Trends at the frontier in Corporate R&D in the digital era

Reinhilde Veugelers
Full Professor at KULeuven, Senior Fellow at Breugel

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Predicted rising inequality/concentration

- Rising income inequality and falling labour share
- Rising concentration especially perceived in digital sectors, cf Big Tech – Competition Policy Cases
Growing concentration in product markets and its positive or negative impact associated with innovation

• ‘Autor et al (2016) : More concentration in industries where productivity increases and technical change is higher

• Andrews, Criscuolo & Gal (OECD, 2017) show an increasing productivity gap between the global frontier and laggard firms
  • This productivity divergence remains after controlling for the ability of frontier firms to charge higher mark-ups

Positive or negative impact of higher concentration associated with innovation

😊 Disruptive innovation by Superstar firms with higher productivity (Schumpeter Mark II)

😊 Incremental innovation by incumbents riding on stock of accumulated assets and experience (Schumpeter Mark I) Acemoglu & Hildenbrand (2017) argue that incumbent innovation advantage has increased over time
Our Research Questions

Does the global corporate R&D landscape become increasingly more concentrated in a few ‘superstars’?

• Compared to concentration in sales/employment
• Who are these innovation superstars: incumbents or new leaders?...
• Where are they from? US, Europe, China
• Sector-specific trends: digital
What do we expect: (digital) technological change is predicted to lead to “winner takes most” industries

- **Economies of scale & scope** in the R&D process, large sunk investments for building R&D capacity, the need to access networks and alliance partners are all characteristics that lead to R&D races increasing characterized as “winner take most” (Schumpeter Mark I: big firms for R&D).

- **Cumulativeness** of knowledge stocks, learning, where incumbent firms are the most likely winners (Schumpeter Mark I: incumbent firms for R&D).

- Sales Concentration in fewer firms more likely in industries characterized by competition through **sunk R&D investments** (Sutton (1992))

However

- The speed with which the latest technological innovations get **diffused** or spill over voluntarily or involuntarily will lead to catching up and dissipating of previous leadership positions.

- Incumbent technology leaderships can be quickly overturned by **radically new** technology avenues, creating room for new winners (Schumpeter Mark II). Even if the landscape will still be concentrated: turbulence in leadership
Our sample: Scoreboard firms: largest R&D spending firms worldwide

- The scoreboard firms cover >90% of EU BERD
  - On average >80% worldwide
- We will only be characterizing the R&D distribution in the top parts of the R&D size distribution
- Scoreboard sample size increases over time (we construct a constant time-comparable sample)
The top corporate R&D investors and the growing importance of digital

Full list of 2500 JRC Scoreboard companies by size of R&D expenditure, 2015

EC-JRC-IPTS Industrial R&D Scoreboard (Largest R&D spenders worldwide, 2005 – 2015)
R&D expenditures by Scoreboard firms are **concentrated** in few firms.

- In 2015, the Top 10% of Scoreboard firms represent 71% of all Scoreboard R&D expenditures.
- The Top 1% of R&D spenders account for 27% of all European R&D scoreboard expenditures.

**Corporate R&D concentrated in few firms**
- R&D expenditures by Scoreboard firms are highly unevenly distributed and concentrated in few firms
- The distribution of sales and employment of Scoreboard firms is also highly unequal and concentrated, but less so than their R&D expenditures.

<table>
<thead>
<tr>
<th></th>
<th>THEIL</th>
<th>GINI</th>
<th>Top1%</th>
<th>Top10%</th>
<th>Top10</th>
<th>Top100</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
<td>1.47</td>
<td>0.76</td>
<td>27%</td>
<td>71%</td>
<td>14.6%</td>
<td>53.1%</td>
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<tr>
<td>SALES</td>
<td>1.32</td>
<td>0.77</td>
<td>22%</td>
<td>66%</td>
<td>12.4%</td>
<td>47.4%</td>
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<tr>
<td>EMPLOY</td>
<td>1.14</td>
<td>0.74</td>
<td>17%</td>
<td>62%</td>
<td>9.53%</td>
<td>44.4%</td>
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<table>
<thead>
<tr>
<th></th>
<th>THEIL (TOTAL)</th>
<th>% OF THEIL DUE TO “BETWEEN” TOP10-BOTTOM90</th>
<th>% OF THEIL DUE TO “WITHIN” TOP10&amp;BOTTOM90</th>
<th>WITHIN TOP10% THEIL</th>
<th>WITHIN BOTTOM90% THEIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
<td>1.47</td>
<td>71%</td>
<td>29%</td>
<td>0.43</td>
<td>0.38</td>
</tr>
<tr>
<td>Sales</td>
<td>1.32</td>
<td>39%</td>
<td>61%</td>
<td>0.56</td>
<td>1.08</td>
</tr>
<tr>
<td>Employment</td>
<td>1.14</td>
<td>30%</td>
<td>70%</td>
<td>0.44</td>
<td>1.06</td>
</tr>
</tbody>
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Source: Calculations on the basis of EC-JRC-IPTS R&D scoreboard data, latest version
## High inequality & concentration of R&D in Health & Digital (services)

