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Transition Towards a Green Economy in Europe: Innovation and Knowledge Integration in the Renewable Energy Sector

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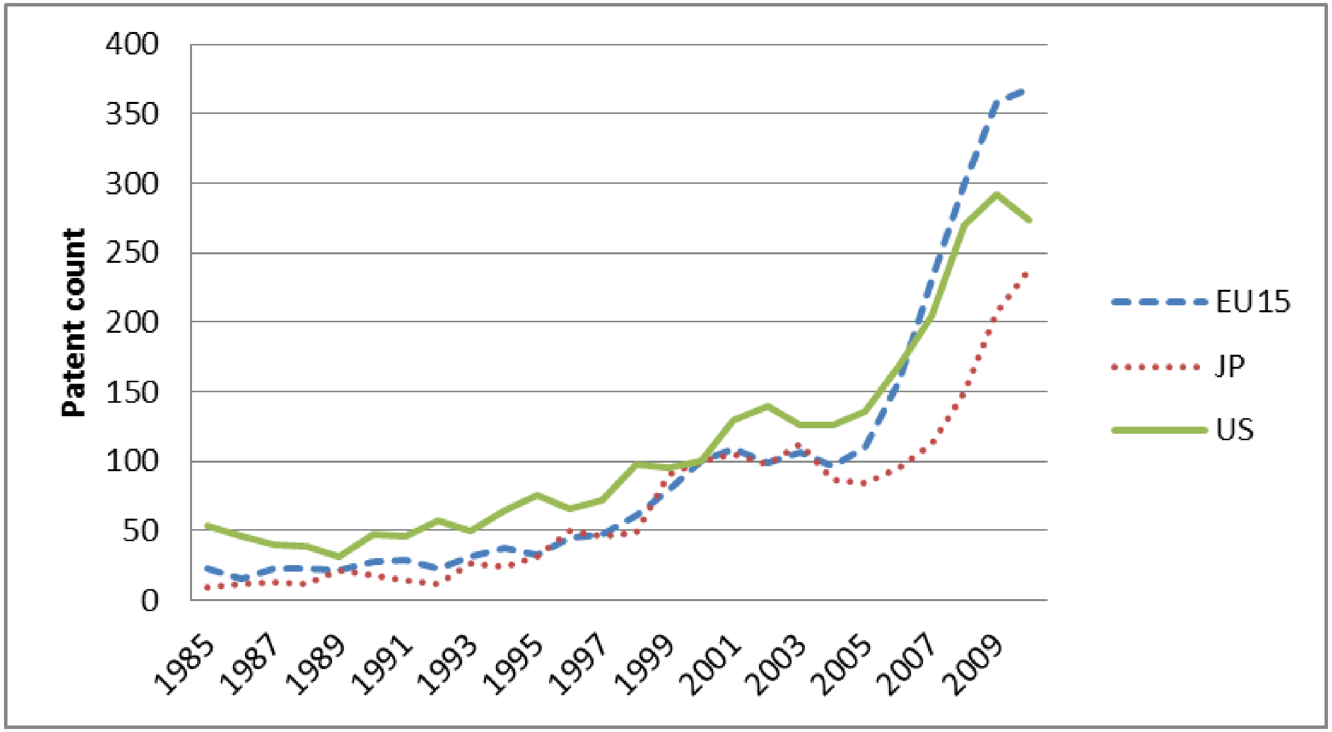
Motivation



Renewable EPO patents, by inventor country and priority year. (2000 = 100)

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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
    - EU research and innovation system is very fragmented (SET Plan, EC 2007; EC 2015)
    - Steps should be taken to foster integration and induce more effective knowledge creation
- fragmentation may hinder knowledge flows and, consequently, spillovers across member countries, thus reducing the EU technological base, suppressing opportunities for further innovations and hindering the movement towards the technological frontier.

