Internationalized R&D activities and technological specialization: an analysis of patent data.

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Patent Statistics for Decision Makers Conference
What are the relations between internationalization in R&D and technological specialization?

Patent counts (PATSTAT); all priority filings (de Rassenfosse, Dernis, Guellec, Picci, de la Potterie, Respol 2013).

International patents: inventors/applicants from different countries

“Inventor” vs. “applicant criterion”, National vs. International
The internationalization of inventive activity

• Patel and Pavit, 1991: internationalization of production vs. localized inventive activity

• “The times they are a changing”: Patel and Vega, 1999; Le Bas and Sierra, 2002

• Anecdotal evidence: The Economist, 2010: “Companies in the Fortune 500 list have 98 R&D facilities in China and 63 in India”

• Industry case-studies:
  - Wireless telecom; Di Minin and Bianchi, 2011; Pharmaceuticals; Bennato and Magazzini, 2009; Biotech; Shan and Song, 1997; Semiconductors; Almeida, 1996
The specialization of inventive activity

- Sharp increase in specialization of inventive activity at national level from 1965 to 1990 (Archibugi and Pianta, 1992; Cantwell and Vertova, 2004).
- But: increasing diversification at firm level (e.g. Garcia-Vega, 2006)

→ Greater internationalization of MNEs leads overseas location to focus on the best that the foreign location has to offer
Research questions

The relationship between technological specialization and internationalization

1. Are there differences across technologies and across countries?

2. What are the motivations for international collaborations and how do they evolve in time?

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Contribution to the literature /1
Structural changes in internationalized patenting activity

Guellec and van Pottelsberghe de la Potterie, 2001; OECD, 2008; Picci, 2010: take global view regardless of technological sectors.

→ We break down data by WIPO’s International Patent Classification (IPC) taxonomy. Specific contributions:

1. Differences in intensity and nature by tech sector.

2. Disentangle pure growth effects from compositional effects

3. New index to contrast between different metrics: applicants vs inventors.
Archibugi and Pianta (1992) and Cantwell and Vertova (2004): tech specialization at the country level increased until 1990

1. We provide the missing picture afterwards
2. Tech profiles: international vs national
3. Tech profiles: applicants vs inventors
Contribution to the literature / Motivations for international collaborations


Some evidence of a shift from exploiting to augmenting

Patel and Pavitt (1991); Cantwell (1999): shift to source abroad tech where they do not have a comparative advantage

**system-driven vs sector-driven motivations**

Gravity model at aggregate level and at sectorial level.

1. Technological proximity, at different levels of granularity.
2. More nuanced view on motivations for internationalization
Results / 1

Since 1990:

1. **Internationalization has increased in all sectors.** Positive but modest role of compositional effects.

2. **Tech specialization has not increased.** This interrupts a trend.

3. **National specialization profiles are “amplified” in the production of internationalized inventions**

4. **“Inventor” countries are more specialized than “applicant” countries.** MNEs tend to reinforce specialization patterns abroad

5. **Specialization cycles?** Specialized emerging (inventor) countries mature, become active in inventing abroad, and eventually de-specialize
5. **Technological proximity** negatively influences collaborations only in some sectors. R&D strategies are technology dependent.

6. **No increase over time** for home-base augmenting motives.

7. “**System-driven vs sector-driven**”.
Dataset

Patstat, EPO 2009
1990 – 2006
50 patent offices
40 countries (OECD + others)

IPC tech classes: WIPO taxonomy (36 classes re-grouped into 5)
10,940,242 priority applications

→ national patents: all inventors and applicants from the same country
→ international: at least one inventor or applicant from another country
263,220 or 2.6%
Fractional counting

1 Patent

4 inventors from: US, US, IT, ES

2 applicants: US, ES
Fractional counting

0.25 + 0.25

0.50

4 inventors from: US, US, IT, ES

2 applicants: US, ES
InvApp *absolute* measure of internationalization

\[
\begin{align*}
0.25 & + 0.25 \quad 0.25 & 0.25 \\
\hline
0.50
\end{align*}
\]

4 inventors: US, US, IT, ES

2 applicants: US, ES

\[
\begin{align*}
\text{InvApp}_{US, ES} &= \text{Inv}_{US} \times \text{App}_{ES} = 0.5 \times 0.5 = 0.25 \\
\text{InvApp}_{ES, US} &= \text{Inv}_{ES} \times \text{App}_{US} = 0.25 \times 0.5 = 0.125
\end{align*}
\]
**Relative measures of internationalization/1**

\[ \text{InvApp}_{US,ES} = \text{Inv}_{US} \times \text{App}_{ES} = 0.5 \times 0.5 = 0.25 \]