<table>
<thead>
<tr>
<th>2015</th>
<th>ALL SECTORS</th>
<th>Bio Pharma</th>
<th>Digital Services</th>
<th>Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>2498</td>
<td>369</td>
<td>852</td>
<td>297</td>
</tr>
<tr>
<td>Theil R&amp;D</td>
<td>1.47</td>
<td>1.78</td>
<td>1.50</td>
<td>1.60</td>
</tr>
<tr>
<td>Theil Sales</td>
<td>1.32</td>
<td>1.83</td>
<td>1.59</td>
<td>1.66</td>
</tr>
<tr>
<td>Theil Empl</td>
<td>1.14</td>
<td>1.65</td>
<td>1.30</td>
<td>1.56</td>
</tr>
<tr>
<td>Top1% R&amp;D Share R&amp;D</td>
<td>27%</td>
<td>25%</td>
<td>31%</td>
<td>34%</td>
</tr>
<tr>
<td>Top10% R&amp;D Share R&amp;D</td>
<td>71%</td>
<td>83%</td>
<td>70%</td>
<td>71%</td>
</tr>
<tr>
<td>Top10% Sales Share Sales</td>
<td>66%</td>
<td>84%</td>
<td>74%</td>
<td>75%</td>
</tr>
<tr>
<td>Top10% Empl Share Empl</td>
<td>62%</td>
<td>76%</td>
<td>67%</td>
<td>72%</td>
</tr>
</tbody>
</table>

**Source:** Calculations on the basis of EC-JRC-IPTS R&D scoreboard data, latest version
• No increasing inequality in R&D, on the contrary, the trend is one of slow decline.
  • Nevertheless, this downward trend seems to have stopped since 2011.
  • Since 2012, the Top1% R&D spenders have forged ahead.
High inequality/concentration slowly declining over time

Theil decomposition over Top 10% - Bottom 90%

Share of Scoreboard Employment, Sales and R&D Expenditure of the Top 1% and Top 10% of Firms in terms of R&D Expenditure

Source: Calculations on the basis of EC-JRC-IPTS R&D scoreboard data

Global time-comparable sample N=1338
In ICT/Digital: decreasing concentration in Top 1% stopped more recently (US digital services)

Source: Bruegel calculations on the basis of EC-JRC-IPTS R&D scoreboard data, latest version
When looking at who inhabits the top, the data show a strong \textit{incumbency} advantage.

- Those few firms that have been able to be a Top10\% leading R&D firm within their sector throughout the period covered, represent more than half of the corporate R&D worldwide.
- Incumbency is also demonstrated by the high share which leaders in 2005 can still command in 2015 and vice versa.
Persistency in R&D leadership

Among the 1314 time traceable Scoreboard companies
- 6% (N=83) are persistent leaders (i.e. belonged to the Top 10% across almost the entire time from 2005 till 2015, i.e. 10 or 11 times).
- 83% are persistent non-leaders, i.e. never belonged to the Top 10%.
- Only 9 firms are “new leaders”, i.e. companies entering the Scoreboard in the Top 10% and stay among the group of leaders in all years until 2015 (one lapse allowed).
- The rest are switchers, i.e. moving in and out of top leadership position.

