Intra-EU knowledge flows in the renewable energy sector: A patent citations analysis

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Motivation

- The EU has been at the forefront of climate policy in the last decades and set ambitious green growth and sustainability targets
- Yet, many lament that the EU research and innovation system is very fragmented
- Steps should be taken to foster integration and more effective knowledge creation

Motivation

In this paper, we ask whether environmental policy has contributed to the integration of the EU renewable energy innovation system

Preliminary results show that EU commitment to sustainability and climate mitigation:

- increased the knowledge flow between EU countries
- pushed the EU closer to the frontier and made it a source country for knowledge spillovers
- Yet, EU is still poorly integrated if compared with US or JP

Outline

- Motivation
- Framing the research question
- Environmental policy in the EU
- Literature
- Data and Descriptive
- Empirical approach
- (Preliminary) results
- Conclusions

Framing the research question

Vast literature exploring the inducement effect of environmental policy instruments on innovation (but also on productivity, competitiveness, trade -- Popp et al. 2011)

Static efficiency: environmental policy lowers the relative price of the clean technology option, directly fostering adoption and diffusion

Dynamic efficiency: EP provides incentives to invest in innovation and improve clean technologies, but also increases the knowledge stock which allows to "stand on the shoulder of the giants"

Framing the research question

Did environmental policy commitment in the EU *also* affected the geographical distribution of knowledge spillovers?

Analysis of (indirect) knowledge flows:

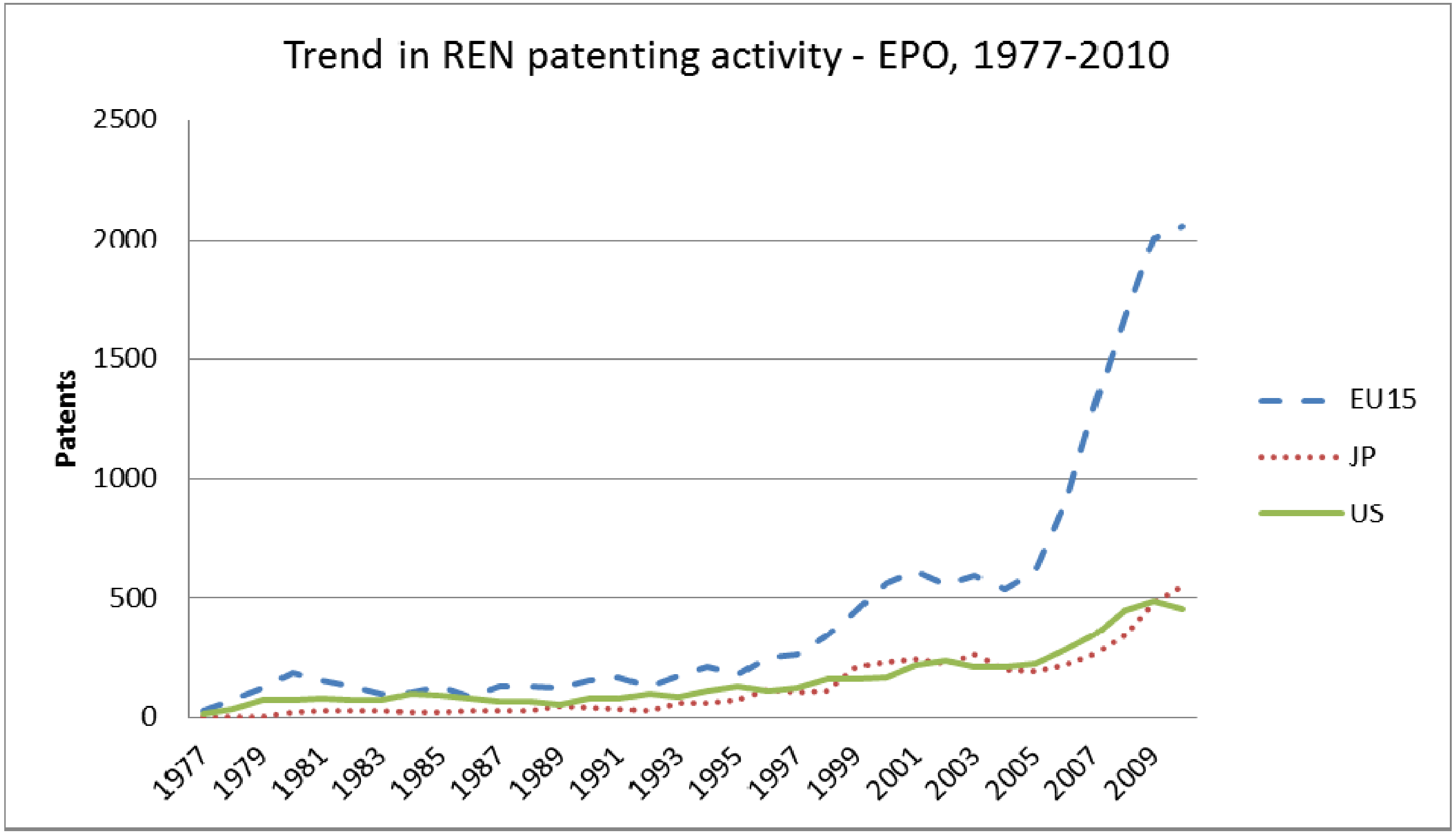
- *Intensity*: closeness/integration
- *Direction*: frontier innovators/major source of knowledge

This has implications not only to assess the **cost of climate mitigation**, but also to understand the potential impact of EP on **firms competitiveness** and on the EU ambition to become an **innovation hub**

EU Environmental Policy

- EU environmental policy: mainly *demand-pull* measures
- *technology-push* policies (SET-PLAN, 2008) still in the making
- **White Paper (1997):** cornerstone of EU environmental policy ⟶ increase renewable energy use by stimulating demand
- Signal of EU commitment to sustainability
- Could have indirect effect on integration

EU Environmental Policy



Change also in the patterns of knowledge flows?