1. This is the absolute measure for 1 patent.

2. Sum across patents and get the country score for internationalization.

3. Weight over the total fractional counting according to inventors or applicants.

\[ \rightarrow \% \text{ of international patents:} \]

\[ \frac{\text{InvApp}_{ij}}{\text{Inv}_i} \quad \text{InvApp}_{ji} \]

\[ \frac{\text{InvApp}_{ji}}{\text{App}_i} \]
Relative measures of internationalization/2: example

InvApp\textsubscript{US,ES} / Inv\textsubscript{US}  
American inventors collaborating with: Spanish applicants relative to: total American inventors.

InvApp\textsubscript{ES,US} / App\textsubscript{US}  
Spanish inventors collaborating with: American applicants relative to: total American applicants.

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Macro-technological sectors

United Kingdom

Other fields
33 - Furniture, games
34 - Other consumer goods
35 - Civil engineering

Electrical engineering
1 - Electrical machinery, apparatus, energy
2 - Audio-visual technology
3 - Telecommunications
4 - Digital communication
5 - Basic communication processes
6 - Computer technology
7 - IT methods for management
8 - Semiconductors

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Breakdown in compositional and pure growth effects
Growth rate of int., InvApp|Inv metric for selected countries

Growth of Internationalization rate, 1990-2006. % points

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Comparison between measures of internationalization / 1
InvApp|Inv and InvApp|App metrics for the USA, France, and Germany, 1990 -2006

InvApp|App:

InvApp_{ES, US} 
App_{US}

InvApp|Inv:

InvApp_{US, ES} 
Inv_{US}

United States  France  Germany
Comparison between measures of int. by tech sector / 2

InvApp|Inv and InvApp|App in Germany, 1990 -2006

Germany

Different measures of internationalization, Chem
DE, 1990 - 2006

Different measures of internationalization, Electr
DE, 1990 - 2006

Different measures of internationalization, Mech
DE, 1990 - 2006

Chem  Electr  Mech

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Applicant Surplus

Bilateral

\[ \text{AppSur}_{ij} = (1 - \frac{\text{InvApp}|\text{App}}{\text{InvApp}|\text{Inv}}) \cdot 100 \]

→ positive: country i contributes with relatively more applicants and country j with relatively more inventors.

National → aggregate over ROW
## Country applicant surplus

<table>
<thead>
<tr>
<th>Period</th>
<th>Country</th>
<th>All tech</th>
<th>Electr</th>
<th>Instr</th>
<th>Chem</th>
<th>Mech</th>
<th>Other</th>
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<tbody>
<tr>
<td>2000-2004</td>
<td></td>
<td>1.00</td>
<td>24.08</td>
<td>-12.96</td>
<td>-24.88</td>
<td>-10.16</td>
<td>-17.18</td>
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<tr>
<td>1990-1994</td>
<td>CN</td>
<td>-46.68</td>
<td>-60.43</td>
<td>-74.75</td>
<td>-34.65</td>
<td>-41.55</td>
<td>3.88</td>
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<tr>
<td>1995-1999</td>
<td></td>
<td>-75.82</td>
<td>-74.36</td>
<td>-23.64</td>
<td>-69.00</td>
<td>-93.66</td>
<td>-60.94</td>
</tr>
<tr>
<td>2000-2004</td>
<td></td>
<td>-73.54</td>
<td>-79.70</td>
<td>-51.60</td>
<td>-82.14</td>
<td>-59.48</td>
<td>-44.16</td>
</tr>
<tr>
<td>2005-2006</td>
<td></td>
<td>-60.70</td>
<td>-61.67</td>
<td>-57.23</td>
<td>-61.10</td>
<td>-62.00</td>
<td>-41.97</td>
</tr>
<tr>
<td>1990-1994</td>
<td>US</td>
<td>174.45</td>
<td>258.73</td>
<td>268.75</td>
<td>135.65</td>
<td>125.30</td>
<td>169.83</td>
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<tr>
<td>1995-1999</td>
<td></td>
<td>172.36</td>
<td>145.68</td>
<td>257.26</td>
<td>187.92</td>
<td>188.50</td>
<td>249.98</td>
</tr>
<tr>
<td>2000-2004</td>
<td></td>
<td>91.58</td>
<td>48.92</td>
<td>90.74</td>
<td>164.74</td>
<td>216.10</td>
<td>173.42</td>
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<tr>
<td>2005-2006</td>
<td></td>
<td>151.73</td>
<td>117.77</td>
<td>103.07</td>
<td>160.50</td>
<td>353.30</td>
<td>298.53</td>
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<tr>
<td>1995-1999</td>
<td></td>
<td>7.52</td>
<td>-17.32</td>
<td>-6.86</td>
<td>71.66</td>
<td>-5.18</td>
<td>2.18</td>
</tr>
<tr>
<td>2000-2004</td>
<td></td>
<td>11.58</td>
<td>-12.58</td>
<td>-5.82</td>
<td>78.28</td>
<td>10.96</td>
<td>1.14</td>
</tr>
</tbody>
</table>
Specialization/1: TecSpec index (Krugman index)

