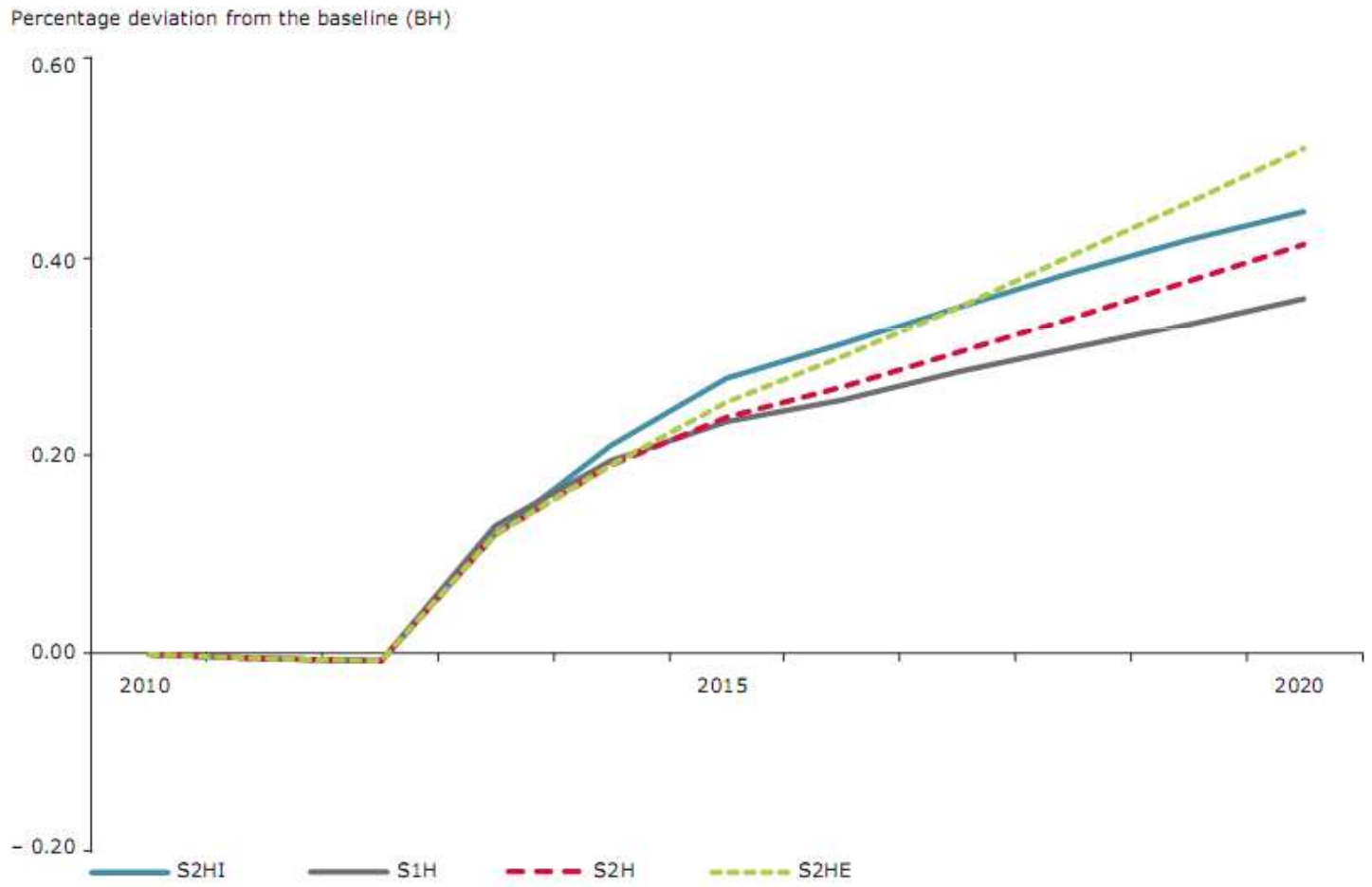
Definition of EI: the EU evidence

Figure 3.1 EU-27 GDP according to four scenarios — deviation from the baseline (BH)



Definition of EI: the EU evidence

Figure 3.2 EU-27 employment according to four scenarios — deviation from the baseline (BH)



The case of biofuels

* A dramatic increase in oil prices volatility
* A growing concern about the consequences of carbon emissions from fossil fuels
* Persistent carbon lock-in in the transport sector

Interest in producing biofuels from agricultural crops

The case of biofuels

- Study the rate and direction of technological change in the biofuels sector
- Collect data about innovation output in the biofuels sector
- Describe the evolution of the biofuels sectoral system of innovation
- Analysis of the geographical distribution of technological knowledge in this field
- Analysis of the impact of technology and environmental policies on technological change in the biofuels sector

The case of biofuels

- **Biofuels system of innovation** (Hillmann et al., 2008; Negro et al., 2008; Suurs and Hekkert, 2009): analysis of the sectoral system of innovation for systematically mapping those processes taking place in innovation systems and resulting in technological change, by adopting a **process analysis** or history event analysis (qualitative analysis)
- Mapping innovation output of the biofuels sectors by using ethanol-related patents in the US Patent Office (based on the patent classification sub-classes for each year) as described in Karmarkar-Deshmukh and Pray (2009).

