Wind of Technical Change: Do Patents Matter?

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- Patent system: trade-off between
  - Right to exclude (i.e. market power)
  - Incentive to R&D effort & diffusion of inventions
- Is the patent system an efficient tool in promoting innovation?
  - Still open for debate (see, e.g., Boldrine and Levine, 2013; Spulber, 2021)
  - Critics: patents serve the interest of firms. Hampering innovation instead of fostering it?
- Relatedly, data on patents is commonly used as a proxy for the innovative activity of firms or countries
  - Availability of data...
  - ...but relies on an alleged relationship between patent counts and the output of the innovative process

- The present paper aims at exploring this relationship in the onshore wind turbine (WT) industry
- We propose a patent-independent measure of technical change
  - We rely on technical characteristics of wind turbines to measure contributions of firms to technical change, over time
- Question: do patents held by firms translate into actual, concrete technical change?
  - Panel data analysis

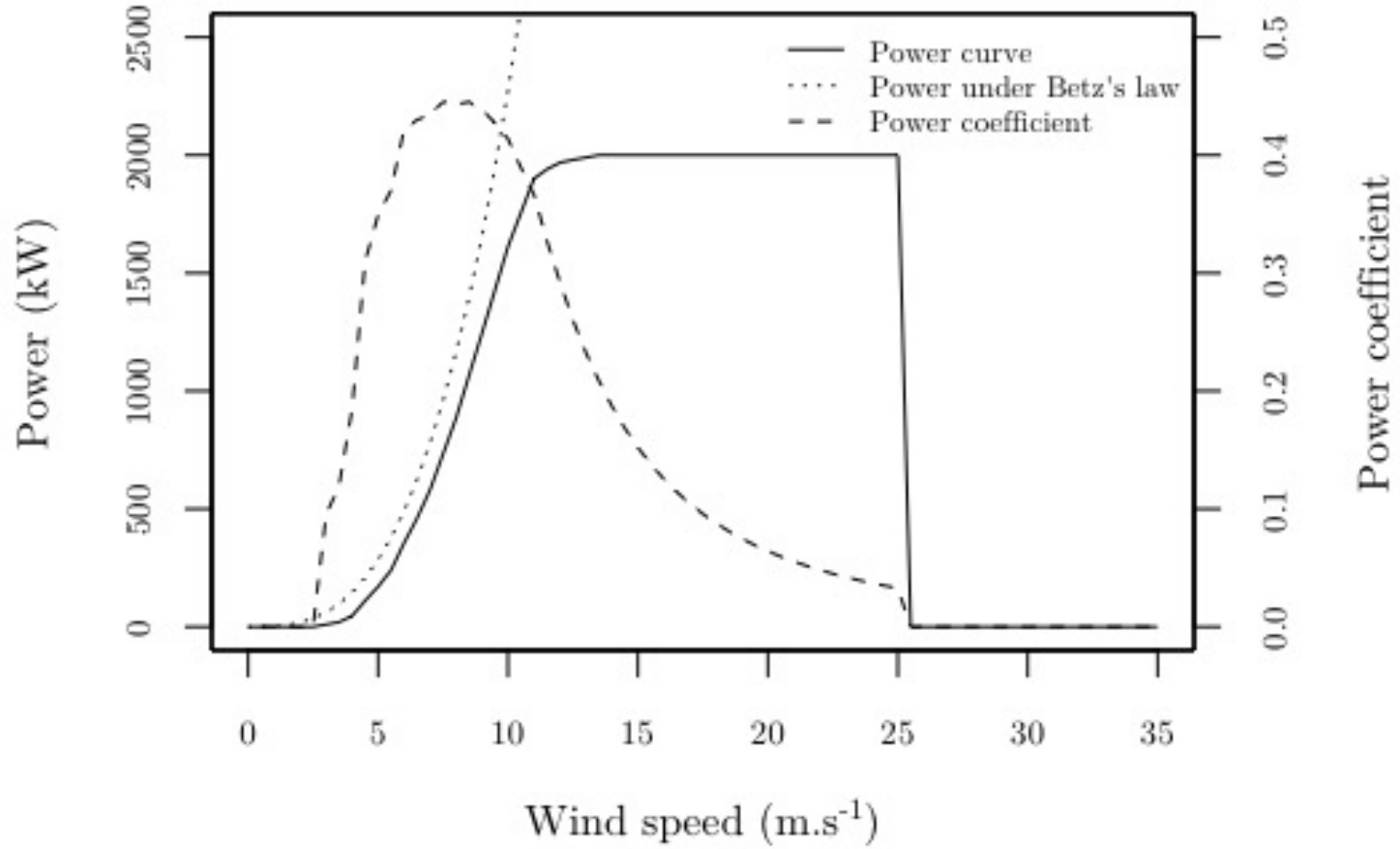
Section 2

Technical change in the wind power industry

- Our measure is based on the power curve of a WT:

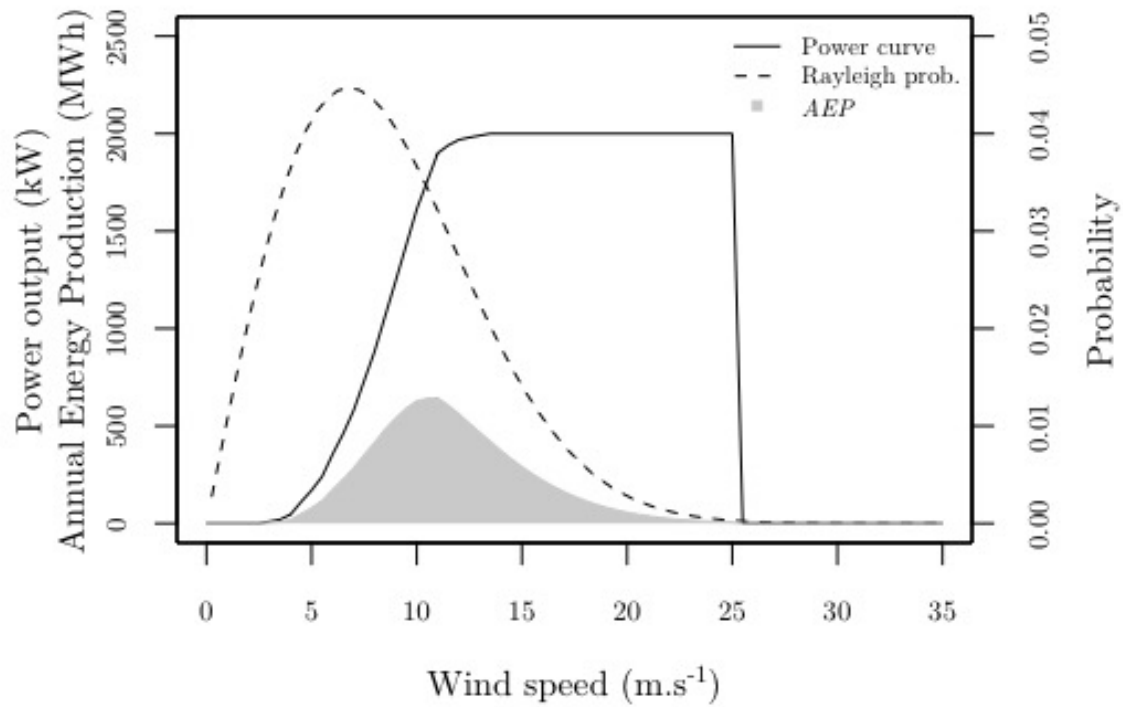
$$P(V) = \underbrace{\frac{1}{2} \times \rho \times \pi \times \left(\frac{D}{2}\right)^2 \times V^3}_{P_w(V)} \times C_p(V)$$

- There are two main levers to increase energy production:
  - Raise the rotor size (D) to capture more energy from the wind
    - "Race towards gigantism"
  - Improve the conversion of kinetic energy into electrical energy by raising the *power coefficient* $C_p(V)$


Power curve
Power under Betz's law
Power coefficient
Power (kW)
0
500
1000
1500
2000
2500
Power coefficient
0.0
0.1
0.2
0.3
0.4
0.5
0
5
10
15
20
25
30
35
Wind speed (m.s-1)

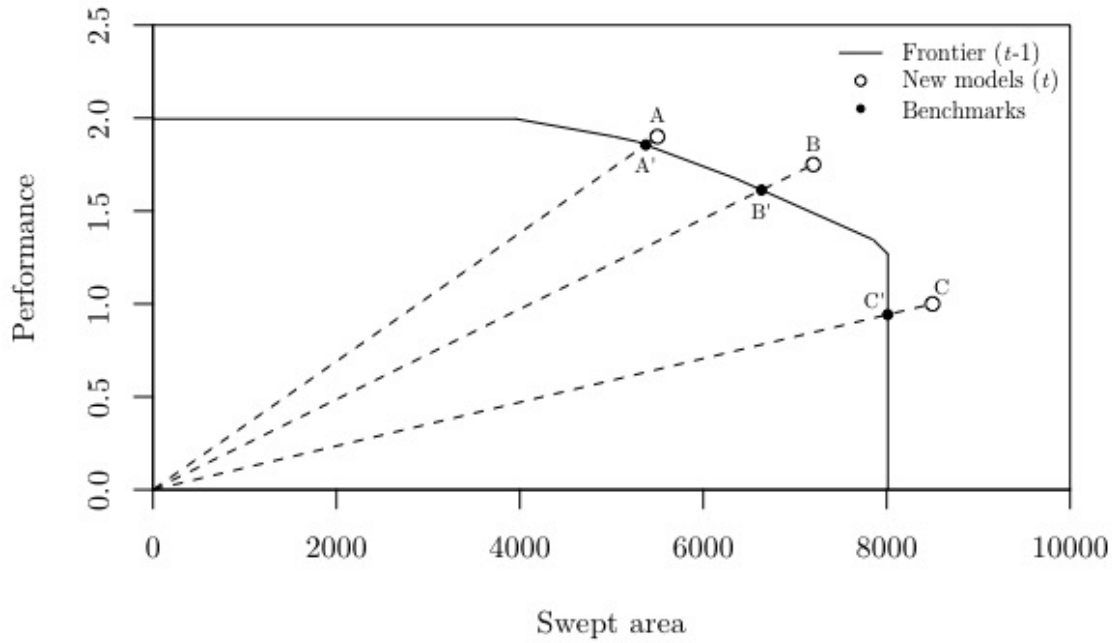
- Information about wind speed distribution associated with the turbine power curve allows one to compute the expected Annual Energy Production