How the tech shares of a country differ from the ROW

\[ \text{TecSpec}_i = \sum_{k=1}^{5} \text{abs}(s_{k,i} - \bar{s}_k) \]

\( \text{TecSpec}=0 \rightarrow \text{same tech prof. ROW} \)

\( \text{TecSpec}=2 \rightarrow \text{no tech shared with ROW} \)

<table>
<thead>
<tr>
<th>Period</th>
<th>National (a)Inv</th>
<th>National (b)App</th>
<th>International (c)Inv</th>
<th>International (d)App</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1993</td>
<td>.399</td>
<td>.410</td>
<td>.368</td>
<td>.618</td>
</tr>
<tr>
<td>2003-2007</td>
<td>.386</td>
<td>.413</td>
<td>.355</td>
<td>.682</td>
</tr>
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</table>
Specialization/1: Correlation between tech profiles

<table>
<thead>
<tr>
<th></th>
<th>Nat</th>
<th></th>
<th>Int</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Inv</td>
<td>Inv</td>
<td></td>
</tr>
<tr>
<td>Nat</td>
<td></td>
<td>1.00</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inv</td>
<td>0.94</td>
<td>0.52</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>App</td>
<td>1.00</td>
<td>0.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>App</td>
<td></td>
<td>0.48</td>
<td>0.47</td>
<td>1.00</td>
</tr>
</tbody>
</table>

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Specialization/2: Technological Revealed Comparative Advantage

TRCA: world share in a sector / total world share in patenting activities

Advantage if >1

<table>
<thead>
<tr>
<th>Period</th>
<th>Electr</th>
<th>Inst</th>
<th>Chem</th>
<th>Mech</th>
<th>Other</th>
<th>AVG</th>
<th>Corr (TRCA&lt;sub&gt;int&lt;/sub&gt;, TRCA&lt;sub&gt;naz&lt;/sub&gt;)</th>
<th>Electr</th>
<th>Inst</th>
<th>Chem</th>
<th>Mech</th>
<th>Other</th>
<th>AVG</th>
<th>Corr (TRCA&lt;sub&gt;int&lt;/sub&gt;, TRCA&lt;sub&gt;naz&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All periods</td>
<td>0.471</td>
<td>0.310</td>
<td>0.246</td>
<td>0.484</td>
<td>0.218</td>
<td></td>
<td></td>
<td>0.557</td>
<td>0.193</td>
<td>0.467</td>
<td>0.223</td>
<td>0.304</td>
<td>0.557</td>
<td></td>
</tr>
</tbody>
</table>

1) International specialization patterns reflect national patterns.

<table>
<thead>
<tr>
<th></th>
<th>StDev(TRCA&lt;sub&gt;int&lt;/sub&gt;) / StDev(TRCA&lt;sub&gt;naz&lt;/sub&gt;)</th>
<th>StDev(TRCA&lt;sub&gt;int&lt;/sub&gt;) / StDev(TRCA&lt;sub&gt;naz&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INV</td>
<td>APP</td>
</tr>
<tr>
<td>1990-1993</td>
<td>1.86 3.51 0.83 1.44 1.65 1.86</td>
<td>1.59 5.51 0.99 7.81 5.97 4.37</td>
</tr>
<tr>
<td>1994-1998</td>
<td>1.43 2.17 0.57 1.80 1.26 1.45</td>
<td>1.18 2.74 1.16 5.44 2.72 2.65</td>
</tr>
<tr>
<td>1999-2002</td>
<td>1.20 1.46 0.86 1.81 1.21 1.31</td>
<td>1.42 4.10 0.90 3.18 1.79 2.28</td>
</tr>
<tr>
<td>2003-2007</td>
<td>1.01 1.43 0.93 1.63 0.90 1.18</td>
<td>1.47 2.65 1.68 3.39 4.45 2.73</td>
</tr>
<tr>
<td>Total</td>
<td>1.42 2.04 0.80 1.70 1.27</td>
<td>1.40 3.69 1.31 5.12 4.08</td>
</tr>
</tbody>
</table>

2) National profiles are amplified in international. No change over time.