Patents classification

- Classification is fundamentally a technical problem related to how patent data are allocated and organized in international databases
- Every patent office places each patent in at least one class providing a code named IPC (International Patent Classification)
- Classification criteria are based on chemical and technological principles, occasionally related to economic sectors (the manufacturing process)
- In order to tackle the lack of specificity from an economic point of view it is possible to follow 2 different approaches

Keywords

IPC selection

Keywords

Several researchers have developed different methodologies essentially based on the exploitation of catchword tools and literature scrutiny

The literature followed three main approaches:

- Co-word study based on the keywords proposed by experts (Looze and Lemarie, 1997)
- Extraction of keywords from title and abstract of patents (for instance Corrocher et al., 2007 with triples applied ex-post)
- Use of descriptors chosen by professional indexers employed in patent offices and research engines (Coulter et al., 1998)

The case of biofuels: IPC classes

The World Intellectual Property Organization (WIPO) supported the creation of the IPC **Green Inventory** (GI). The inventory consists in a list of IPC classes that are suitable to contain patents related to green technologies.

GI assigns to each class an object the is not the IPC class object. For example, the class A01H, which, according to GI, is suitable for containing patents related to "liquid biofuels obtained by genetically engineered organisms", can actually contain, according to the IPC, all the patents that fall into the category (subclass title) "new plants or processes for obtaining them, plant reproduction by tissue culture techniques".

At present, the GI website does not display any statistics on the effective number of patents in each class that are also coherent with the object assigned (as a sort of **validation**).

The case of biofuels: IPC classes

We validated a sample of patents included in the IPC classes indicated above by asking a **team of experts** from the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (**ENEA**) to check their coherence.

Using Thomson Innovation Router, we tested the IPCs related to biofuels as follows:

- Extraction of all patents for the 45 classes (from 4 to 10 digits) for USPTO granted, EPO application and granted and WIPO applications, from 01-01-1990 to 31-12-2010
- Elimination of duplicates (ending up with 107,161)
- Random selection of a 1% sample of the total amount of patent
- Sample validation (distinguishing between patents with a **direct** application in the biofuel production process and an **indirect** one)

The case of biofuels: IPC classes

On average, only 25% of the patents included in the sample has an application in the biofuels sector

Some examples of the GI classes:

IPC Subgroup and subclass	N. of patents	Technologies (hierarchical definition)	IPC name
A01H	20,189	Biofuels –Liquid fuels -From genetically engineered organisms	New plants or processes for obtaining them
C07C 67/00	9,671	Biofuels – Liquid fuels - Biodiesel	Preparation carboxylic acid esters
C10L 1/00	2,713	Biofuels – Liquid fuels	Liquid carbonaceous fuels
C12N 9/24	2,754	Biofuels – Liquid fuels - Bioethanol	Enzymes acting in glycosyl compounds
C12P 7/64	1,931	Biofuels – Liquid fuels - Biodiesel	Carboxylic acid esters (fats)

The case of biofuels: skipping weaknesses

- The patents related to biofuels are highly spread among several IPC classes because the technology that characterizes the sector basically consists in thermo/bio-chemical processes that can find various application in several fields
- A keywords approach can be more appropriate.
- Using exclusively the triples of words approach is more appropriate when the investigated sector is sufficiently wide to cover an entire section of the IPC (which is not the case for biofuels). Moreover, it is also more appropriate when patents' novelty is based on engineering contents, which are more likely to fit into ad hoc classes
- Expanding the use of keywords to descriptions and claims is more likely to catch all patents with a hypothetical, and not necessarily direct, utility in the biofuels production system

The case of biofuels: skipping weaknesses

- Selecting keywords might reflect **preconceptions**, different backgrounds and points of view of the words' selectors and differences in the training and backgrounds of professional indexers. In order to skip over this issue we decided to consult a **team of technical experts in the field of biofuels** to complete the list of keywords derived from the scrutiny of a consistent number of scientific publication and from the keywords list given by Scopus

IPC Classes:

- The method used by several international organizations, which includes all patents directly or indirectly linked each other's through IPC in a single family, is not appropriate when it comes to work on patents highly spread among IPC classes, since it is more likely to consider external elements
- As shown by our analysis, the WIPO green inventory classes maintain a high risk of including external elements

The case of biofuels: BioPat methodology

We divided keywords into:

1. "**raw material**". A consistent number of technical and scientific papers has been analysed to select the terms describing the biomass used (or potentially used) to produce biofuels
2. "**transformation process**", including pre-treatment process, chemical agents involved in the process and technical instrumentation used

Keywords selected by the scrutiny of scientific literature were then tested on "Scopus" http://www.scopus.com, a tool which provides access to a large number of scientific publications and, at the same time, allows to check the existence of patents containing the selected keywords

The final keywords selection comes from an iterative procedure which allows comparing results from scientific articles with results derived from patents in Scopus

All process-specific and raw material keywords were used jointly with a more general keyword (such as bio-diesel, bio-ethanol, bio-gas, bio-fuels)

Our keywords list has been checked by a team of experts from ENEA

The case of biofuels: BioPat methodology

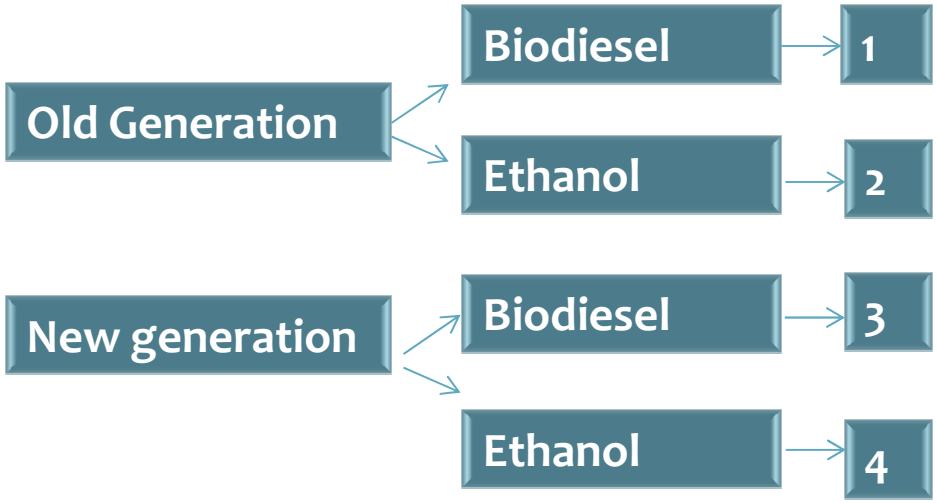
The download of patents has been carried out using Thomson Innovation. We downloaded information on patents from the following patent data offices:

WIPO Applications	published international patent applications, fully searchable, language: 70% English, 15% German, 5% French, 1% Spanish	01/01/1990 31/12/2010 Kind Code A1 and B1
US Granted	fully searchable, language: English	
European Granted, Applications	potentially 31 countries, fully searchable, language: 60% English, 30% German, 10% French	

By selecting patents related to keywords, it is also possible to assign specific categories to patents belonging to each keyword:

- raw material keywords have been grouped into 10 categories
- transformation process keywords have been grouped into bio-chemical route and thermo-chemical route

The case of biofuels: BioPat methodology



Examples of our classification

TYPE	KEYWORD	BLOC	GENERATION	DIESEL	ETHANOL
algae	Chlorella vulgaris	3-4	2	1	1
food	Corn	2	1	0	1
ligno	Miscanthus	4	2	0	1
oleaginous	Jatropha	3	2	1	0
sugar	Bagasse	2	1	0	1

The case of biofuels: BioPat validation

In order to link each patent with the nationality of a specific applicant, we looked for country codes in the variable "assignee address" obtaining information on 37 countries

Country	Count	Share	EPO	WIPO	USPTO	EPO %	WIPO %	USPTO %
US	272,234	21.1	81,038	103,124	88,072	30.5	39.6	11.5
JP	129,683	10.0	79,158	5,465	45,060	29.8	2.1	5.9
DE	84,675	6.6	20,693	6,882	47,100	7.8	6.5	6.1
CA	55,348	4.3	3,100	7,528	44,720	1.2	2.9	5.8
GB	40,288	3.1	15,481	17,717	7,090	5.8	6.8	0.9
CH	28,633	2.2	11,153	10,787	6,693	4.2	4.1	0.9
FR	26,715	2.1	8,405	5,827	12,483	3.2	2.2	1.6
NL	18,433	1.4	8,937	5,802	3,694	3.4	2.2	0.5
Others	535,224	41.4	7,150	49,761	478,313	2.7	19.1	62.4

The case of biofuels: BioPat validation

All the patents downloaded using our methodology amount to 1,293,197 patents (21% EPO, 59% USPTO, 20% WIPO).

Given the difficulty of managing data deriving from different patent offices at the same time, we decided to start with EPO, since it significantly reduces data management problems compared with other sources.

We asked the team of experts from ENEA to validate the same classes indicated in the **GI filtered with our keywords**.

The sample was built as follows:

- we took the EPO patents in our database;
- we selected the patents that shown at least one IPC class indicated by the GI;
- we eliminated the duplicates; and
- we delivered 1% of the selected patents to the experts from ENEA.

The case of biofuels: BioPat validation

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	Green Inventory	Share of biofuels related patents between direct and indirect application	Green Inventory filtered by keywords	Share of biofuels related patents between direct and indirect application
Direct application in biofuels	5%	28	15%	40
Indirect application in biofuels	14%	72	23%	60
Total	19%		38%	

The case of biofuels: BioPat description

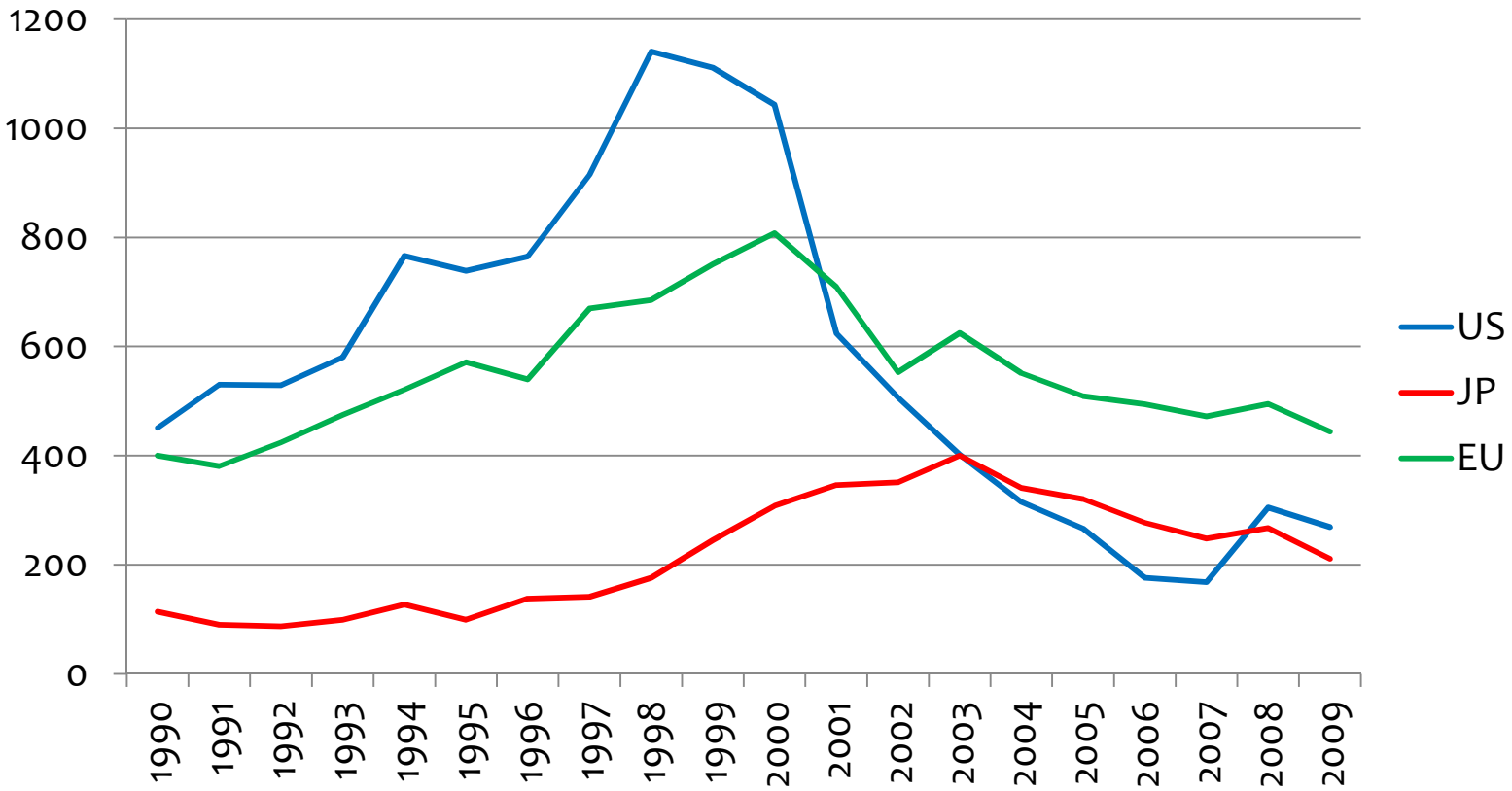
The database obtained by Thomson Innovation consist in 72 different fields that can be classified as follows:

- Patent identification (international, national and office codes, etc.)
- Patent object (title, description, claims, abstract, etc)
- Patent owners (applicants, inventors, assignee, buyers, etc)
- Patentability process stages and dates
- Patent opposition (other claims on the invention)
- Patent quality (citations)

Publication Number, Title (Original), Title (English), Abstract, Abstract (English), Claims, Claims Count, Claims (English), Description, Assignee/Applicant, Assignee/Applicant First, Assignee – Standardized, Assignee – Original, Assignee - Original w/address, Assignee Count, Inventor, Inventor First, Inventor – Original, Inventor - w/address, Inventor Count, Publication Country Code, Publication Kind Code, Publication Date, Publication Month, Publication Year, Application Number, Application Country, Application Date, Application Year, Priority Number, Priority Country, Priority Date, Priority Year(s), Related Applications, Related Application Number, Related Application Date, Related Publication Number, Related Publication Date, PCT App Number, PCT App Date, PCT Pub Number, PCT Pub Date, IPC – Current, IPC Class, IPC Class Group, IPC Section, IPC Subclass, IPC Subgroup, IPC Class First, IPC Class Group First, IPC Section First, IPC Subclass First, IPC Subgroup First, ECLA, US Class, US Class – Main, US Class – Original, Locarno Class, Cited Refs – Patent, Count of Cited Refs – Patent, Cited Refs - Non-patent, Count of Cited Refs Non-patent, Citing Patents, Count of Citing Patents, Citing Pat 1st Assignee, Litigation (US), Opposition (EP), Opposition (EP) – Opponent, Opposition (EP) - Date Filed, Opposition (EP) – Attorney, Language of Publication

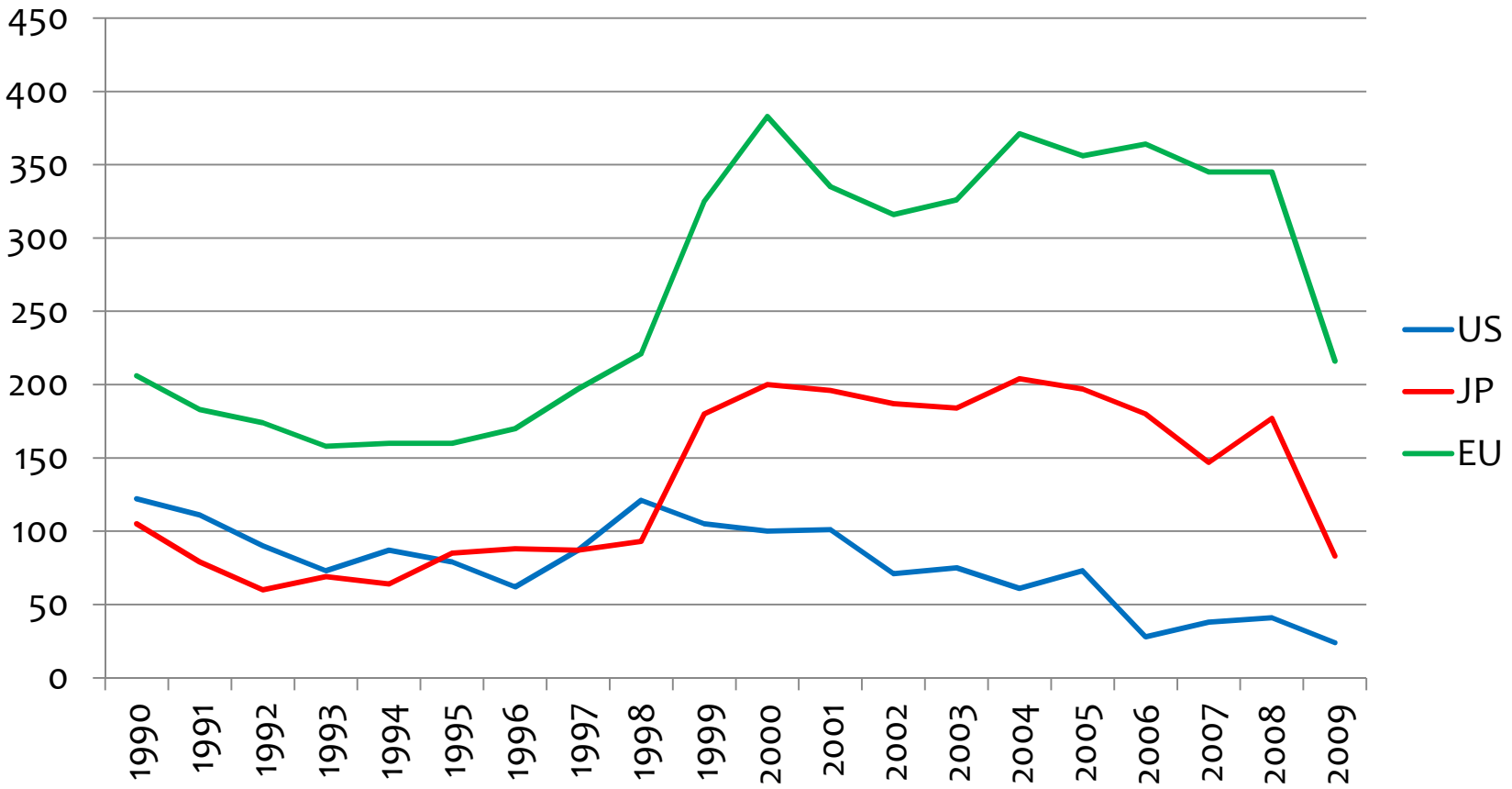
The case of biofuels: BioPat description