$$AEP = T. \int_{V_{ci}}^{V_{co}} [(f(V) \times P(V)] \, \mathrm{d}V$$



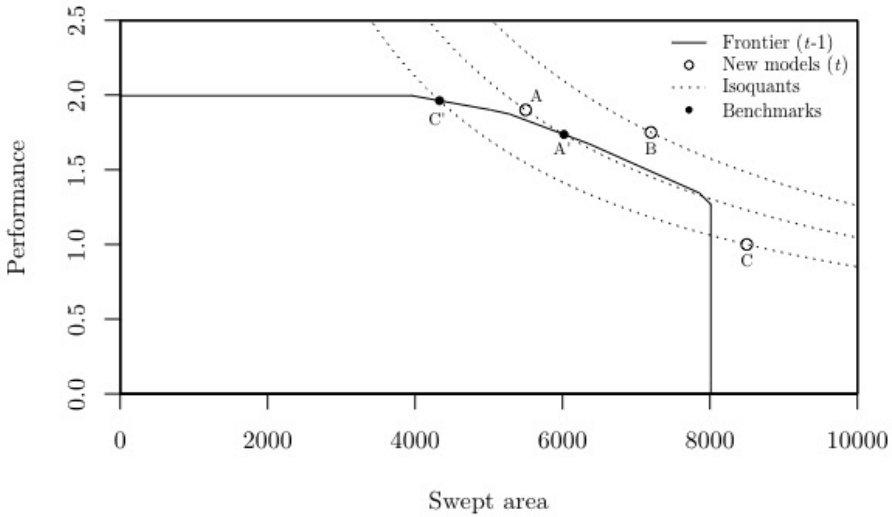
- $\frac{AEP}{D}$ can be seen as the overall "performance level" of a turbine
- Thus, one can locate each wind turbine model in a performance-size 2-dimensional space
- Estimation of the *frontier of possible characteristics*
  - Rely on Data Envelopment Analysis (DEA) techniques
  - Idea: a turbine lies on the frontier if it offers the highest performance level at a given size level
- Do new models of turbine push the frontier forward?
  - Location of a WT model entering the market at year t relative to the $t-1$ frontier

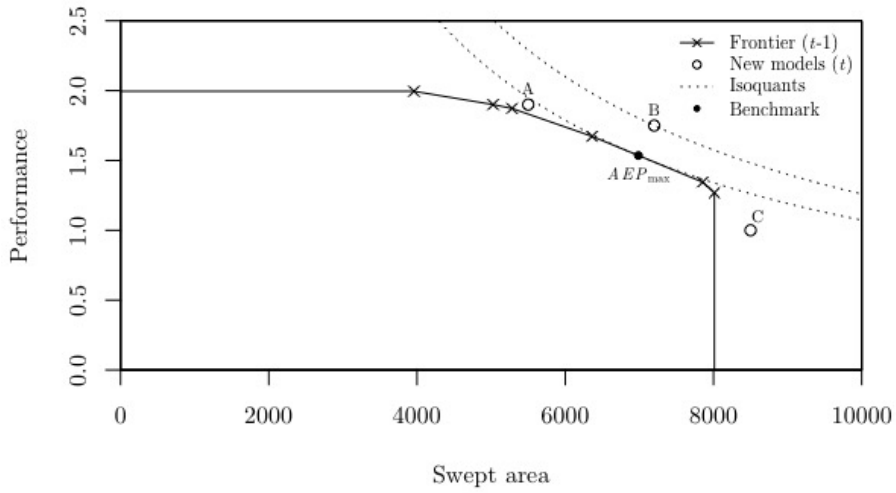
- First measure is based on radial distances: the contribution of a model J is $\theta_J^1 = \frac{0J}{0J'}$



- Ability to propose a novel combination of characteristics. J is considered as innovative if $\theta_J^1 > 1$

- Second measure relies on isoquants: the contribution of a model J is $\theta_J^2 = \frac{X_J Y_J}{X_{max} Y_{max}}$ where $X_{max} Y_{max}$ gives the highest reachable AEP at $t-1$

