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Innovative Activity in Renewable Energy Technologies

Empirical Evidence on Knowledge Spillovers Using Patent Data

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Motivation and Aim

Motivation

- Technological change key driver for sustainable energy future
- Renewable energy (RE) technologies are available
  … not competitive with traditional energy supply
- Few research on innovation dynamics in RE technologies
  - Johnestone et al. 2008
- Few application of patent data as measure for environmental innovation
  - Jaffe and Palmer 1997; Brunnermeier and Cohen 2003; Popp 2002

Aim

- Empirical study of drivers of innovation in RE
- RE technologies: Wind and solar
- Patent data to infer innovative activity

Knowledge spillovers drive RE innovations

- External knowledge stimulates new innovations via spillovers

→H1: Domestic knowledge spillovers spur RE innovations

→H2: International knowledge spillovers spur RE innovations

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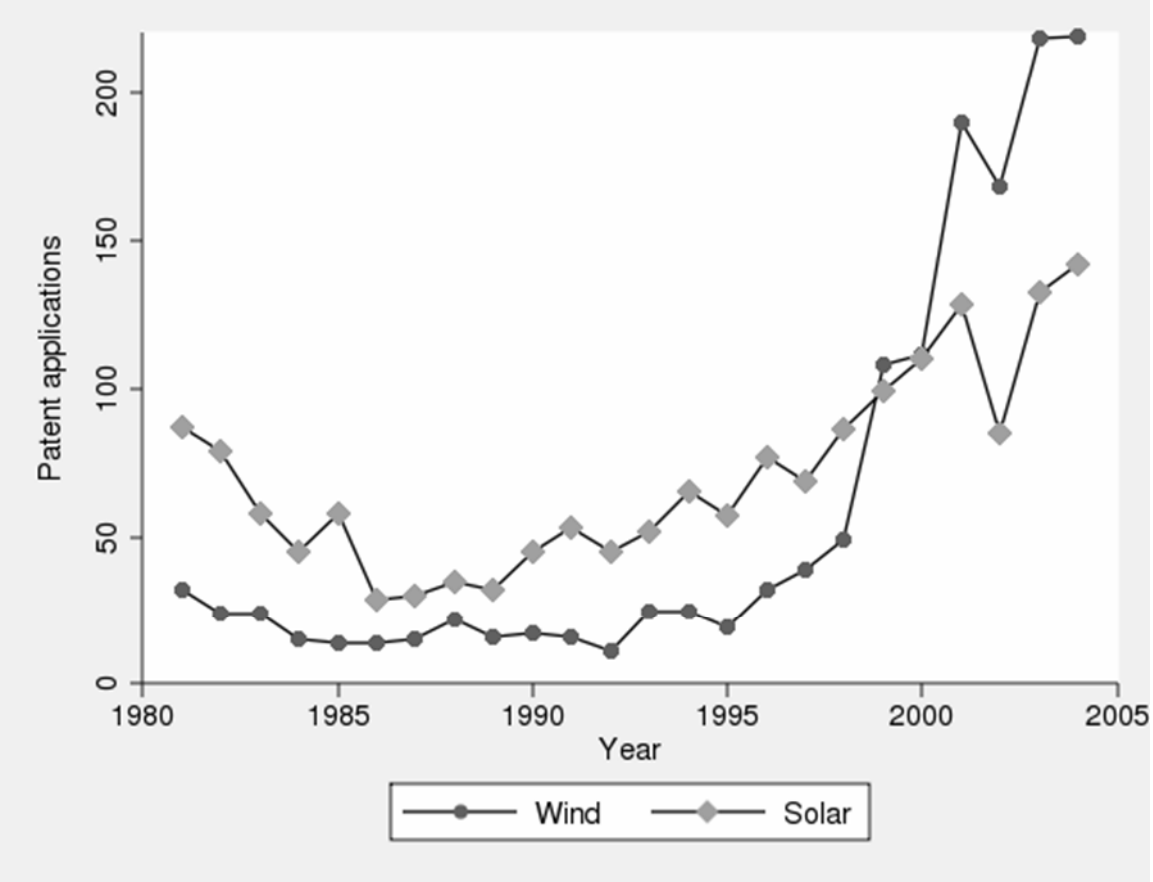
Data & Empirical Model

World wide patent applications in wind and solar technology 1981-2004 (European Patent Office)



Empirical Model – Knowledge Production Function

- Framework to model process of knowledge generation
- Well-established in innovation literature - not applied to environmental innovation

$$I_{RE} = (HC, DomesticSpillover, ForeignSpillover, R\&D, Policies)$$

- Innovative output in RE = product of knowledge generating inputs

Why Patent Data?