EPO patents count (application) by country and year, Green Inventory



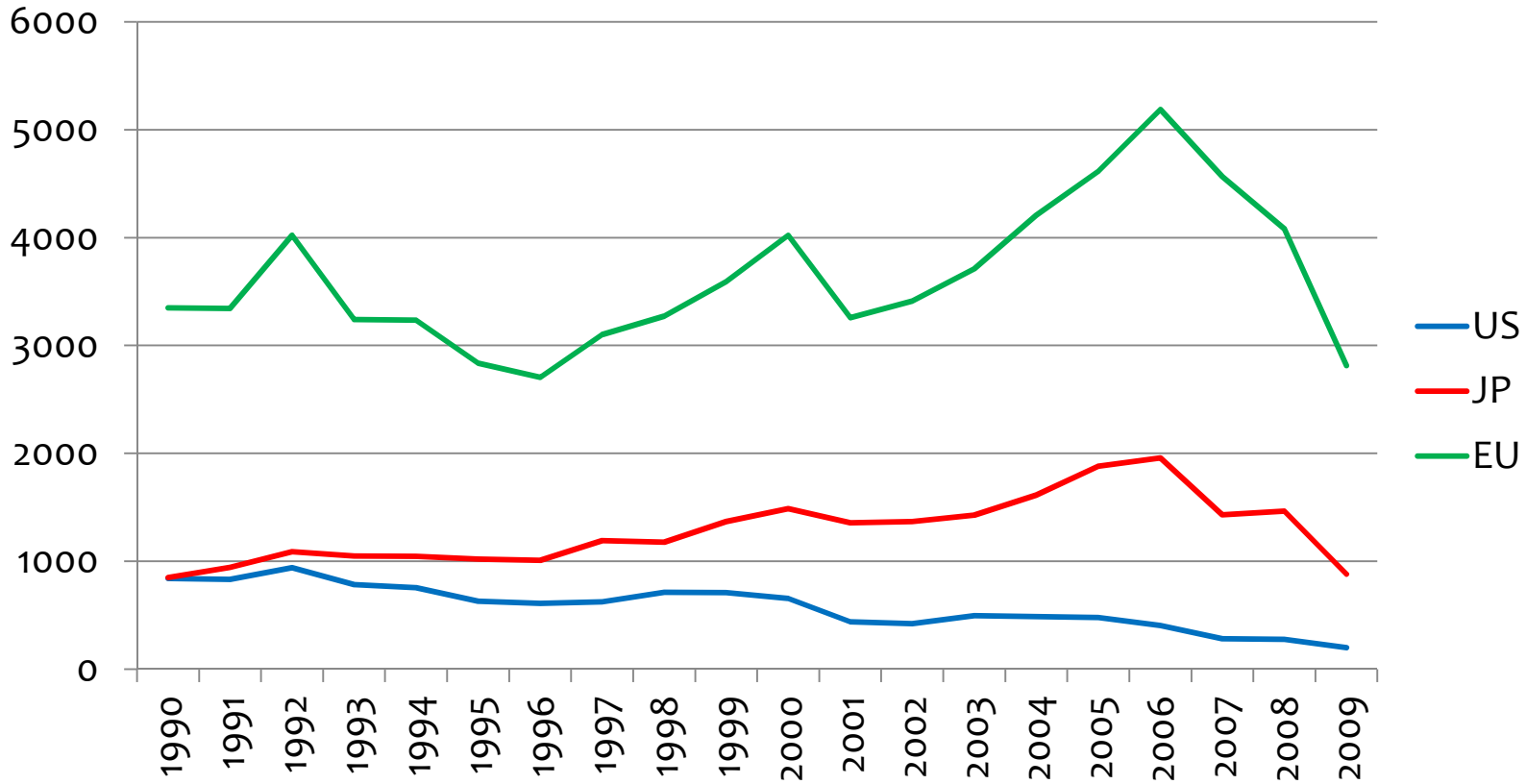
The case of biofuels: BioPat description