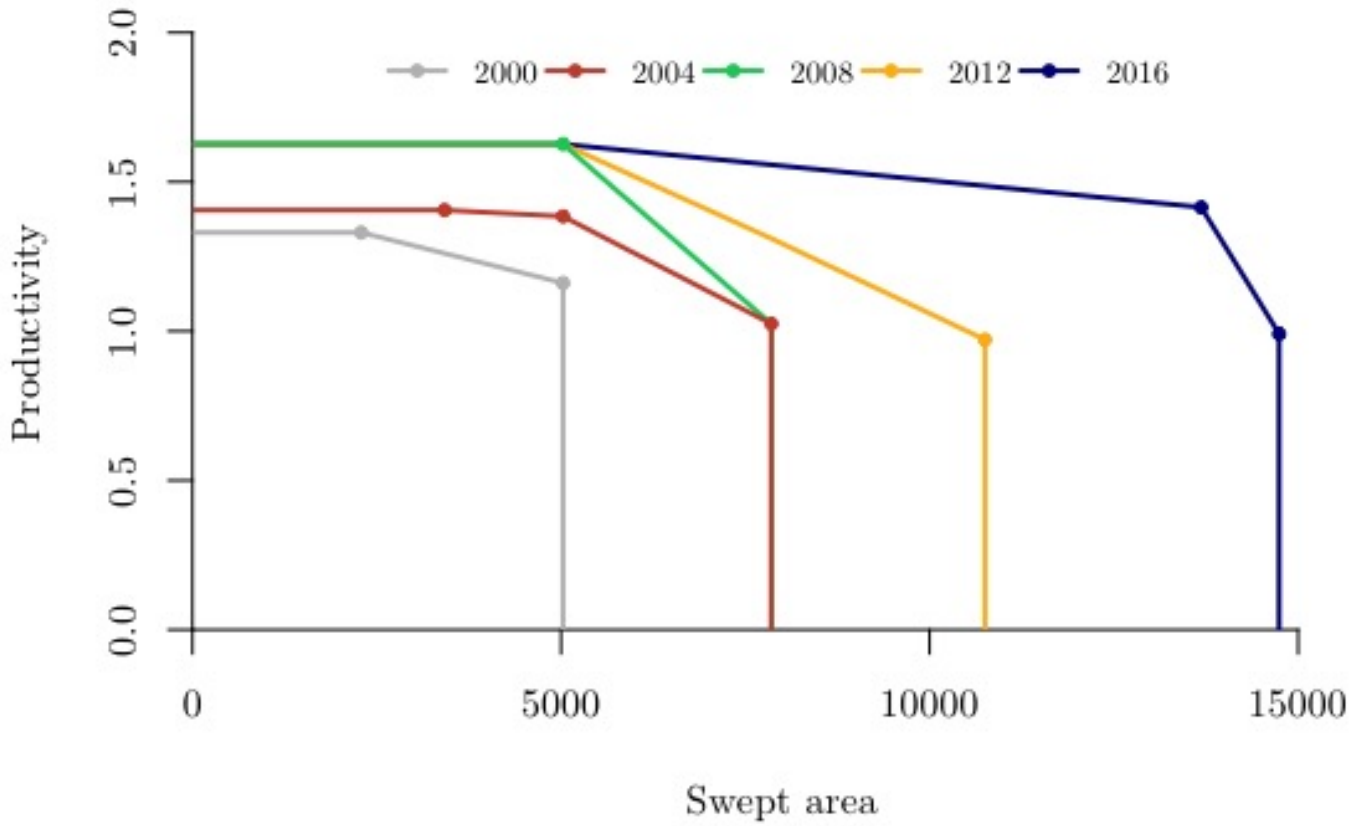




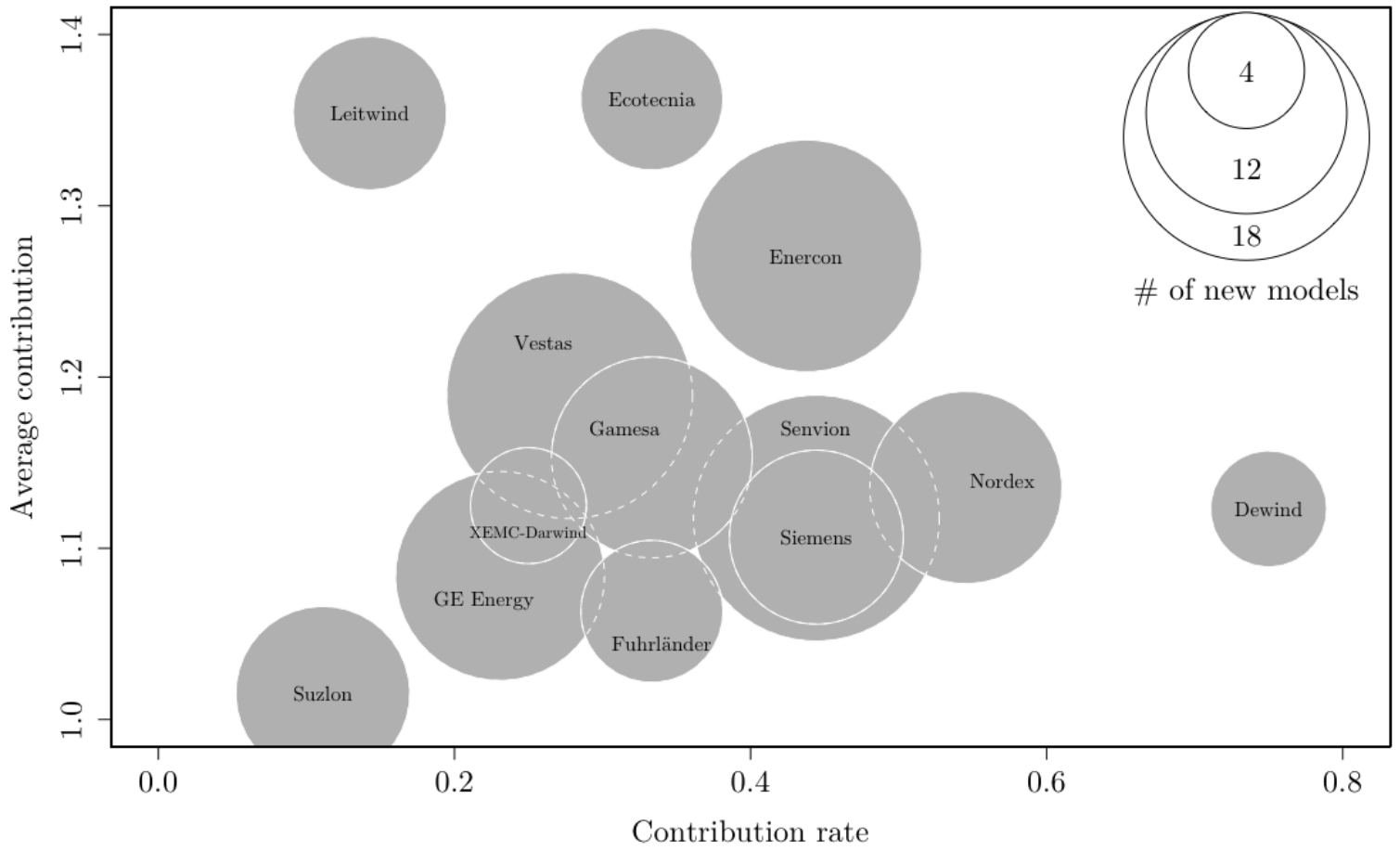
- More direct interpretation: increase in energy production
- Also, J is innovative if $\theta_J^2 > 1$. More strict: here, only turbine B considered as innovative

