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

E. Verdolini

joint work with:
C. Conti, M. L. Mancusi,
F. Sanna-Randaccio, R. Sestini

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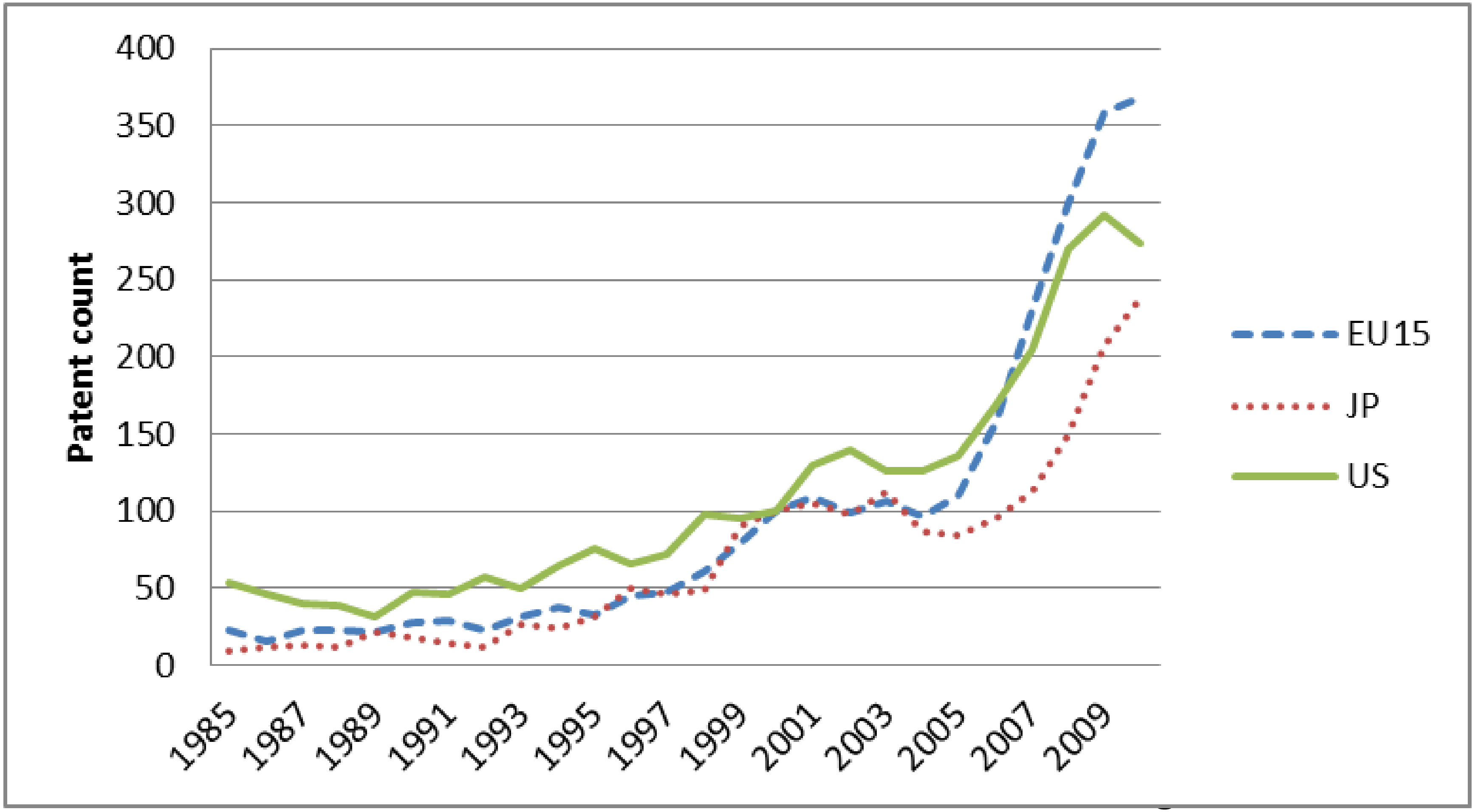
Motivation



Patent count
400
350
300
250
200
150
100
50
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
EU15
JP
US

Contribution

Investigate the fragmentation of the EU renewable (RES) innovation system by estimating the intensity and direction of knowledge flows over the years 1985-2010.