EPO patents count (application) by country and year, Green Inventory in Biopat



The case of biofuels: BioPat description

EPO patents count (application) by country and year, Biopat



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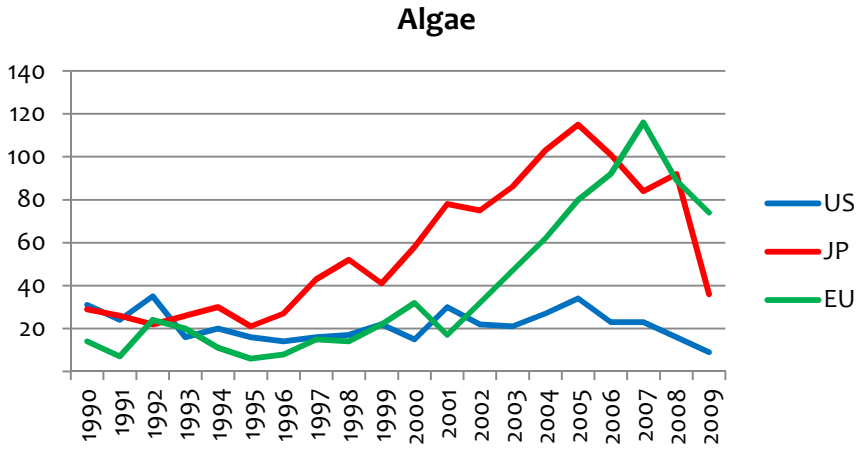

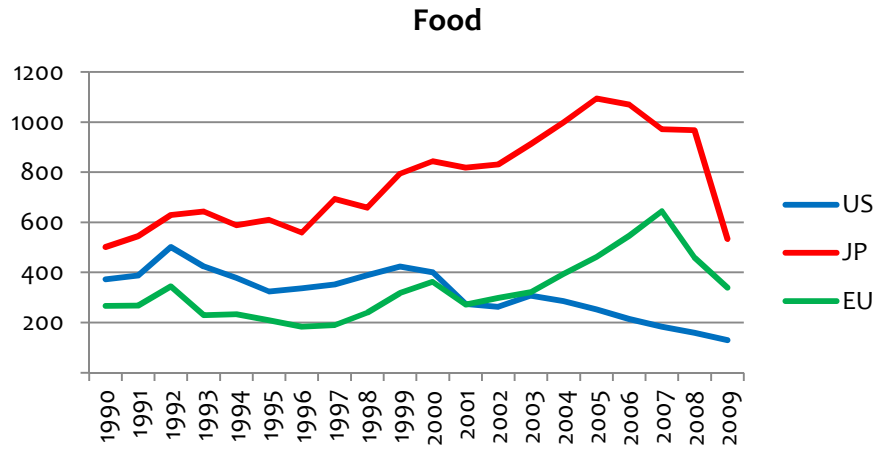

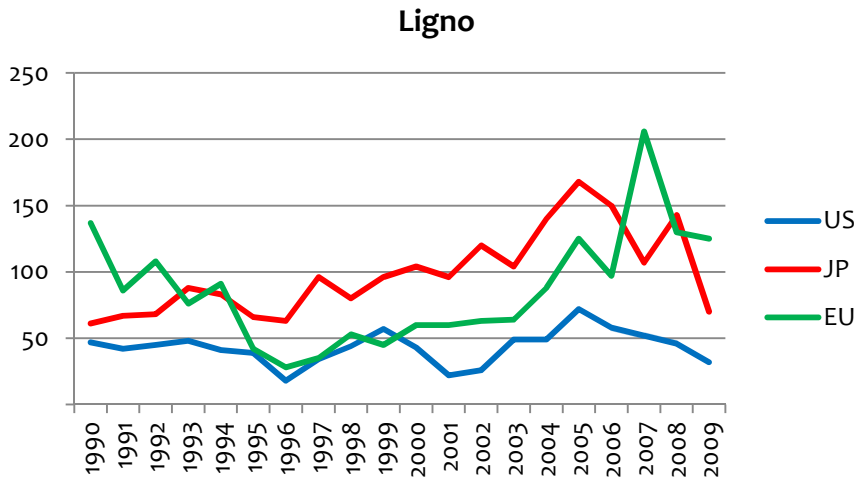

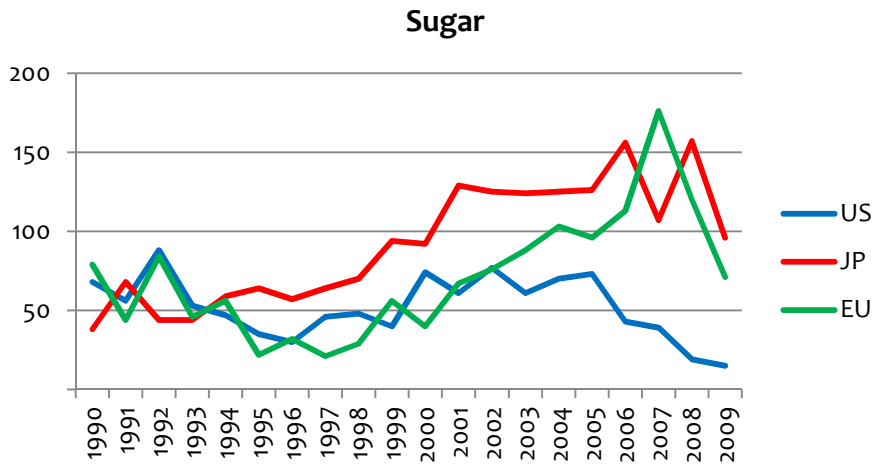

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

Technology

* Investments in R&D, domestic: Loschel (2002); (Smith, 2008); foreign: Poop (2006a)
* Technology stock, technological capabilities: Jaffe et al. (2006), Horbach (2008)
* Spill-over effects and technology learning: Clarke et al. (2006)
* Existing innovation system as a whole, Techno-Institutional Complex : Unruh (2000; 2002), (Smith, 2008)