- We rely on data from *TheWindPower* database
- Information about wind turbine models. The required information is:
  - Year of commercialization
  - Rotor size / swept area
  - Power curve
  - IEC wind class (I, II or III) for which the turbine is designed for
    - Each of those classes is defined by an average wind speed
    - Allows us to apply the relevant Rayleigh wind speed distribution and to compute the expected *AEP* for each turbine
    - So that turbines are compared in common, "optimal" conditions
- Sample: 185 wind turbines that entered the market between 2000 and 2017 (+ 15 models used to construct the 1999 frontier)

- Chronological evolution of the IEC III frontier: both upward and rightward shifts



- Summary of firms' contributions over the 2000-2017 period



Section 3

Patents & contributions to technical change

- In this section, we wish to explore if patents translate into concrete, actual technical change
- Patents held by wind turbine manufacturers are collected from the *Patstat* database
  - Patents granted by the European Patent Office
  - Y02E 10/7 CPC class and subclasses (except offshore-specific ones)
- We consider four alternative yearly counts:
  i. P the cumulative number of successful (i.e. granted) applications
  ii. PP the patent portfolio (i.e. valid patents): **renewals**
  iii. WPP the value-weighted patent portfolio: **forward citations**
  iv. $(W)PPP$ the (weighted) product patent portfolio: **"productness"**

i. A granted patent j is considered in the count at time t if

$$t_{Fj} < t$$

with t_{Fj} the application filing year of patent j

ii. A granted patent j is considered as part of its applicant's portfolio at year t if:

$$\begin{cases} t_{Fj} < t < t_{Lj}, & \text{if patent } j \text{ lapsed} \\ t_{Fj} < t, & \text{if patent } j \text{ is still "alive"} \end{cases}$$

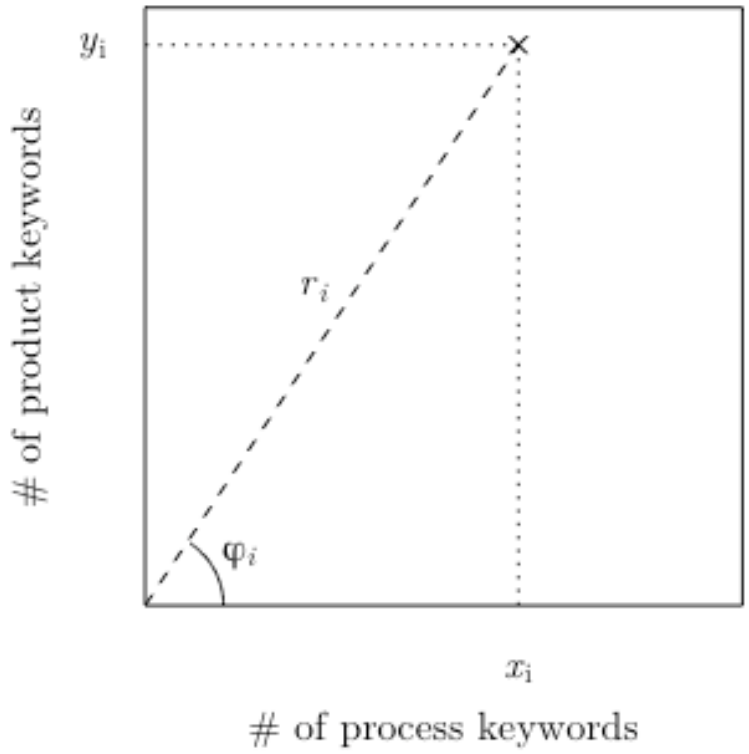
with t_{Fj} the application filing year of patent j and t_{Lj} its lapse year.

iii. The weight of a patent j filed at year t in its applicant's portfolio is:

$$w_j = \frac{C_{jt}}{\bar{C}_t}$$

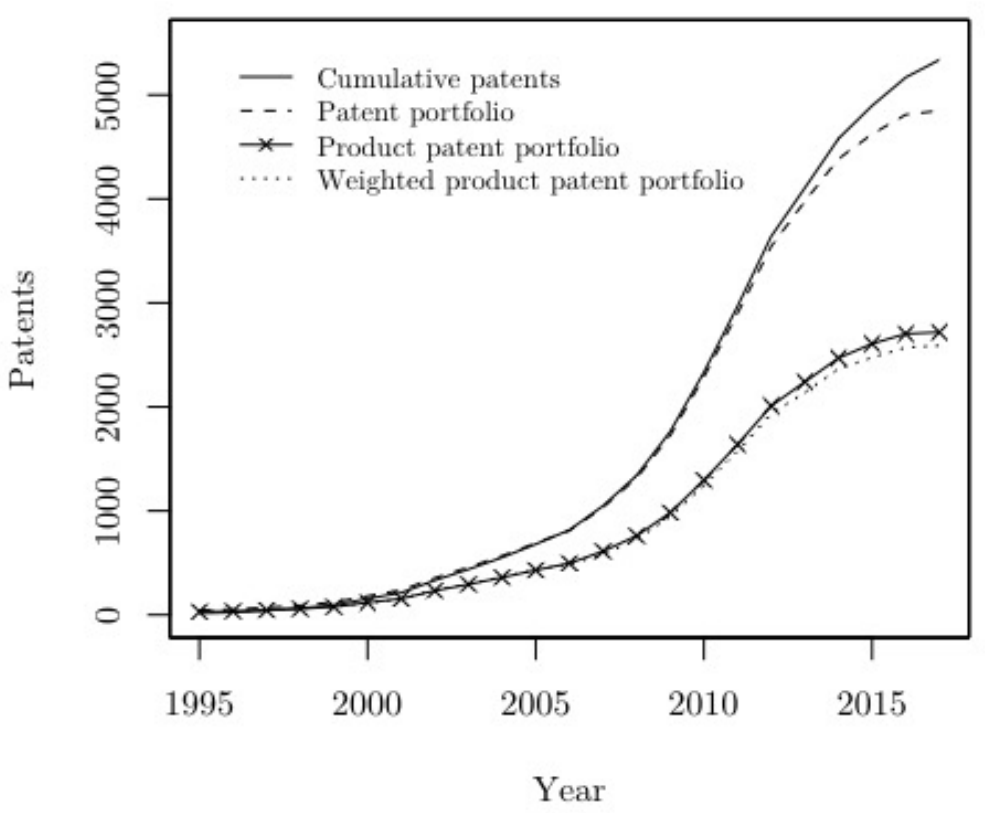
with C_{jt} the number of citation received by patent j (filed at year t) and $\bar{C}_t$ the average number of citations received by patents filed in t