Literature

We measure **knowledge flows** focusing on **patent citations**

- Focus is on codified knowledge
- Shortcomings linked with patent (and citation) indicators: "valid but noisy measure of technology spillovers" (Jaffe et al. 1998)

Relevant strands of the empirical literature

- Analysis of knowledge flows across countries by estimating the probability of citation (Jaffe and Trajtenberg, 1999; Popp, 2006; Hu and Jaffe, 2003; Hu, 2009)
- Patent citations to test whether geographic distance or institutional features represent barriers for the diffusion of knowledge across EU areas (Maurseth and Verspagen, 2002; Fisher et al., 2009; Le Sage et al. 2000)

Data and Descriptive

- Patent application at EPO between 1985 and 2010 (EP-CRIOS)
- Wind, solar, geothermal, hydroelectric, ocean, biomass and waste (*)
- IPC code – alternatively, Y02 code
- Assigned to EU15, US and JP based on inventor country
- Data on EU15 Member States are pooled (EU15 as a single region)
- *Backward citations* to previous EPO REN patents assigned to EU15, US and JP
- Within EU15: *national* citations and *international* citations

Data and Descriptive

Country	*REN Patents*	*Percent*	*Citations*	*Avg Citation/Patent*
EU15	14,263	0.62	26,311	1.84
JP	4,169	0.18	7,489	1.80
US	4,730	0.20	13,195	2.79
Total	23,162	1	46,995	2.03

Data and Descriptive

Percentage distribution of backward citations by country

Cited patents: 1987-1990 -- Citing patents: 1987-1997

	cited			
	EU15		**JP**	**US**
citing	*nat*	*int*		
EU15	0.38	0.23	0.09	0.30
JP	0.23		0.39	0.38
US	0.32		0.10	0.58

Data and Descriptive

Percentage distribution of backward citations by country

Cited patents: 2000-2003 -- Citing patents: 2000-2010

	cited			
	EU15		**JP**	**US**
citing	*nat*	*int*		
EU15	0.35	0.42	0.09	0.13
JP	0.24		0.65	0.12
US	0.40		0.16	0.44

Empirical Approach

- Raw citation shares are misleading, as they are affected by several factors (size of the potentially cited and potentially citing patents, specific patterns of citation between cohorts, truncation issues)
- We follow an established literature that focuses on the **probability of citation**

$$p_{iTjt} = \frac{C_{iTjt}}{(N_{iT})(N_{jt})}$$

- Estimate a double exponential model to explore whether there was a change in citation patterns

Empirical Approach

Empirical citation frequencies (p_{iTjt}) as function of lag btw citations

Empirical Approach

Double exponential knowledge diffusion model (J-T 1999)

$$p_{iTjt} = \alpha_T \alpha_t \alpha_{ij} [1 + \phi_{ij} * D_{post97}] \exp[-\beta_1 (T - t)] (1 - \exp[-\beta_2 (T - t)]) + \varepsilon_{iTjt}$$

α_{ij}: *relative* likelihood that the average patent *j* is cited by a patent from i → differences in the *intensity* of citations

ϕ_{ij}: additional likelihood of citation post97→ policy effect

Results

	(1)	(2)	(3)	(4)
Citing/cited country pairs ($\alpha_{i,j}$) [(a)]				
US citing US	1	1	1	1
US citing EU15	0.281***	0.195***	0.280***	0.193***
US citing JP	0.401***	0.402***	0.398***	0.398***
EU15 citing EU15	0.376***	0.344***		
EU15 citing EU15 (National)			0.624***	0.685***
EU15 citing EU15 (International)			0.268***	0.183***
EU15 citing US	0.258***	0.287***	0.259***	0.286***
EU15 citing JP	0.152***	0.156***	0.152***	0.155***
JP citing EU15	0.124***	0.127***	0.124***	0.125***
JP citing US	0.236***	0.238***	0.237***	0.238***
JP citing JP	0.967	0.976	0.972	0.978
Citing pattern differences for post-1997 patents (φ_{ij}) [(b)]				
US citing US		0		0
US citing EU15		0.562***		0.565***
EU15 citing EU15		0.114		
EU15 citing EU15 (National)				-0.097
EU15 citing EU15 (International)				0.541***
EU15 citing US		-0.116		-0.112
EU15 citing JP		-0.021		-0.018
JP citing EU15		-0.017		-0.011
Decay (β_1) [(b)]	0.294***	0.294***	0.297***	0.297***
Diffusion (β_2) [(b)]	0.001***	0.001***	0.001***	0.001***
No. of obs.	3159	3159	3510	3510

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Results (work in progress)

- **Choice of cut off**
  - ✓ Change the cut off pointless (average effect over two periods)
  - ✓ Interaction of country pairs with 2-years time dummies: no significant effects before 1997
- **Comparison with other fields or "average" patent**
  - ✓ Preliminary results with a random sample over all technological fields suggest that this is not a general trends, it could the effect of policy commitment
  - ✓ Comparison with "grey" and "dirty" technologies in electricity production: work in progress

Conclusions and policy implications

- Commitment to sustainability/environmental policies seems to have pushed EU to become a frontier innovator
- The integration of the EU innovation system in REN technologies is progressing but at a moderate pace
- The innovative activity at the EU level is still poorly integrated if compared to the American and Japanese experience
- Importance of introducing complementary technology-push policies

Thank you

Comments/suggestions welcome

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