The 1st round: Multiple Modes of Knowledge Exchange

“Matching the type of scientific human capital with aim of R&D alliances”

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Layout

- Aim of presentation
- Research setting
- Trial Mark I and related research
- Trial Mark II and related research
- Suggestions for future research
In order to understand the nature of University-industry linkage (UIL), the viewpoint of multimodal knowledge exchange between academia and the private sector is important.

Most of the previous studies have relied heavily on limited kinds of data such as scientific papers, patents and licenses.

Yes, but how can we approach the issues systematically?

We suggest the efficacy of pairing patent and publication data approach.
An indicator of the firm’s knowledge capture

The number of research articles written jointly by firm scientists and discovering “star” scientists.

Distinctively differentiated assumption: “two way interaction” of advanced materials innovation

**Commercializing science**

Co-evolution of science and technology:
Importance of user needs

**Indicator of firms’ knowledge capture**

Bi-directional knowledge flow
- Flow of tacit (scientific) knowledge from university to industry
- Flow of tacit (know-how) knowledge from industry to university.
When TiO₂ absorbs UV light, very strong oxidation power is produced, decomposing most organic compounds adsorbed on its surface. Such a photo-induced reaction is called TiO₂ photocatalysis (Fujishima, Rao et al. 2000).

- TiO₂-coated materials can achieve clean conditions only with sunlight and rainwater, without using any chemicals.
- Among the commercialized applications by now: self-cleaning building materials, anti-bacterial ceramic tiles, and anti-fogging window glass (Fujishima, Hashimoto et al. 1997; Fujishima, Hashimoto et al. 2000).
Photocatalysis Applications of Titanium Dioxide $\text{TiO}_2$

- TiO$_2$ coated tent material
- TiO$_2$ coated glass
- TiO$_2$ coated exterior tiles
- TiO$_2$ coated interior tiles

Developed in Japan from 1989, thanks to the research work of two outstanding scientists: Fujishima and Hashimoto.

Fujishima and Hashimoto were ranked first and second in terms of the cumulative numbers of individual applications up to 2002: 119 applications for Fujishima, and 117 for Hashimoto. The number of applications for the next most highly ranked university scientist was 34.

Fujishima and Hashimoto have been energetically publishing both original and review papers on photocatalysis with epochal discoveries since the end of the 1960s. Among Japanese scientists, they were ranked second in terms of the cumulative numbers of publication with 191 papers, but were ranked first in terms of the cumulative number of paper citation with 3,228.
An indicator of firms’ knowledge capture in advanced materials

“Core researchers” in firms.

Emergence of “core researcher” in firms

Positive impact on firms’ R&D productivity.
Function of core researchers (1)

- Observed by co-authoring of academic papers

Tacit scientific knowledge

Eg. Personal exchanges
(Zucker and Darby 2001; Hicks et.al. 1995)

Deep social commitment

University

Firm

Tacit know-how knowledge
Function of core researchers (2)

- Observed by co-invention of patents

Accumulation of background knowledge for problem solving

(Pavitt 1998; Salter et.al. 2000)

University

Know-how (in the form of consultancy)

Firm
Function of core researchers (3)

- Observed by firms' applying more than 10 patents

Exploitation capacity of external knowledge

Cohen and Levinthal 1998

Firm
Definition of core researchers

(i) jointly apply at least one patent with university scientists

(ii) jointly publish at least one research article with university scientists

(iii) apply more than 10 patents independently at firms.
Conclusion

- Emergence of core researchers increases firms’ R&D productivity measured by the number of granted patents.
- Firms’ collaboration with star scientists exerts negative impact on their R&D productivity in advanced materials
- UIL working as central conduits for interaction of tacit knowledge (scientific and know-how)
Since the evolutionary logic that selects out “better” patents is different than that which selects the most influential papers, we do not expect influential papers to lead to influential patents.

Individual scientists who inhabit both the world of open science and the world of technology creation, by bridging the worlds of discovery and innovation, are able to reconcile these two conflicting logics more effectively than those specializing in either science or technology.

Those bridging scientists play an important role in transforming scientific ideas into useful innovations.
What type of scientific human capital is more likely to be conducive of successful knowledge interactions with R&D alliances in advanced materials? 

What types of UIL, by means of co-patenting with corporate researchers, are more influential in transforming scientific knowledge into technological achievements, and thus, for increasing firm’s R&D productivity?
Previous research

- The key actors of the U-I knowledge transfer
    - biotechnology
  - Core scientists (Furukawa and Goto 2006a, 2006b)
    - pharmaceutical and electronics industries

- Testing a new concept
  - using Quadrant model of Stokes(1997) to categorize individual scientists, not just areas of science
  - Pasteur scientists
    - Advanced materials, medical device
Quadrant model by Stokes (1997)

Adapted from Stokes (1997)
Operationalization of the concept of Quadrant model (Stokes 1997)

- Citations to their papers to measure contribution to fundamental understanding
- Patents to measure contribution to social utility (body of practice)
Data and sampling procedure: Patent data

- Main source of data is the Japanese Patent Office (JPO)
- Full-text search by supplying the keyword “Photocatalyst” in the PATOLIS-J database
  - 19,784 patent applications from 1970 to 2006 (97.2% from Japan).
  - 6,749 inventors from 3,207 organizations (2,994 firms, 109 PROs and 104 universities)
    - The affiliations of 956 inventors are unidentified.
    - For corporate inventors, affiliation was identified by address (basically, the corporate name and address are listed in the “place of inventor” field in the patent gazette).
    - For university and PRO researchers, affiliation is not always indicated in patent journal descriptions.
      - Directory Database of Research and Development Activities (ReaD) - the Japanese Science and Technology Corporation (JST) - and Database of Grants-in-Aid for Scientific Research - the National Institute of Informatics
    - By incorporating acquisition and merger or change and variation of corporate names, we identified 2,726 distinct firms.