Market

* Energy and resource prices: Newell et al. (1999; 2006); Poop (2002)
* Demand vs supply factors: Poop (2006; 2002); Beise and Rennings (2005); Nemet (2009)
* Factors internal to the firm: Del Rio Gonzalez (2009); Jaffe et al. (2006); Wagner (2007)

Regulation

* Policy stringency: Lanjouw and Mody (1996); Brunnermeier and Cohen (2003)
* Command&control vs market based, different policies for different types of technologies: Johnstone et al. (2010), Carraro et al. (2010)

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

- Country-level analysis are more common than panel analysis (recent years)
- **Dependent variable**
  - Patent count (for examined technologies): Johnstone et al. (2010); Popp (2006b); Johnstone et al. (2011);
  - Stocks of knowledge: Rave et al. (2011)
- **Explanatory variables**
  - R&D expenditure, domestic: Johnstone et al. (2010); Popp et al. (2011a; 2011b); Johnstone et al. (2011); foreign: Poop (2006b)
  - Total patents: Popp et al. (2010); Johnstone et al. (2010); Johnstone et al. (2011)
  - Stocks of knowledge: Popp (2002); Popp et al. (2011b)
  - Policies for examined sectors: Johnstone et al. (2010); Popp et al. (2011a); Johnstone et al. (2011)
  - GDP per capita: Popp et al. (2011a); Popp et al. (2011b)
  - Energy prices: Johnstone et al. (2010);
  - Energy consumption: Johnstone et al. (2010); Popp et al. (2011b)

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

- **Regulation** plays a key role in both the development and diffusion of environment-related technologies: Popp (2006); Popp et al. (2011) Johnstone et al. (2011)
- Broad-based policies (i.e. tradable energy certificates) induce innovation for technologies close to competitive fossil substitute, whereas targeted subsidies (i.e. feed-in tariffs) are needed for more costly technologies: Johnstone et al. (2010)
- **Policies** acts both on the demand (1) and supply (2) sides; (1) they affect relative prices, enhancing substitution between energy-intensive and non energy-intensive products (2) they favor substitution between inputs with different environmental characteristics: Carraro et al. (2010)
- Public pressure is a key factor in orienting public intervention and then innovation processes: Popp et al. (2011)
- A strongly oriented policy framework has the potential to direct technological change, with implications for policy design (Costantini and Crespi, 2011).
- Environmental policies and technology policies should be integrated in order to produce a significant impact on technological competitiveness in the energy sector (Costantini and Crespi, 2008).

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

The estimated equation is:

$$Y_{i,t} = \beta_0 + \beta_1(\text{INNOVATION}_{i,t-1}) + \beta_2(\text{POLLUTION}_{i,t-1}) + \\ + \beta_3(\text{REGULATION}_{i,t-1}) + \beta_4(\text{CONTROLS}_{i,t}) + \delta_t + \varepsilon_{i,t}$$

where i=1,…,35 indexes countries, t=1990,…,2008 indexes time and δt is time fixed effect to control for cyclical variations in the number of patent count

Our dependent variables, pc_gi, pc_kw, and several bloc-specific pc_kw are:
- count variables (non-negative integer values)
- strongly overdispersed (variance greater than the mean)
- with approximately 20% of 0

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

Variable name	Definition	Source
	Dependent variables	EPO
Patent count IPC	Patent count IPC classes in Green Inventory	EPO
Patent count KEYWORDS	Patent count selected by keywords or bloc	
	Regressors	
Gerd % GDP	Gross domestic expenditure on R&D as a percentage of gdp	OECD
Total Patents per capita	Total number of patent application by residents per 1000 habitants	World Bank
Specific Patent stock	Stock of past applied patents (calculated on past values of the dependent variable as $= ln \sum_{s=0}^{t} \mathrm{PAT}_{is}^{k} e^{[-\beta_1(t-s)]}$ where PAT_{is}^{k} represents the number of patents produced in bloc k in country i in year s and s represents an index of years up to and including year t, whereas is the decay rate (=0.15).	EPO
Carbon intensity	Ratio between CO2 emissions (kt) and GDP in PPP (current international $)	World Bank
Energy consumption	Total energy used including petroleum products, natural gas, electricity, and combustible reneewable and waste as % of GDP in PPP (current international $)	World Bank
Road energy consumption	Total energy used in the road sector including petroleum products, natural gas, electricity, and combustible reneewable and waste as % of GDP in PPP (current	World Bank
Export %GDP	Total export value as % of GDP	World Bank
Excise exemption (biofuels)	Value of excise tax reductions for bioethanol and biodiesel (US $ per litre), simple average. Normalised by the maximimum and minimum value in each year	GSI
Excise exemption (bioethanol)	Value of excise tax reductions for ethanol (US $ per litre). Normalised by the maximimum and minimum value in each year	GSI
Excise exemption (biodiesel)	Value of excise tax reductions for biodiesel (US $ per litre). Normalised by the maximimum and minimum value in each year	GSI
Fuel mandate	Mandates for miscelation targets for ethanol and biodiesel consumption on gasoline and diesel	GSI

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

Basic models for count data

* Poisson Regression Model (PRM)
* Negative Binomial Model (NBM)

