Types of innovation and firms’ economic performance

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This paper uses augmented production function framework, and investigates how the different types of innovation affect firms’ economic performance.

The different types of innovation are measured by patent-based indicators.
Outline:

1. Motivation and Conceptual Framework
2. Data and Methodology
3. Results
4. Conclusions
Motivation

- Highly representative firm sample in terms of business R&D spending;
- Firm-level R&D spending and patenting information;
- Innovation type indicators through patents;
  - Originality and novelty
  - Forward citation weights and breakthrough inventions
  - Generality
- Contribution to innovation strategy and policy making.
Conceptual Framework

Research Question

R&D spending $\Rightarrow$ The types of innovation $\Rightarrow$ Firm performance

Patent-based Type Indicators

<table>
<thead>
<tr>
<th>Ex-ante type indicators</th>
<th>Ex-post type indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Originality</td>
<td>Forward citations</td>
</tr>
<tr>
<td>Novelty in recombination</td>
<td>Breakthrough inventions</td>
</tr>
<tr>
<td>Novelty in tech. origins</td>
<td>Generality</td>
</tr>
</tbody>
</table>
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**Firm sample:** The EU 2014 Industrial R&D Investment Scoreboard

Information available: Number of employees, Capital expenditure, R&D Expenditure, Operational Profit, Sector and Country.

Period: 2005 - 2013


Information used in the analysis:
- Patent applications at the EPO of type A and kind PI at family-level
- Priority filing dates
- 7-digits IPC technology class information
- Backward and forward citations at the EPO or at least at two IP5 patent offices
Originality: Hall at al. (2001):

\[ \text{Originality}_p = 1 - \sum_{j}^{n_p} s_{p,j}^2 \]

where \( s_{p,j} \) is the percentage of citations made by patent \( p \) to patent class \( j \) out of the \( n_p \) 7-digits IPC contained in the cited patents.

Novelty: Verhoeven et al. (2016):

Novelty in recombination (NR): “If a patent contains at least one pair of IPC groups that were previously not connected.”

Novelty in technological origins (NTO): “If a patent makes a novel combination between its own IPC code and an IPC code of cited patents.”
Methodology: Forward-looking Type Indicators

**Forward citations** are normalized levels per technology field and year (Squicciarini et al., 2013).

**Breakthrough inventions** are the top 1% cited patent applications (Ahuja and Lampert, 2001).

**Generality:** Squicciarini et al. (2013):
“Let $X$ be the focal patent with $y_i$ citing patents, with $i = 1\ldots N$:

$$\text{Generality}_X = 1 - \sum_{j=1}^{M_i} \left( \frac{1}{N} \sum_{i=1}^{N} \frac{T_{j,i}^n}{T_i^n} \right)^2$$

where $T_i^n$ is the total number of IPC $n$-digit classes of $y_i$, $T_{j,i}^n$ is the total number of IPC $n$-digit classes in the $j^{th}$ IPC7-digit classes in $y_i$, and $j = 1\ldots M_i$ is the cardinal of all IPC7-digit classes in $y_i$."

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The augmented production function model proposed by Griliches (1979):

\[ Y_{it} = A_t L_{it}^{\beta_1} C_{it}^{\beta_2} K_{it}^{\beta_3} e^{u_{it}} \]

Type Premium

Following Jaffe (1988):

\[ \text{Premium}_{it}^k = \text{stype}_{i,t}^{-k} + (1 + \gamma)\text{stype}_{i,t}^k \]

Taking logarithm, our estimation equation is following:

\[ y_{i,t} = c + \beta_1 c_{i,t} + \beta_2 l_{i,t} + \beta_3 k_{i,t} + \beta_4 \gamma \text{stype}_{i,t}^k / K_{i,t} + \tau_t \]
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Descriptive Results: Type indicators at the EPO

- The Scoreboard firms’ R&D spending constitute the 90% of global industrial R&D (The 2014 EU Industrial R&D Investment Scoreboard).

- The Scoreboard firms’ patenting and innovation types at the EPO:

  - Patenting: 52%
  - Novelty in Recombination: 45%
  - Novelty in Technological Origins: 50%
  - Breakthrough inventions: 67%

Source: Authors’ own elaboration

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Descriptive Results: Type indicators by sectors

Type indicators by sectors, 2000-2010

Source: Authors' own elaboration
### Econometric Results: Fixed-Effects Estimation

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<tr>
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<tr>
<td>Number of Employees - Log</td>
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<td>0.576***</td>
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<tr>
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<td>Type stock/R&amp;D stock - Lagged</td>
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<td>-0.692*</td>
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<td>0.034**</td>
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Robust standard errors in parentheses:

*** p < 0.01, ** p < 0.05, * p < 0.1

Hausman test results favors the fixed-effects estimator relative to random effects estimator.
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What is the impact of an innovation type on firm performance?

- **Originality and novelty of an invention:**
  - *Uncertainty in terms of commercial and technological success in the markets.*

- **Impact of an invention:**
  - *Positive impact of forward citations weighted inventions on firm performance.*
  - *Breakthrough inventions have even stronger impact.*

- **Multi-field usability of an invention:**
  - *Positive impact of general invention strategy on firm-level private returns*
What is next?

- **Extension of analysis:**
  - Sectoral analysis
  - Sub-samples according to firms’ characteristics and regions

- **Endogeneity and simultaneity issues:**
  - Estimations using two-stage least squares and GMM for panel data models
Thank you for your attention!

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