Propensity to patent, R&D and market competition

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Some questions

- Why do firms invest in R&D?
- Why do firms publish patents?
- In your opinion, what determines the proportion of R&D protected by patents at firms?

<table>
<thead>
<tr>
<th>Industry</th>
<th>Number of firms</th>
<th>Number of patents</th>
<th>Patents/firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Paper, printing</td>
<td>89</td>
<td>16,877</td>
<td>190</td>
</tr>
<tr>
<td>2 Chemicals</td>
<td>82</td>
<td>40,449</td>
<td>493</td>
</tr>
<tr>
<td>3 Rubber, plastics</td>
<td>82</td>
<td>5,045</td>
<td>62</td>
</tr>
<tr>
<td>4 Wood, lumber, furniture</td>
<td>154</td>
<td>10,310</td>
<td>67</td>
</tr>
<tr>
<td>5 Primary metals</td>
<td>63</td>
<td>2,874</td>
<td>46</td>
</tr>
<tr>
<td>6 Fabricated metals</td>
<td>98</td>
<td>4,869</td>
<td>50</td>
</tr>
<tr>
<td>7 Machinery, engines</td>
<td>261</td>
<td>23,720</td>
<td>91</td>
</tr>
<tr>
<td>8 Electrical machinery</td>
<td>109</td>
<td>34,006</td>
<td>312</td>
</tr>
<tr>
<td>9 Autos</td>
<td>93</td>
<td>20,015</td>
<td>215</td>
</tr>
<tr>
<td>10 Transportation equipment</td>
<td>38</td>
<td>20,410</td>
<td>537</td>
</tr>
<tr>
<td>11 Textiles, apparel, footwear</td>
<td>79</td>
<td>1,487</td>
<td>19</td>
</tr>
<tr>
<td>12 Pharmaceuticals</td>
<td>530</td>
<td>54,681</td>
<td>103</td>
</tr>
<tr>
<td>13 Food, tobacco</td>
<td>77</td>
<td>3,314</td>
<td>43</td>
</tr>
<tr>
<td>14 Computers, comp. eq.</td>
<td>1232</td>
<td>251,446</td>
<td>204</td>
</tr>
<tr>
<td>15 Petroleum refining, prods.</td>
<td>32</td>
<td>27,287</td>
<td>853</td>
</tr>
<tr>
<td>16 Non–manufacturing</td>
<td>1457</td>
<td>42,939</td>
<td>29</td>
</tr>
<tr>
<td><strong>Total hi–tech</strong></td>
<td><strong>1991</strong></td>
<td><strong>400,992</strong></td>
<td><strong>201</strong></td>
</tr>
<tr>
<td><strong>Total non–hi–tech</strong></td>
<td><strong>2485</strong></td>
<td><strong>158,737</strong></td>
<td><strong>64</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4476</strong></td>
<td><strong>559,729</strong></td>
<td><strong>125</strong></td>
</tr>
</tbody>
</table>
Patent count per firm and R&D per firm in the U.S.

Each point is a year from 1979 to 2000

What is your conclusion from the figure?
Patent application count in the U.S., 1979 to 2000

What can you see on this figure from the end of the 1980s?
From the end of the 1980s, U.S. firms increased significantly patent activity.

In your opinion, what drove this increase?
Propensity to patent in the U.S., 1979 to 2000

Propensity to patent = patent application count / R&D expenses.

What can you see on this figure?
It seems that firms’ propensity to patent increased significantly from the end of the 1980s.

This means that significantly larger proportion of R&D was protected by patents.

In your opinion, what drove this increase?
According to Shapiro (2007), the observed increase in R&D efficiency through the 1990s could be due to *increases in R&D differentiation, the increase in the number of research fields and technologies, and the use of more sophisticated patent strategies due to increases in competitive pressure through time.*

Some literature

Data

- We start with a U.S. panel data set of 4476 firms for period 1979 to 2000.
- We focus on a specific cluster of technologically similar U.S. firms (technological cluster).
- The cluster includes 111 U.S. firms that are mostly from the pharmaceutical product-market sector.
Pharmaceutical technological cluster, 1979 to 2000
We identify patent innovation leaders and innovation followers in the technological cluster.

1. Merck (2834)  
2. Eli Lilly (2834)  
3. Abbott Lab. (2834)  
4. Warner-Lambert (2834)  
5. Pfizer (2834)  
6. Bristol-Myers (2834)  
7. Am. Home Prod. (2834)  
8. Alza (2834)  
9. Mallinckrodt (2835)  
10. Pharmacia & U. (2834)
Patent count model
We use a Poisson–type patent count data model to separate patented and non-patented R&D activity.