- (iv) "Productness" of patents: based on keyword search (Banholzer et al., 2019) in patent descriptions



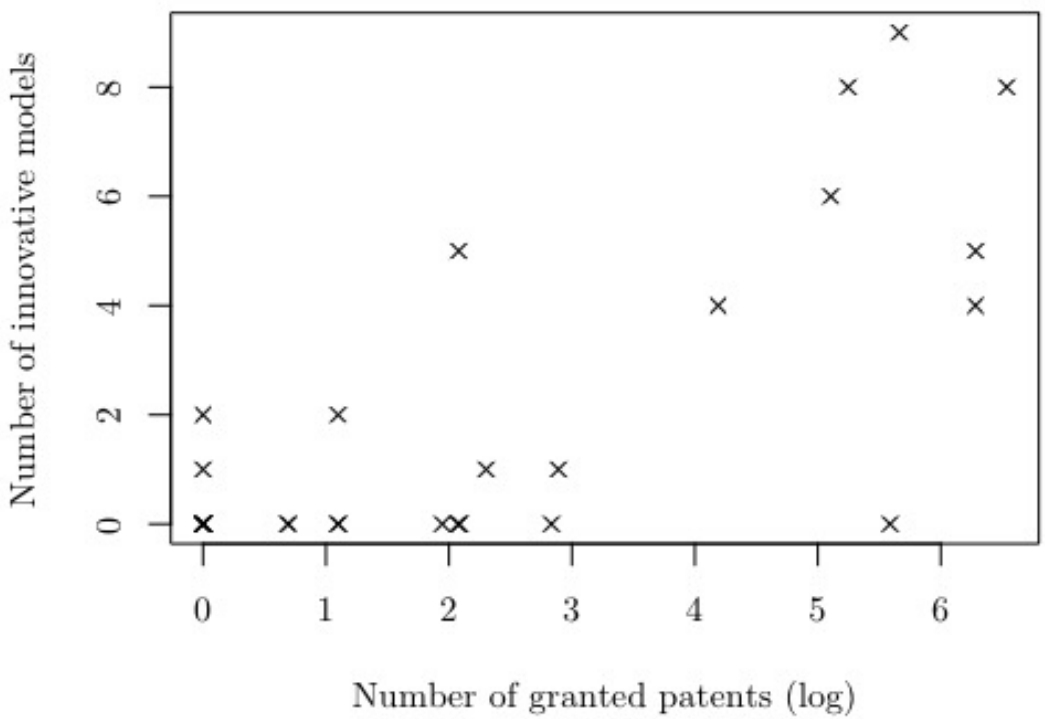
- Improvement in the characteristics of the good: *product innovation*
  - Attempt to identify "product patents"

- Differences in counts across time in the whole industry



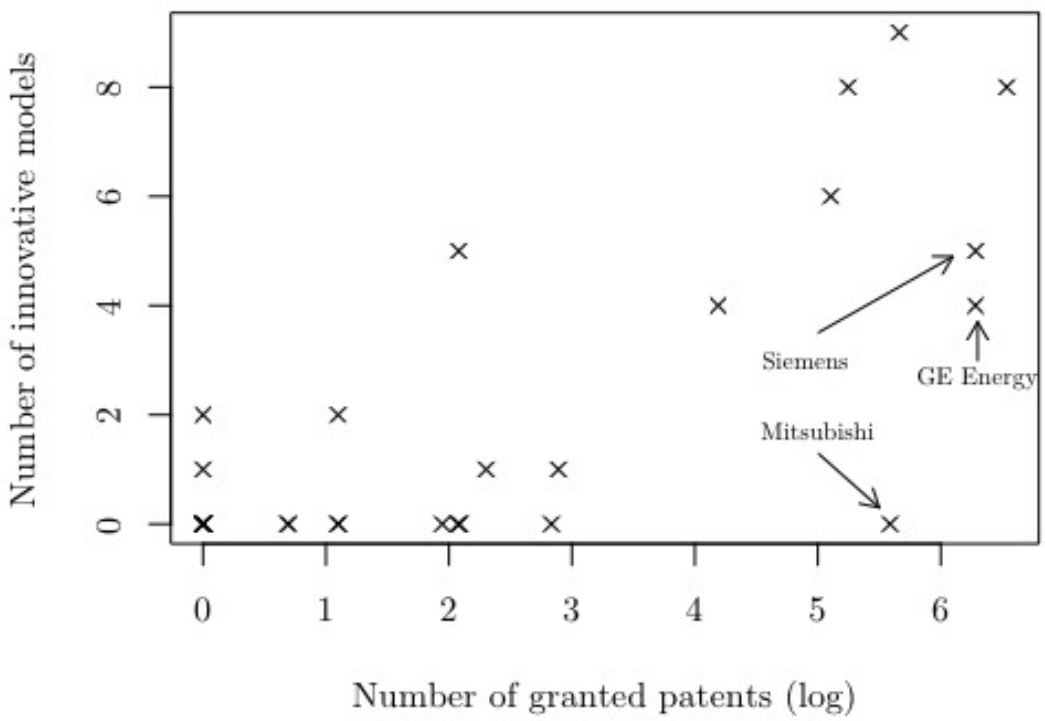
- First observation: wind power actors do not rely much on patent protection until the beginning of the 2000s
  - Yet, technical change has been enhanced before