Most **important indicator** of research / innovation output

- By definition related to inventiveness
- Based on objective standard
- Patent data widely available
- Detailed information:
  - Precise technological description; standardized classification of invention; origin of the inventor …

Drawbacks

- Measuring just one component of innovative output
- Value of patents skewed to the right

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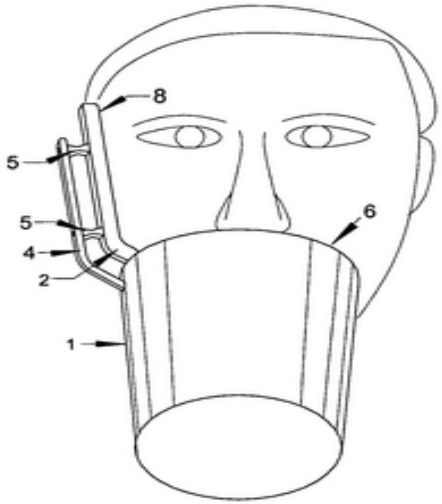
Information contained in patent applications

Title:
Device for the treatment of hiccups
Document Type and Number:
United States Patent 7062320

Abstract:
A device for the treatment of hiccups, and more specifically, to a method and apparatus for the treatment of hiccups involving galvanic stimulation of the Superficial Phrenetic and Vagus nerves using an electric current.

Primary Class: 607/ 2

main class **subclass**



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Information contained in patent applications

"Method of controlling the tip speed ratio of wind turbine blades"

Application number: 09250445.5
Date of filing: 20.02.2009
Applicant: General Electric Company
Int Cl.: **F03D 7/00**

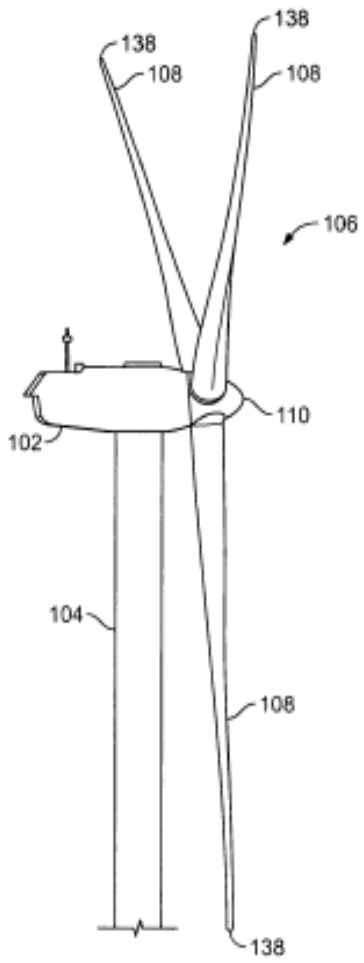

FIG. 1

Abstract

The present invention relates to a method of controlling the aerodynamic load of a wind turbine blade 108 by controlling the tip speed ratio (TSR) and/or blade pitch setting of the wind turbine blade so as to optimize power production.

Variables

Dependant variable – Innovation output

- Number patent EPO applications in wind or solar
  - Technologies identified by classification Johnstone et al. 2008

Knowledge-generating inputs

- Domestic spillovers – Knowledge stock domestic patents
- International spillovers – Knowledge stock foreign patents
- Human capital – Thsd. researcher / workforce (OECD)
- Public R&D expenditures (IEA)
- Industry indicators – Share sector patent applications to all applications
  - Machinery; Electrical&Optical Equipment
- Policy support dummies (IEA)

Count Data Models

Dependant variable count variable

- Integer variable
- Typically many zeros and ones

- Explanatory variables lagged by 2 years

Count data model - Negative binomial model

Panel estimator – fixed effects

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Results for panel 19 OECD countries 1981-2004