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Preview

- This paper investigates the fragmentation of the EU innovation system in the field of renewable energy sources (RES) by estimating the intensity and direction of knowledge flows over the years 1985-2010.
    - relative performance of EU countries vis-à-vis other top innovators in this field
    - effectiveness of actions and policy support to promote RES development
- Our results show:
    - Increased knowledge flows across EU countries
    - pushed the EU closer to the frontier and made it a source country for knowledge spillovers
    - Yet, EU is still poorly integrated compared to US or JP

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Outline

1. Literature
2. Data and descriptives
3. Empirical approach
4. Maing Results
5. Robustness
6. Conclusions

Literature

- We measure knowledge flows focusing on **patent citations**
  - Focus is on codified knowledge
  - *Advantages* linked with patent and citation indicators:
    - Patents are a valid measure of innovation output
    - Citations provide linkages between innovations in the technology and geographical space
    - Available data: long time series, detailed classification, uniform evaluation procedures ensure cross-country comparisons
  - *Shortcomings* linked with patent and citation indicators:
    - noisy measure of innovation (Griliches, 1990)
    - noisy measure of technology spillovers (Jaffe et al. 1998)

Literature

- Citation patterns have been used to show that:
  - The intensity of knowledge flows declines with geographical distance (e.g. Bottazzi and Peri 2003; Peri 2005)
  - It increases with technological proximity (e.g. Jaffe and Trajtenberg, 1999; Hu and Jaffe, 2003; Hu, 2009)
  - National borders, language and institutional distance all represent an obstacle to knowledge diffusion (e.g. Maurseth and Verspagen, 2002)
  - The ability of a country to absorb foreign knowledge is related to its own technological base (Mancusi, 2008)
- A few applications also in energy and environment (Popp 2006, Verdolini and Galeotti 2011), but with a different focus

Data and descriptives

- Use patent applications at the EPO between 1985 and 2010 and their citations (EP-CRIOS Database)
- Patents assigned to EU15, US and JP based on the country of residence of the inventor
- Identify RES technologies using IPC codes: Hydro, Solar, Wind, Biomass, Geothermal, Ocean, Waste

RENEWABLE ENERGY TECHNOLOGIES

Country	*Patents*	*Percent*	*Backward citations*	*Avg Citation/Patent*	*Citations received*	*Received Citation/Patent*
EU15	14,263	0.62	24,478	1.72	23,082	1.62
JP	4,169	0.18	6,482	1.55	8,098	1.94
US	4,730	0.2	12,130	2.56	11,910	2.56
Total	23,162	1	43,090	1.86	43,090	1.86

Data and descriptives

RENEWABLE TECHNOLOGIES

Period of reference		**1987-1997**			
Cited country		EU15		JP	US
		Nat	*Int*		
Citing country	EU15	0.33	0.25	0.10	0.32
	JP	0.27		0.29	0.44
	US	0.34		0.12	0.54

Period of reference		**2000-2010**			
Cited country		EU15		JP	US
		Nat	*Int*		
Citing country	EU15	0.32	0.44	0.10	0.14
	JP	0.26		0.61	0.13
	US	0.41		0.17	0.42

Empirical approach

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

$$\alpha_T \; \alpha_t \; \alpha_{ij} \left[1 + \phi_{ij} * D_{2000}\right] \exp[-\beta_1 (T-t)] \left(1 - \exp[-\beta_2 (T-t)]\right) + \varepsilon_{iTjt}$$

- p_{iTjt}: probability of citation
- α_{ij}: relative likelihood that the average patent from i cites a patent from country j
- ϕ_{ij}: increase in the likelihood of citation from patents with priority after 2000
- We look at 3 regions (US, EU15, JP) and distinguish between EU_{nat} and EU_{int} citations
- Note: α_{ij} have to be interpreted with reference to the null of 1 and the reference group “US citing US”

Main Results

	(1)	(2)	(3)	(4)	(5)
Citing/cited country pairs (αi,j) [(a)]					
US citing US	1	1	1	1	1
	NA	NA	NA	NA	NA
EU15 citing EU15	0.384***				
	(0.013)				
EU15 citing EU15 (national)		0.582***	0.661***	0.647***	0.655***
		(0.022)	(0.045)	(0.043)	(0.044)
EU15 citing EU15 (international)		0.299***	0.249***	0.243***	0.246***
		(0.011)	(0.019)	(0.018)	(0.019)
EU15 citing US	0.279***	0.280***	0.317***	0.281***	0.314***
	(0.013)	(0.013)	(0.025)	(0.013)	(0.025)
EU15 citing JP	0.170***	0.170***	0.215***	0.171***	0.213***
	(0.008)	(0.008)	(0.022)	(0.008)	(0.022)
US citing EU15	0.315***	0.314***	0.314***	0.261***	0.264***
	(0.013)	(0.013)	(0.013)	(0.020)	(0.020)
US citing JP	0.470***	0.469***	0.468***	0.469***	0.468***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
JP citing EU15	0.140***	0.140***	0.139***	0.169***	0.170***
	(0.007)	(0.007)	(0.007)	(0.015)	(0.015)
JP citing US	0.262***	0.264***	0.263***	0.264***	0.264***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
JP citing JP	0.814***	0.817***	0.813***	0.819***	0.816***
	(0.038)	(0.038)	(0.039)	(0.039)	(0.039)