- Performance of EU countries vis-à-vis other top innovators
- For the EU, distinguish between domestic and other EU citations
- Focus on two periods: pre and post 2000
- (Indirectly) test the effectiveness of actions and policy support to promote RES development

Results

- Knowledge flows across EU countries increased
- The importance of the EU as a source country for knowledge spillovers increased
- Yet, EU is still poorly integrated compared to US or JP

Empirical Proxies

Patent citations

=

flows of codified knowledge

+ : Valid measures of linkages between innovations

+ : Widely used to study how knowledge diffuses across geographical and technological spaces, few applications in environmental/energy technologies

- : Noisy measures (Griliches, 1990, Jaffe et al. 1998)

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Data and Descriptives

- Patent applications at the EPO between 1985 and 2010 and their citations (EP-CRIOS Database)
- Patents assigned to EU15, US and JP (country of residence of the inventor)
- RES technologies identified by IPC codes: Hydro, Solar, Wind, Biomass, Geothermal, Ocean, Waste (but also Y02)

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

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Data: Citation patterns pre/post 2000

EU RES support (and innovation) ↑ steadily

What about knowledge flows?

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

EU15 ↑ EU15

EU15 ↓ US

US ↑ EU15

JP ↑↑ JP

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Empirical Approach

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

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

- α_{ij} → relative likelihood that the average patent from i is cited by patent from j
- ϕ_{ij} → increase in the likelihood of citation by patents applied for after 2000
- We look at 3 regions (US, EU15, JP), and distinguish between between EU_{nat} and EU_{int} citations

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Main Results

	α_{ij} (1)	α_{ij} (2)
Citing/cited country pairs (αi,j) [(a)]		
US citing US	1	1
	NA	NA
EU15 citing EU15	0.384***	
	(0.013)	
EU15 citing EU15 (national)		0.582***
		(0.022)
EU15 citing EU15 (international)		0.299***
		(0.011)
EU15 citing US	0.279***	0.280***
	(0.013)	(0.013)
EU15 citing JP	0.170***	0.170***
	(0.008)	(0.008)
US citing EU15	0.315***	0.314***
	(0.013)	(0.013)
US citing JP	0.470***	0.469***
	(0.027)	(0.027)
JP citing EU15	0.140***	0.140***
	(0.007)	(0.007)
JP citing US	0.262***	0.264***
	(0.014)	(0.014)
JP citing JP	0.814***	0.817***
	(0.038)	(0.038)

EU to EU
38% as likely
as US-US

NAT
>
OTHER EU

EU/OTHER EU
=
EU/US

US – JP
>
US - EU

JP/JP
~
US/US

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Main Results

$$\alpha_{ij}\left[1+\phi_{ij}*D_{2000}\right]$$

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

Main Results

$$\alpha_{ij}\left[1+\phi_{ij}*D_{2000}\right]$$

	(1)	(2)	(3)	(4)	(5)
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

EU15 ↓ *Nat*, US, JP **wrt to US/US**

EU15 ↑ EU15

US ↑ EU15

JP ↓ EU15

Robustness

- This is not driven by Germany (top inventor).
  - Likelihood of **DE/EU14** increases post-2000
  - Likelihood of **US/EU14** increases post-2000
  - Likelihood of **JP/EU14** DOES NOT decrease post-2000
- We don’t find the same pattern of change in knowledge flows in **fossil technologies**
  - On the contrary, the likelihood that a US inventor cites a fossil EU15 patent decreases by 21 percent
- We don’t find the same pattern of change in knowledge flows in **other radically new technologies (3D, IT, biotechnology, robot)**
- Change in pattern is not due to multi-country patenting

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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
- Stronger integration of the EU RES knowledge
- The EU strengthened its position as source of RES knowledge for the US

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Conclusions

Likely explanation:

EU strong commitment to RES climate policies

↑ EU RES innovation

<u>but also</u>

↔ **strengthened EU15(14) linkages**

and

↑ **EU RES innovation relevance**
for the US *(not JP)*

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Conclusions

However, EU RES innovative activity still poorly integrated compared to the US or Japan

Call for increased policy support to fully exploit the potential of increased RES innovation

Caveats to our analysis

- *Focus on innovation and knowledge flows, not on markets (China and solar panels)*
- *Evidence of policy impact is suggestive, further analysis needed*

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Thank you

elena.verdolini@cmcc.it

This project has received funding from the
European Union's Horizon 2020
research and innovation programme - grant agreement
No 730403 - INNOPATHS.