PRM assumes equidispersion. If this fails to be true, the estimates are consistent but the standard errors are biased downward

incorrect inference

NBM explicitly models overdispersion. If the variance specification is correct, the model is consistent and more efficient than the PRM

The case of biofuels: BioPat for the analysis of EI drivers. The modeling choice

Choice of the model

1. We fit both models and perform a LR Test on the overdispersion parameter: the NBM is a significantly better fit

2. Hausman specification Test: fixed effect estimators

(in the NBM 'fixed effect' refers to the distribution of the overdispersion parameter)

Fixed Effect Negative Binomial Model is used

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	Patents IPC green inventory			BioPat		
	(1)	(2)	(3)	(4)	(5)	(6)
Gerd % GDP	0.66***			1.44***		
Total Patents per capita		-0.13			0.18**	
Specific Patent stock			0.29***			0.69***
Carbon intensity	-1.04***	-0.74**	-1.33***	-1.70***	-2.12***	-1.81***
Excise exemption (biofuels)	-0.11	-0.18*	-0.08	0.30***	0.20**	0.13**
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	294	323	332	294	323	340
ll	-1016	-1096	-1139	-1046	-1154	-1181
chi2	124	142	160	217	161	314

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	BioPat					
	(1)	(2)	(3)	(4)	(5)	(6)
Gerd % GDP	1.29***			1.39***		
Total Patents per capita		0.27***			0.43***	
Specific Patent stock			0.72***			0.66***
Carbon intensity	-0.79	-1.56***	-0.84**	-0.72	-1.52***	-0.95**
Excise exemption (biofuels)	0.33***	0.24***	0.17***	0.33***	0.22***	0.19***
Export %GDP	0.85***	1.38***	0.52***	0.70***	1.15***	0.70***
Energy consumption	0.15	0.42***	-0.16			
Road energy consumption				0.03	0.48*	0.20
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	294	323	340	294	323	340
ll	-1035	-1128	-1165	-1035	-1130	-1165
chi2	282	281	431	282	272	417

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	BioPat			
	(1)	(2)	(3)	(4)
Total Patents per capita	0.27***	0.26***	0.29***	0.23**
Carbon intensity	-1.40***	-1.40***	-1.42***	-1.62***
Excise exemption (biofuels)	0.25***			
Excise exemption (bioethanol)		0.26***		
Excise exemption (biodiesel)			0.23***	
Fuel mandate				-0.06
Export %GDP	1.31***	1.29***	1.33***	1.32***
Energy consumption	0.53***	0.57***	0.49***	0.50***
Dummy biodiesel	0.77*	0.75*	0.80**	0.60
Year dummies	Yes	Yes	Yes	Yes
N	323	323	323	323
ll	-1127	-1126	-1128	-1132
chi2	308	312	300	264

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	Bioethanol			Biodiesel		
	(1)	(2)	(3)	(4)	(5)	(6)
Total Patents per capita	0.29***	0.27***	0.32***	0.26**	0.25**	0.27**
Carbon intensity	-1.53***	-1.53***	-1.58***	-1.36***	-1.39***	-1.37***
Excise exemption (biofuels)	0.32***			0.29***		
Excise exemption (bioethanol)		0.34***			0.30***	
Excise exemption (biodiesel)			0.30***			0.28***
Export %GDP	1.18***	1.16***	1.20***	1.51***	1.49***	1.54***
Energy consumption	0.50***	0.56***	0.43**	0.69***	0.72***	0.66***
Dummy biodiesel	0.88**	0.86**	0.90**	0.78*	0.71	0.87*
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	323	323	323	323	323	323
ll	-1039	-1038	-1040	-989	-988	-990
chi2	293	298	284	264	268	258

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	Food				Sugar	
	(1)	(2)	(3)	(4)	(5)	(6)
Total Patents per capita	0.46***	0.45***	0.47***	0.38**	0.36**	0.40**
Carbon intensity	-1.59***	-1.59***	-1.66***	-2.50*	-2.30	-2.94**
Excise exemption (biofuels)	0.37***			0.33**		
Excise exemption (bioethanol)		0.38***			0.41***	
Excise exemption (biodiesel)			0.35***			0.23
Export %GDP	1.45***	1.42***	1.49***	0.80*	0.81*	0.78
Energy consumption	0.44***	0.47***	0.40***	0.57**	0.61***	0.53**
Dummy biodiesel	0.35	0.30	0.39	1.06	1.01	1.04
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	323	323	323	323	323	323
ll	-1002	-1001	-1003	-630	-629	-632
chi2	245	250	236	165	171	162

The case of biofuels: BioPat for the analysis of EI drivers. Main results

	Ligno			Algae		
	(1)	(2)	(3)	(4)	(5)	(6)
Total Patents per capita	-0.01	0.01	-0.02	0.31	0.31	0.28
Carbon intensity	-2.24**	-2.19**	-2.47***	-4.19***	-4.10***	-4.74***
Excise exemption (biofuels)	0.21			0.58***		
Excise exemption (bioethanol)		0.23*			0.60***	
Excise exemption (biodiesel)			0.16			0.49**
Export %GDP	0.39	0.36	0.33	2.35***	2.23***	2.56***
Energy consumption	0.62***	0.60***	0.60***	1.36***	1.32***	1.40***
Dummy biodiesel	-13.62	-13.97	-12.83	1.10	1.02	0.92
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	323	323	323	323	323	323
ll	-631	-631	-633	-491	-489	-493
chi2	181	183	173	311	316	300

Conclusions

* Green systems of innovations is an intriguing field of analysis
* Great policy concern!
* Need to use appropriate data
* Environmental/energy policy spurs innovation in the biofuels sector
* Relevant links between innovation/energy/environmental policies
* Need for strong policy co-ordination

THANK YOU!

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