Determinants of innovative activity wind

Variable	Coefficient (S.E.)	Coefficient (S.E.)	Coefficient (S.E.)	Coefficient (S.E.)
Human capital	1.465***	0.394	0.487	0.646
	(-0.417)	(-0.540)	(-0.524)	(-0.575)
R&D	0.218**	0.152*	0.150*	0.150*
	(-0.092)	(-0.087)	(-0.087)	(-0.086)
Domestic spillover		0.441***	0.198	0.192
		(-0.142)	(-0.148)	(-0.149)
Foreign spillover			3.280***	3.442***
			(-0.663)	(-0.706)
Machinery				0.468
				(-0.652)
Fit	0.075	0.115	0.009	-0.006
	(-0.207)	(-0.208)	(-0.203)	(-0.204)
Obl	0.776***	0.849***	0.304	0.304
	(-0.191)	(-0.182)	(-0.204)	(-0.204)
Cert	0.532**	0.485**	0.389*	0.367*
	(-0.220)	(-0.222)	(-0.216)	(-0.218)
Observations	258	258	258	258
Groups	19	19	19	19

- Primarily foreign spillovers significant factor
- Certificate systems promotes solar innovation
- R&D significant input
- Machinery no effect

Determinants of innovative activity solar

	Solar (1)	Solar (2)	Solar (3)	Solar (4)
	Coefficient	Coefficient	Coefficient	Coefficient
Variable	(S.E.)	(S.E.)	(S.E.)	(S.E.)
Human capital	0.648	-0.649	-0.293	0.158
	(-0.427)	(-0.515)	(-0.518)	(-0.600)
R&D	0.152**	0.106	0.098	0.130*
	(-0.074)	(-0.072)	(-0.072)	(-0.072)
Domestic spillover		0.629***	0.388**	0.480**
		(-0.159)	(-0.189)	(-0.195)
Foreign spillover			2.316***	2.363***
			(-0.542)	(-0.527)
Machinery				1.278**
				(-0.551)
Electrical and Optical				-0.109
				(-0.354)
Fit	0.636***	0.648***	0.351**	0.343**
	(-0.177)	(-0.169)	(-0.178)	(-0.171)
Obl	0.398**	0.288**	-0.091	-0.087
	(-0.156)	(-0.143)	(-0.158)	(-0.150)
Cert	0.261	0.318	0.163	0.061
	(-0.220)	(-0.212)	(-0.202)	(-0.200)
Observations	234	234	234	234
Groups	17	17	17	17

- Domestic & international spillovers significant factors
- Primarily feed-in tariffs induce solar innovation
- Human capital insignificant
- Machinery spurs innovation

Determinants of patents in wind *or* solar, 1981-2004

Variable	Wind I Coefficient (S.E.)	Wind II Coefficient (S.E.)	Solar I Coefficient (S.E.)	Solar II Coefficient (S.E.)
Human capital	0.487	0.646	-0.293	0.158
	(-0.524)	(-0.575)	(-0.518)	(-0.600)
R&D	0.150*	0.150*	0.098	0.130*
	(-0.087)	(-0.086)	(-0.072)	(-0.072)
Domestic spillover	0.198	0.192	0.388**	0.480**
	(-0.148)	(-0.149)	(-0.189)	(-0.195)
Foreign spillover	3.280***	3.442***	2.316***	2.363***
	(-0.663)	(-0.706)	(-0.542)	(-0.527)
Machinery		0.468		1.278**
		(-0.652)		(-0.551)
ElectOpt				-0.109
				(-0.354)
Fit	0.009	-0.006	0.351**	0.343**
	(-0.203)	(-0.204)	(-0.178)	(-0.171)
Obl	0.304	0.304	-0.091	-0.087
	(-0.204)	(-0.204)	(-0.158)	(-0.150)
Cert	0.389*	0.367*	0.163	0.061
	(-0.216)	(-0.218)	(-0.202)	(-0.200)
Observations	258	258	234	234
Groups	19	19	17	17

Different innovation dynamics

- Diverging sources of knowledge spillovers:
  - International spillovers drive innovation in both fields
  - Domestic spillover spur only solar innovation

- Effects of policies differ:
  - Feed-in tariff promote solar
  - Certificates promote wind

Conclusion

Summary & Conclusions

- Knowledge spillovers stimulate innovative activity
- Effects differ across technologies

- Need for technology policies facilitating the absorption of knowledge across sectors and countries
- Policy design needs to consider different innovation dynamics and incentives across technologies
- Countries with large industrial knowledge base such as Germany or Japan large potential to lead in RE innovation

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Thank you very much for your attention.

Literature

International Energy Agency (IEA), 2004. Renewable energy. Market and policy trends in IEA Countries. Paris, France.

International Energy Agency (IEA), 2008a. Energy technology research and development database. Paris, France (http://www.iea.org/textbase/stats/rd.asp) (accessed 03 December 2008).