Main Results

Citing pattern differences since 2000 (ϕ_{ij}) *(b)*					
US citing US			0	0	0
			NA	NA	NA
EU15 citing EU15 (national)			-0.145**	-0.118*	-0.133**
			(0.063)	(0.065)	(0.065)
EU15 citing EU15 (international)			0.233**	0.272***	0.251**
			(0.098)	(0.101)	(0.101)
EU15 citing US			-0.147*		-0.135*
			(0.077)		(0.078)
EU15 citing JP			-0.244***		-0.233***
			(0.084)		(0.086)
US citing EU15				0.267**	0.245**
				(0.104)	(0.104)
JP citing EU15				-0.207***	-0.220***
				(0.079)	(0.079)
Decay (β_1) (b)	0.263***	0.264***	0.263***	0.263***	0.263***
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
Diffusion (β_2) (b)	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
N° of obs.	3,159	3,510	3,510	3,510	3,510

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Robustness

	(1)	(2)	(3)	(4)	(5)
Citing/cited country pairs (αi,j) [(a)]					
US citing US	1	1	1	1	1
	NA	NA	NA	NA	NA
EU14 citing EU14	0.550***				
	(0.022)				
EU14 citing EU14 (national)		2.020***	2.479***	2.411***	2.449***
		(0.097)	(0.209)	(0.203)	(0.207)
EU14 citing EU14 (international)		0.344***	0.277***	0.269***	0.273***
		(0.015)	(0.029)	(0.028)	(0.028)
EU14 citing DE	0.268***	0.270***	0.224***	0.218***	0.221***
	(0.012)	(0.012)	(0.028)	(0.027)	(0.027)
EU14 citing US	0.339***	0.343***	0.467***	0.342***	0.462***
	(0.018)	(0.018)	(0.045)	(0.018)	(0.044)
EU14 citing JP	0.162***	0.163***	0.192***	0.163***	0.189***
	(0.009)	(0.009)	(0.027)	(0.009)	(0.027)
DE citing DE	0.432***	0.435***	0.441***	0.429***	0.435***
	(0.017)	(0.017)	(0.033)	(0.032)	(0.032)
DE citing EU14	0.304***	0.306***	0.250***	0.244***	0.247***
	(0.014)	(0.014)	(0.025)	(0.024)	(0.024)
DE citing US	0.224***	0.224***	0.195***	0.224***	0.193***
	(0.011)	(0.011)	(0.018)	(0.011)	(0.017)
DE citing JP	0.179***	0.180***	0.233***	0.179***	0.231***
	(0.009)	(0.009)	(0.027)	(0.009)	(0.027)

