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
Introduction

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:

\[ P(V) = \frac{1}{2} \times \rho \times \pi \times \left( \frac{D}{2} \right)^2 \times V^3 \times C_p(V) \]

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 \textit{power coefficient} \( C_p(V) \)
Technical change in the wind power industry

Some physics

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

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

![Graph showing power output and annual energy production vs. wind speed with power curve and Rayleigh probability density functions.]
\( \frac{AEP}{D} \) 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 \textit{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 $\theta_J^1 = \frac{0J}{0J^r}$.

- 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
  \[ \theta^2_J = \frac{X_J Y_J}{X_{\text{max}} Y_{\text{max}}} \]
  where $X_{\text{max}} Y_{\text{max}}$ gives the highest reachable $AEP$ at $t - 1$
  
  
- More direct interpretation: increase in energy production
  
- Also, $J$ is innovative if $\theta^2_J > 1$. 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:

1. $P$ the cumulative number of successful (i.e. granted) applications
2. $PP$ the patent portfolio (i.e. valid patents): renewals
3. $WPP$ the value-weighted patent portfolio: forward citations
4. $(W)PPP$ 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 $t$. 
“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

\[ C_{i,t} = PC_{i,t-a} + MS_{i,t-b} + \beta_3FIT_{i,t-c} + \alpha_i + \lambda_t + \epsilon_{it} \]

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 \( t - c \)
- \( \alpha_i \) and \( \lambda_t \) 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

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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:

![Graph showing performance vs. swept area with points A, B, and C, and labels for Frontier (t-1), New models (t), Isoquants, and Benchmark.](image)
Competition and innovation