Johnstone, N., Hascic, I., Popp, D., 2008. Renewable Energy Policies and Technological Innovation: Evidence based on patent counts. NBER Working Paper 13760.

Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 28 (4), 1661-1707.

Cohen, W.M, Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99 (3), 569-596.

Jaffe, A.B., 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value. The American Economic Review 76 (5), 984-1001.

Lanjouw. J.O., Mody, A., 1996. Innovation and the international diffusion of environmentally responsive technology. Research Policy 25 (4), 549-571.

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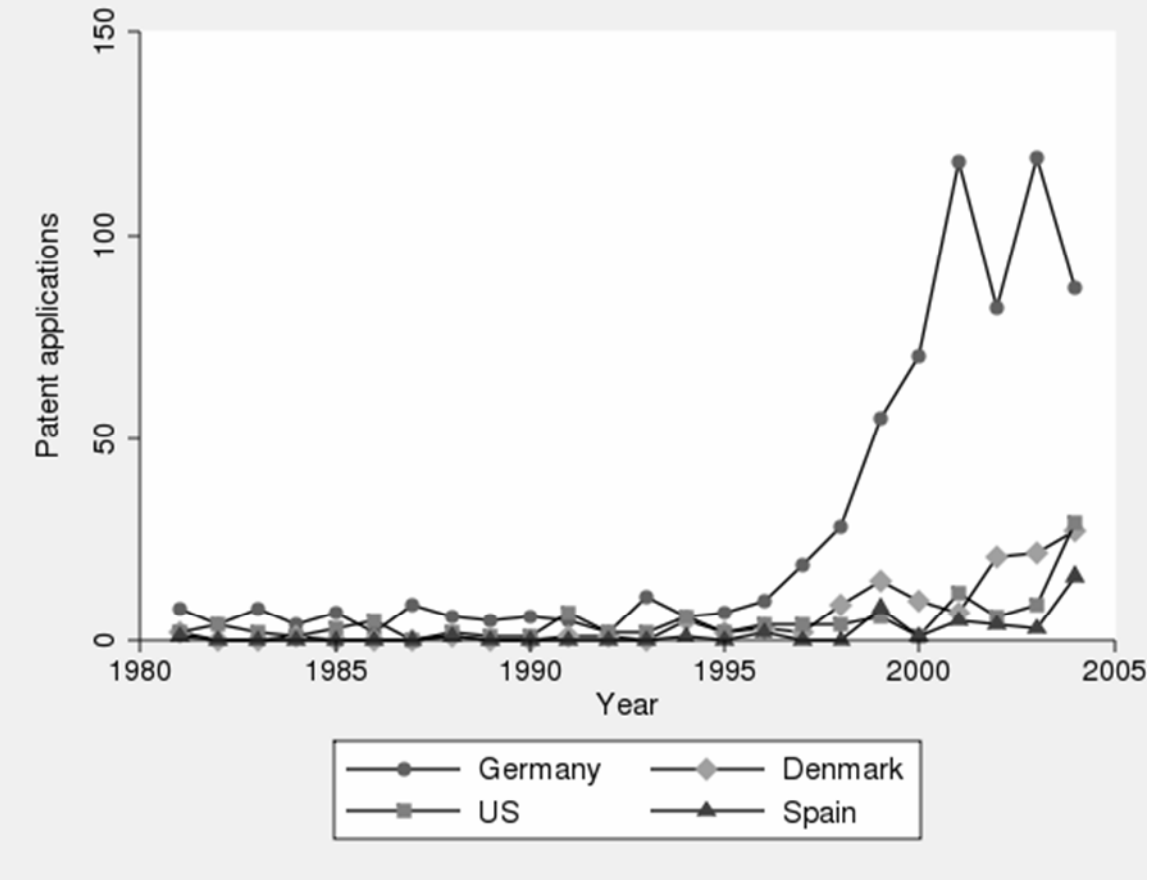
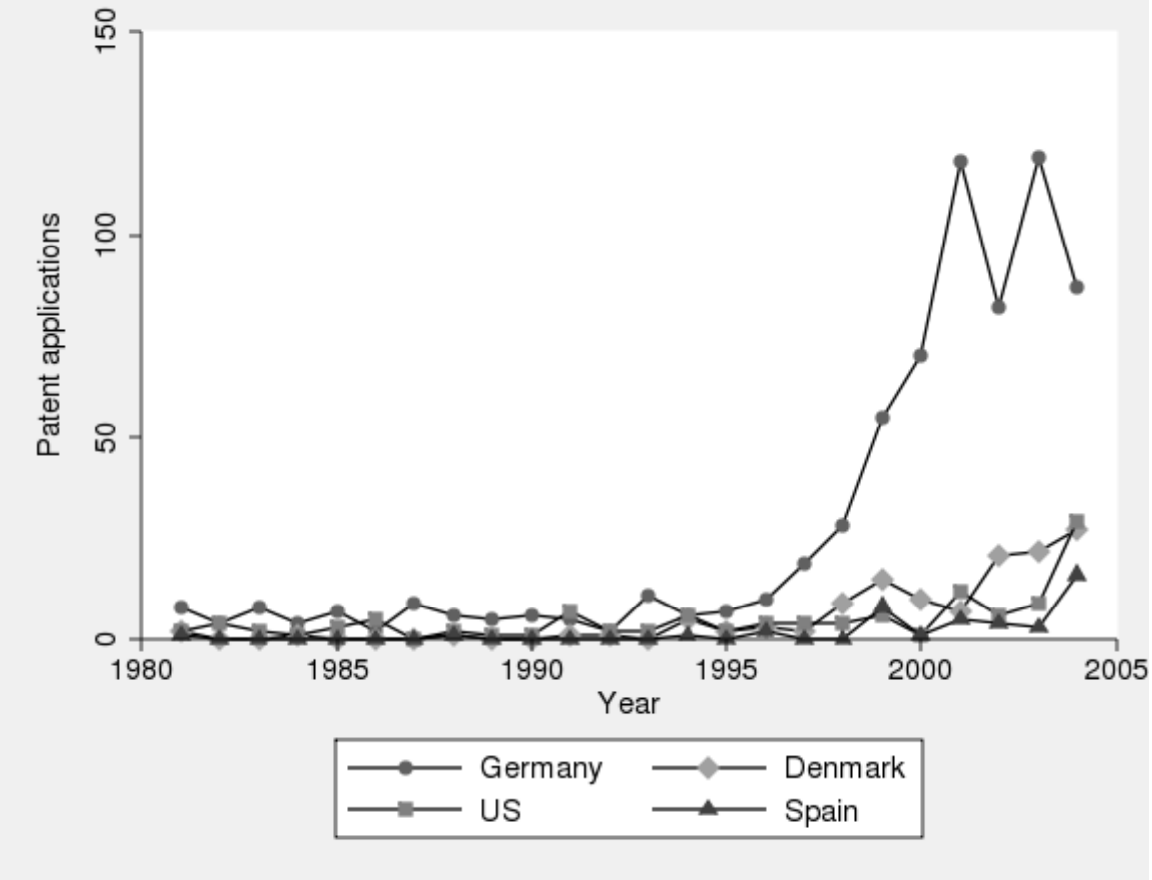
Further Information