- Relationship between the number of granted patents and the number of innovative models over the 2000-2017 period



- Second observation: manufacturers having contributions to the frontier are mostly those holding patents

- Relationship between the number of granted patents and the number of innovative models over the 2000-2017 period



- Third observation: the ratio patents / innovative models is higher for conglomerates

- To account for the first observation, we will consider a normalized measure of patent portfolios (relative to the average size the same year)
  - A quite low number of patents can hide a high representation in the global portfolio
- We have an unbalanced panel
  - We observe, on a yearly basis, contributions, patents and market share of 31 firms from 2000 to 2017
  - But not all firms have commercialized a new model each year...
  - ... and not all firms have been active during the whole time period
- We focus on manufacturers for which we have at least 4 yearly observations

- We consider a simple fixed effects model of the form

$$C_{i,t} = PC_{i,t-a} + MS_{i,t-b} + \beta_3 FIT_{i,t-c} + \alpha_i + \lambda_t + \epsilon_{it}$$

in which:

  - $C_{i,t}$ is the (maximum) contribution of new models from firm i entering the market at year t
  - $PC_{i,t-a}$ is the normalized patent count of firm i at year $t-a$
  - $MS_{i,t-b}$ is the market share of firm i at year $t-b$
  - $FIT_{i,t-c}$ is the stringency of feed-in tariff policy in firm i's country at year $t-c$
  - α_i and λ_t are resp. firm and year fixed effects

- Best subset method based on R^2 value (a, b, $c \in [0:5]$)

Table 1: Best-fitting fixed effects regressions

	Dependent variable:			
	Max(θ^1_{it})		Max(θ^2_{it})	
	(1)	(2)	(3)	(4)
$PP_{i,t-4}$	0.0175***	0.0184***		
	(0.0055)	(0.0043)		
$PPP_{i,t-4}$			0.0270***	0.0278***
			(0.0089)	(0.0068)
$MS_{i,t-3}$	-0.0081***	-0.0075***	-0.0131***	0.0122***
	(0.0027)	(0.0027)	(0.0042)	(0.0039)
$FIT_{i,t}$	-0.2834		-0.6037	
	(0.2378)		(0.3780)	
$STR_{i,t-5}$		0.0113		0.0271
		(0.0075)		(0.0166)
Indiv. FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
R^2	0.1033	0.1038	0.0978	0.1017
Observations		114		
N		17		
T		4-18		
Note:		$^*p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

Our results suggest that:

- There is a positive relationship between patent counts and contributions of firms to innovation
  - Need to take into account the renewal of patents
  - A larger product patent portfolio is associated with higher contributions to energy production
  - Weighting portfolios by forward citations do not provide much additional information
- It takes some time for patented technologies to reach the market
  - Increasing portfolio size leads to an increase of contribution 4 years later
- Firms seek to stand out from competitors by innovating
  - Negative relationship between contribution and 3-years lagged version of market share
  - Consistent with the idea that competition fosters innovation

Thank you for your attention!