- \( E(\tilde{P}_{it}|F_t) = \lambda_{it} = \tilde{P}_{it}^o \tilde{P}_{it}^* \)

- \( \ln \tilde{P}_{it}^o = \mu_0 + \gamma_1 t + \gamma_2 t \tilde{r}_{it} + \gamma_3 \tilde{r}_{it}^2 + \gamma_4 \tilde{B} \tilde{V}_{it} + \gamma_5 \tilde{P}_{i1} + \sum_{k=0}^{q} \beta_k \tilde{r}_{it-k} + \sum_{k=0}^{q} \omega_k \text{BC}_{\text{intra},it-k} \tilde{r}_{it} + \sum_{k=0}^{q} \phi_k \text{BC}_{\text{inter},it-k} \tilde{r}_{it} + \sum_{k=1}^{p} \kappa_k \ln \tilde{P}_{it-k}^o \)

- \( \ln \tilde{P}_{it}^* = \ln \Phi(\mu_i + \sigma_i l_t^*) \)

- \( l_t^* = \mu^* l_{t-1}^* + u_t \text{ with } u_t \sim N(0, 1) \text{ i.i.d.} \)
Patented R&D = total R&D ($\tilde{P}^o$) x propensity to patent ($\tilde{P}^*$)

Non-patented R&D ($\tilde{P}^x$) = $\tilde{P}^o$ x ($1 - \tilde{P}^*$)

Propensity to patent of firms is driven by a common latent factor, $l^*$.

A-priory, we do not know what this common latent factor is.
We use the maximum likelihood method.

The likelihood of \( (\tilde{P}_{it}, l_t^* : t = 1, \ldots, T; i = 1, \ldots, N) \)

is

\[
\prod_{i=1}^{N} \prod_{t=1}^{T} f(\tilde{P}_{it} | F_t) f^*(l_t^* | l_{t-1}^*)
\]

However, \( l^* \) are not observed. We maximize

\[
\mathcal{L}(\tilde{P} | F_e; \theta) = \int_{RT} \prod_{i=1}^{N} \prod_{t=1}^{T} \frac{\exp(-\lambda_{it}) \tilde{P}_{it}}{\tilde{P}_{it}!} \frac{1}{\sqrt{2\pi}} \exp \left[ - \frac{(l_t^* - \mu^* l_{t-1}^*)^2}{2} \right] dL^*
\]

Efficient importance sampling technique
(Richard and Zhang, 2007, JoE)
Propensity to patent and market competition
Common latent factor, $l^*$, 1979–2000:

$\text{Competition}_t = 1 - \frac{1}{N} \sum_{i=1}^{N} \frac{\text{operating profit}_{it} - \text{financial costs}_{it}}{\text{sales}_{it}}$
Propensity to patent and market competition seem to move together in the technological cluster.

This may suggest that pharmaceutical firms reacted to the increasing level of market competition by patenting a significantly higher proportion of their innovation output after 1990.
For every year (1979–2000):
   a) Total R&D investment
   b) Patent application count
   c) Non-patented R&D and competition
We find an inverted–U relationship between competition and three measures of innovation:

a) Total R&D investment ($\tilde{P}^0$)
b) Patent application count ($\tilde{P}$)
c) Non–patented R&D ($\tilde{P}^\times$)

The maximum level of innovation is achieved at the 95%–97% level of competition, which is equivalent to an average 3%–5% price cost margin in the drug industry.
Within-firm effects; PVAR(1) model

We study the dynamic relations among stock return ($q$), log R&D ($r$), log patented R&D ($\ln P$), and log non-patented R&D ($\ln P^\times$) within firms.
PVAR(1) with fixed effects
See Fig. 4.
We study the dynamic relations among stock return ($q$), log R&D ($r$), log patented R&D ($\ln P$), and log non-patented R&D ($\ln P^\times$) between the innovation leader and its followers.
Extended PVAR(1) with fixed effects

\[ Y_{it} = a_i + \zeta^* Y_{it-1} + \zeta_{IL}^* Y_{IL,t-1} D_{it} (i \in \text{IF}) \]

\[ + \zeta_{IF}^* \left( \sum_{k \in \text{IF}} Y_{kt-1} \right) D_{it} (i = \text{IL}) + \Omega^* e_{it} \]

\[ Y_{it} = (q_{it}, r_{it}, \ln P_{it}, \ln P_{it}^x)' \]

PVAR(1) with fixed effects
See Figs 5 to 7.
Discussion

- Aghion, Bloom, Blundell and Griffith (2005, QJE) conclude that increasing market competition discourages laggard firms to innovate while encourages neck-to-neck firms to innovate.

- In the cluster analyzed, we find positive spillover effect between innovation leaders and followers in both directions. These indicate that in the cluster studied firms are neck-to-neck in innovation activity.

- The results show that the innovations leader has a contemporaneous impact on followers and for followers it takes about three years to influence the leader.
Thank you for your attention!

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