EPO patent applications in wind technology for Germany, Denmark, US and Spain 1981-2004



EPO patent applications in solar technology for German, US, Japan and Australia 1981-2004



IPC Codes RE technologies (Johnstone et al. 2008)

APPENDIX. IPC codes for renewable energy technologies

WIND	Class	Sub-Classes
Wind motors with rotation axis substantially in wind direction	F03D	1/00-06
Wind motors with rotation axis substantially at right angle to wind direction	F03D	3/00-06
Other wind motors	F03D	5/00-06
Controlling wind motors	F03D	7/00-06
Adaptations of wind motors for special use;	F03D	9/00-02
Details, component parts, or accessories not provided for in, or of interest apart from, the other groups of this subclass	F03D	11/00-04
Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L	8/00
Effecting propulsion by wind motors driving water-engaging propulsive elements	B63H	13/00
SOLAR		
Devices for producing mechanical power from solar energy	F03G	6/00-08
Use of solar heat, e.g. solar heat collectors	F24J	2/00-54
Machine plant or systems using particular sources of energy - sun	F25B	27/00B
Drying solid materials or objects by processes involving the application of heat by radiation - e.g. sun	F26B	3/28
Semiconductor devices sensitive to infra-red radiation - including a panel or array of photoelectric cells, e.g. solar cells	H01L	31/042
Generators in which light radiation is directly converted into electrical energy	H02N	6/00
Aspects of roofing for the collection of energy – i.e. solar panels	E04D	13/18
Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L	8/00