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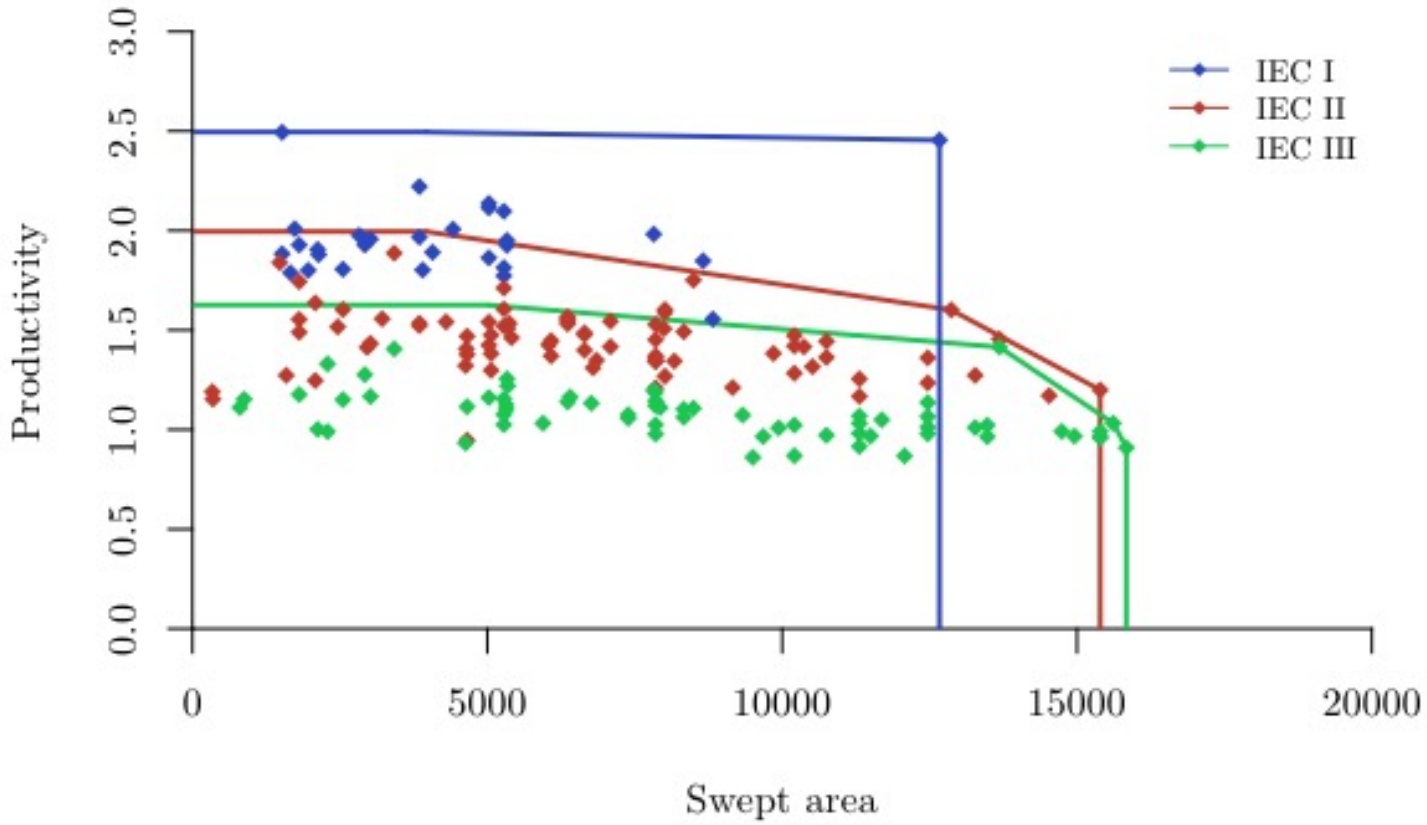
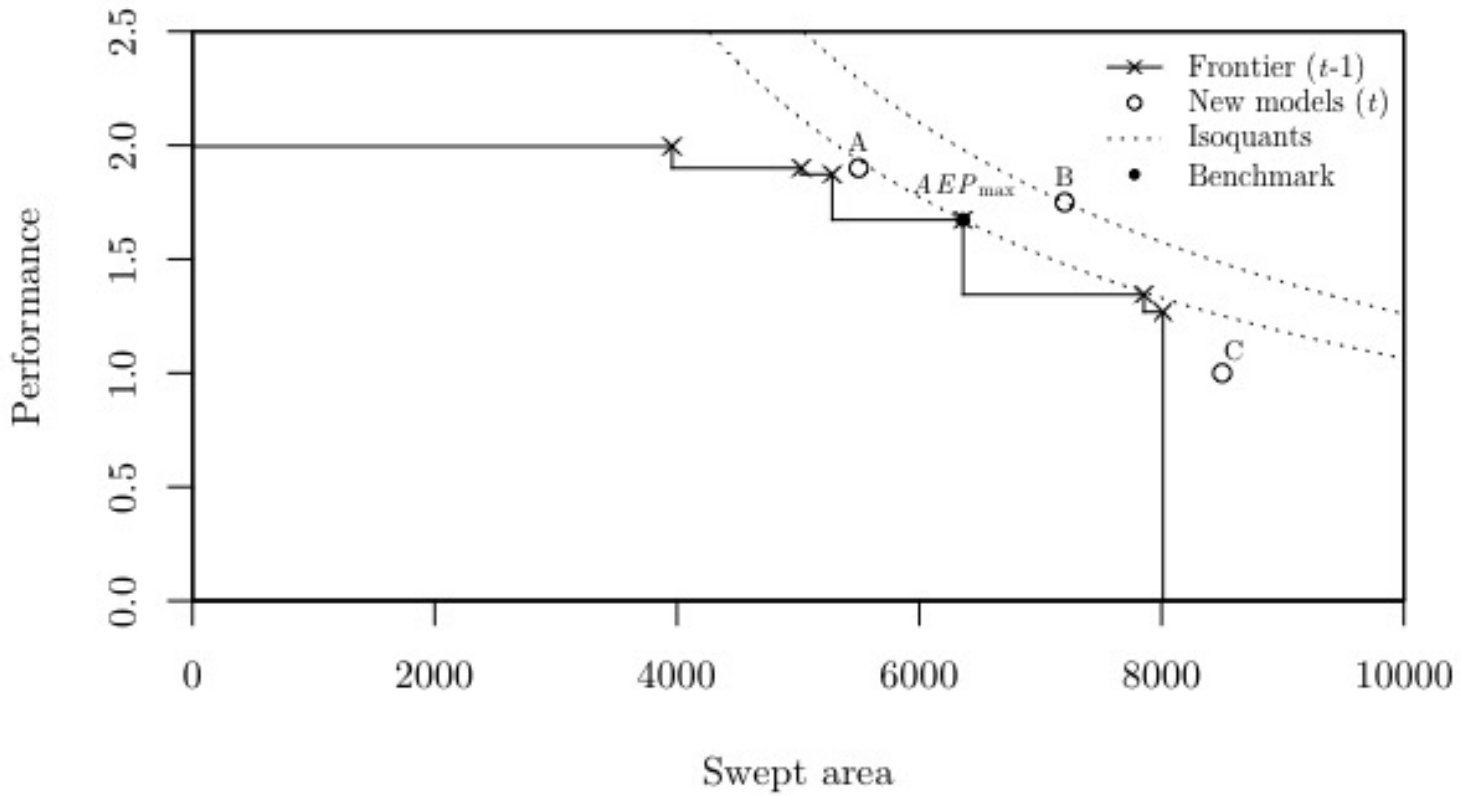
2017 frontier, by IEC class



Relaxing the concavity assumption:



Competition and innovation