Robustness

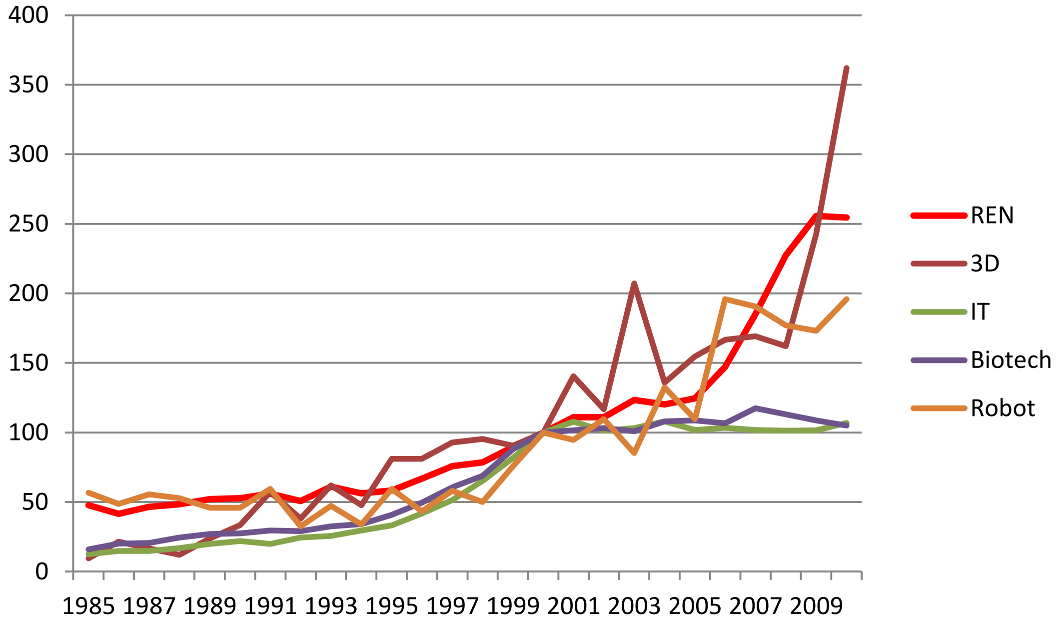
Citing pattern differences since 2000 (ϕ_{ij}) [(b)]			
US citing US	0	0	0
	NA	NA	NA
EU14 citing EU14 (national)	-0.237***	-0.204***	-0.222***
	(0.072)	(0.075)	(0.074)
EU14 citing EU14 (international)	0.264*	0.318**	0.287**
	(0.138)	(0.145)	(0.142)
EU14 citing DE	0.224	0.276*	0.247
	(0.158)	(0.165)	(0.162)
EU14 citing US	-0.335***		-0.324***
	(0.072)		(0.074)
EU14 citing JP	-0.181		-0.166
	(0.124)		(0.126)
DE citing DE	-0.026	0.016	-0.008
	(0.078)	(0.082)	(0.081)
DE citing EU14	0.259*	0.309**	0.281**
	(0.134)	(0.139)	(0.138)
DE citing US	0.181		0.201*
	(0.119)		(0.122)
DE citing JP	-0.278***		-0.265***
	(0.090)		(0.092)
US citing EU14		0.343**	0.312**
		(0.148)	(0.146)
US citing DE		0.251*	0.221
		(0.138)	(0.136)

Further Robustness

- Perform the same empirical exercise using highly efficient **fossil-based technologies**
- Fossil-based technologies allow producing energy by burning oil, coal or gas. They significantly reduce emissions per unit of energy in the short-to-medium term and, contrary to the case of RES, they do not imply a significant shift in the energy system
- Robustness meant to check if observed patterns are common to all energy technologies aimed at reducing emissions and not specific to RES
- Patterns we found in RES technologies after 2000 do not emerge here. In particular:
  - there is no evidence of any increase in cross-country/within EU15 citation intensity for fossil technologies - $\phi_{EU15,internat}$ is (negative and) not significant in all specifications.
  - there is no evidence of any increase in the likelihood that a US inventor cites a EU15 patent, which instead significantly decreases by 21 percent

Further Robustness

- Perform the same empirical exercise for each of the following **radically new technologies: 3D, IT, biotechnology, robot**
- Robustness meant to check if results emerging from the analysis of RES technologies also characterize other technologies at an early stage of development and with high economic potential



- None of the patterns we found in RES technologies after 2000 emerges.

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Further Robustness

- 8% of RES patents in our sample are “multiple-country” patents

REN TECHNOLOGIES		
	1985-1999	2000-2010
co-patenting EU15-EU15 on total EU15 patents	0.04	0.08
co-patenting EU15-US on total US patents	0.20	0.17

- Robustness meant to check if increasing intensity of citation across EU countries is due to increasing share of co-patenting (direct collaborations vs knowledge flows)
- We perform the same empirical exercise on a RES sample which excludes patents with multiple-country inventors
- All findings are strongly confirmed.

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Conclusions

- Positive message:
  - EU RES inventors have increasingly built “on the shoulders of the other EU giants”, intensifying their citations to other member countries and decreasing those to domestic inventors.
  - The EU strengthened its position as source of RES knowledge for the US.
- One potential explanation: the commitment of the EU to RES energy development and deployment supported and promoted stronger integration of the innovation space.
- However:
  - the process of EU technological integration is advancing at a moderate pace and innovative activities in RES at the EU level are still poorly integrated if compared to the US or Japan. EU15 inventors rely more on domestic innovation than on spillovers from other EU15 countries.
  - Moreover, knowledge spillovers from EU15 countries are lower as compared to knowledge spillovers from other top inventors

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Thank you!

Comments/suggestions welcome

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