- We identified the number of patent applications co-invented with researchers affiliated with PROs and universities. In this sample, 10.3% are classified as UI co-inventorship.
Main source of data is the bibliographic database of academic articles prepared by Thomson Scientific Inc. (called SCI-EXPANDED)

Full-text search to extract photocatalyst-related articles.
- 6,992 articles published from 1970 to 2004
- 9,801 individual researchers from 2002 organizations.
  - 26.8% of articles (1,873) are authored or co-authored by Japanese researchers (including researchers affiliated with firms, PROs, and universities).
    - we counted the number of papers and the number of citations (the sum of citations eventually received by all the papers the organization has ever published)
**Classification of scientists**

UPRO_QPUB counts the average quality of the publications of the universities and PROs (Number of citations divided by number of publications).

UPRO_PAT counts the number of patent applications reported by the universities and PROs.

<table>
<thead>
<tr>
<th>Number of patents (UPRO_PAT)</th>
<th>Quality of publications (UPRO_QPUB)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOW</strong> (UPRO_PAT ≤ 10)</td>
<td>LOW (UPRO_QPUB ≤ 2.5556)</td>
<td>206 (83.1%)</td>
</tr>
<tr>
<td><strong>LOW</strong> (UPRO_PAT ≤ 10)</td>
<td>Others</td>
<td>175 (70.6%)</td>
</tr>
<tr>
<td></td>
<td>175 PROs (60.57%)</td>
<td>55 universities (31.43%)</td>
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<tr>
<td></td>
<td>5 PROs (16.13%)</td>
<td>26 universities (83.87%)</td>
</tr>
<tr>
<td><strong>HIGH</strong> (UPRO_PAT &gt; 10)</td>
<td>HIGH (UPRO_QPUB &gt; 2.5556)</td>
<td></td>
</tr>
<tr>
<td><strong>HIGH</strong> (UPRO_PAT &gt; 10)</td>
<td>Edison scientists</td>
<td>19 (7.7%)</td>
</tr>
<tr>
<td></td>
<td>19 PROs (73.68%)</td>
<td>5 universities (26.32%)</td>
</tr>
<tr>
<td></td>
<td>Pasteur scientists</td>
<td>23 (9.3%)</td>
</tr>
<tr>
<td></td>
<td>4 PROs (17.39%)</td>
<td>19 universities (82.61%)</td>
</tr>
<tr>
<td>Total</td>
<td>194 (78.2%)</td>
<td>54 (21.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>248 (100%)</td>
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**Note:**
- 2.5556 is the mean value of the distribution of the variable UPRO_QPUB
- 10 is the mean value of the distribution of the variable UPRO_PAT
Testable hypotheses

Firm-Pasteur scientists collaborations

Firm-Bohr scientists collaborations

Firm-Edison scientists collaborations

R&D productivity of firms

Hyp. 1
Yes!

Hyp. 2

Hyp. 3

Hyp. 1

Hyp. 2
Conclusions

- Collaborations with Pasteur scientists have a positive and significant impact on the firm’s innovative performance.
  - Hyp. 1 is supported, it’s important for corporate managers to select university partners with high scientific value and technological experience.

- Collaborations with Bohr scientists are not significant in improving the firm’s innovative performance.
  - Hyp. 2 is supported, being a star scientist is not a sufficient condition to engage in a two-way knowledge interaction process with corporate researchers conducive to innovation.

- Collaborations with Edison scientists have a lower, but still positive and significant impact on firm’s innovative performance.
  - Hyp. 3 is rejected, being an inventor not well respected in the scientific community is not a sufficient condition to provide firms with the appropriate knowledge base to develop new products incorporating cutting edge science.
Theoretical implications

- The concept of Pasteur scientists was tested empirically first by the authors, to deepen the present understanding of industrial heterogeneity in innovation processes and to offer new insights for the formulation of corporate innovation strategies.

- Our findings strongly support the importance of consulting as mean for knowledge re-combination and tacit knowledge flows between firms and universities through the contribution of Pasteur scientists, who work as boundary spanners, combining their science-based background with the knowledge, mainly ingrained into practice and trial-and-error procedures, of corporate researchers.
Related research: “Pasteur bridging scientists” in biotechnology (Subramanian, et.al.: 2013)

- Innovation impact on a focal firm depends upon the composition of the firm’s scientific human capital and how that human capital interacts with the type of external R&D alliances.
- Pasteur bridging scientists substitute for academic R&D partners, and therefore interact negatively with the UI R&D alliances.
- Edison bridging scientists complement the firm’s R&D alliances with university partners and therefore exhibit a positive interaction term.
Fig. 1. Types of scientists.