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Inventors surplus countries should be more specialized

→ negative relation with AppSur

Spearman correlations between the two measures are low, negative and significant at 1%
Motivations: A gravity model of sectorial inventive activity

\[
\ln(\text{InvApp}_{ijt}^s) = \beta_0 + \beta_1 \ln(A_{it}^s) + \beta_2 \ln(A_{jt}^s) + \beta_3 \ln(\text{dist}_{ij}) + \lambda L_{ijt} + \beta_4 D_{it} + \beta_5 D_{jt} + \epsilon_{ijt}
\]

**macro-sector**

- **Inv.mass**
  - country i (pat count)
  - country j (pat count)

- Distance between i & j capital cities

**Vars vector:**
- Tech(s) → 35 sect
- Tech → 5 sect
- • Com. borders
- • Com. language
- • Similar language
- • Religion
- • EU members
- • Eu. Monetary Un.
- • IP protection

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**Tech:** country vector correlation *between macro-sectors*

**Techsec:** country vector correlation *within macro-sectors*

*Negative:* home-base augmenting
Poisson/2: time variation in the role of the country portfolio

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>$\ln(\text{Inv}<em>{is})</em>{s=0,1...,5}$</th>
<th>$\ln(\text{Inv}<em>{js})</em>{s=0,1...,5}$</th>
<th>$\ln(\text{App}_{is})$</th>
<th>$\ln(\text{App}_{js})$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{InvApp}^0_{\text{All technologies}}$</td>
<td>$\text{InvApp}^1_{\text{Electrical}}$</td>
<td>$\text{InvApp}^2_{\text{Instruments}}$</td>
<td>$\text{InvApp}^3_{\text{Chemistry}}$</td>
</tr>
<tr>
<td>a. 1990-1998</td>
<td>4.860*** (0.221)</td>
<td>1.953*** (0.112)</td>
<td>4.611*** (0.333)</td>
<td>3.215*** (0.168)</td>
</tr>
<tr>
<td>b. 1999-2006</td>
<td>4.267*** (0.186)</td>
<td>1.895*** (0.0896)</td>
<td>4.030*** (0.304)</td>
<td>3.173*** (0.160)</td>
</tr>
<tr>
<td>a. 1990-1998</td>
<td>-4.721*** (0.182)</td>
<td>-2.755*** (0.164)</td>
<td>-1.584*** (0.231)</td>
<td>-1.996*** (0.210)</td>
</tr>
<tr>
<td>b. 1999-2006</td>
<td>-4.550*** (0.162)</td>
<td>-2.258*** (0.123)</td>
<td>-1.563*** (0.207)</td>
<td>-2.114*** (0.198)</td>
</tr>
<tr>
<td>a. 1990-1998</td>
<td>-3.987*** (0.217)</td>
<td>-1.092*** (0.101)</td>
<td>-3.936*** (0.334)</td>
<td>-2.655*** (0.154)</td>
</tr>
<tr>
<td>b. 1999-2006</td>
<td>-3.441*** (0.181)</td>
<td>-0.953*** (0.0834)</td>
<td>-3.789*** (0.307)</td>
<td>-2.578*** (0.147)</td>
</tr>
<tr>
<td>a. 1990-1998</td>
<td>4.887*** (0.191)</td>
<td>2.962*** (0.153)</td>
<td>2.361*** (0.233)</td>
<td>2.214*** (0.212)</td>
</tr>
<tr>
<td>b. 1999-2006</td>
<td>4.636*** (0.168)</td>
<td>2.410*** (0.116)</td>
<td>2.226*** (0.211)</td>
<td>2.436*** (0.202)</td>
</tr>
</tbody>
</table>

No increase over time
Home-base augmenting
Summary of results & future research

1. Increase of internationalization over time across tech sectors, no compositional effects.

2. No increase in specialization over time \( \Rightarrow \) Specialization cycles?

3. National technological profiles differ sensibly from international ones.

4. Countries with an inventors surplus are more specialized \( \Rightarrow \) role of MNEs.

5. Technological proximity affects collaborations with important differences across sectors \( \Rightarrow \) sector-specific policies.

6. Evidence of home-base augmenting motives. But other taxonomy?

7. No increase over time. Intriguingly consistent with no increase in specialization.

\( \Rightarrow \) Specialization & internationalization policies should be connected: competition for subsidiaries charters (Birkinshaw and Hood, 1989)

\( \Rightarrow \) Hollowing out
Thanks!

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