Source: Bruegel calculations on the basis of EC-JRC-IPTS R&D scoreboard data
## Persistency of Leadership in Digital

<table>
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<tr>
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<th>Share of sector R&amp;D 2005</th>
<th>Share of sector R&amp;D 2015</th>
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<tbody>
<tr>
<td><strong>Digital (N=466)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent top 10% firms (5%)</td>
<td>46%</td>
<td>43%</td>
</tr>
<tr>
<td>Old firms (40%)</td>
<td>62%</td>
<td>40%</td>
</tr>
<tr>
<td>Youngest firms (28%)</td>
<td>9%</td>
<td>19%</td>
</tr>
<tr>
<td>Top 10% firms in 2005</td>
<td>64%</td>
<td>48%</td>
</tr>
<tr>
<td>Top 10% firms in 2015</td>
<td>43%</td>
<td>62%</td>
</tr>
</tbody>
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Next to Alphabet, Microsoft, Cisco, Oracle and Qualcomm as young persistent leaders, there is also in 2015 **Huawei** in 5th position, Apple in 6th, Facebook in 12th position. None of these young new R&D leaders are EU.

## Persistency of Leadership in BioPharma

<table>
<thead>
<tr>
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<th>Share of sector R&amp;D 2005</th>
<th>Share of sector R&amp;D 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bio/Pharma (N=145)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent top 10% firms (7%)</td>
<td>60%</td>
<td>54%</td>
</tr>
<tr>
<td>Old firms (48%)</td>
<td>85%</td>
<td>76%</td>
</tr>
<tr>
<td>Top 10% firms in 2005</td>
<td>68%</td>
<td>63%</td>
</tr>
<tr>
<td>Top 10% firms in 2015</td>
<td>57%</td>
<td>63%</td>
</tr>
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</table>

There are 11 persistent R&D leaders (Novartis, Roche, J&J, Pfizer, Merck, BristolMyersSquibb, Sanofi, AstraZeneca, Bayer, GSK, EliLilly) in BioPharma. All of these persistent leaders are “old”.

A few young (biotech) firms made it close to this group of 10: Abbvie; Amgen, Celgene, and Gilead Sciences. All of these companies are US.

*Source: Bruegel calculations on the basis of EC-JRC-IPTS R&D scoreboard data*
EU’s position at the (digital) corporate R&D frontier

Source: Calculations on the basis of EC-JRC-IPTS R&D scoreboard data, latest version
Also innovative output in the form of patents are highly concentrated.

- In 2014, the top 10% of corporate R&D investors accounted for 61% of IP5 patent families (inventions patented in the five top IP offices) (68%) of Scoreboard R&D)
- The top 1% of corporate R&D investors accounted for 15% of IP5 patents families

Source: OECD, STI 2017
Top corporate R&D investors in the “Computers and electronics” industry are, by far, the most reliant on intellectual property (IP) rights and account for about one-third of total patent filings by top R&D investors.

They account for the ownership of about **75% and 55% of global ICT-related patents and designs**, respectively.

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The digital patent landscape is highly concentrated in top R&D investors

OECD, STI 2017
The development of artificial intelligence-related technologies, as measured by inventions patented in the five top IP offices (IP5), increased by 6% per year on average between 2010 and 2015, twice the average annual growth rate observed for patents in every domain.

The development of AI technologies is concentrated.

Top 2000 corporate R&D investors own 75% of the IP5 patent families related to artificial intelligence (AI).

R&D corporations based in Japan, Korea, Chinese Taipei and China account for about 70% of all AI-related inventions belonging to the world’s 2000 top corporate R&D investors and their affiliates, and US-based companies for 18%.

Source: OECD, STI 2017
“Computers and electronics”, accounts for 64% of the AI portfolio of top R&D players, but AI patents are also in other sectors: “general-purpose-technology”
• R&D expenditures by Scoreboard firms are concentrated in few firms
  • R&D concentration stronger than for Sales and Employment.
• The Scoreboard data do not signal increasing concentration in R&D, on the contrary, the trend is one of slow decline.
  • Nevertheless, this downward trend still leaves high levels of concentration and furthermore seems to have stopped since 2011.
• The Scoreboard data show a strong incumbency advantage:
  • Those few firms that have been able to be a Top10% leading R&D firms throughout the period covered, represent more than half of the corporate R&D worldwide. Incumbency is also demonstrated by the high share which leaders in 2005 can still command in 2015 and vice versa.
• The EU is relatively well represented as the home base for persistent R&D leaders, particularly in biopharma and vehicles.
What do we find in digital sectors?

- The distribution of R&D spending among digital Scoreboard firms is indeed highly concentrated, but less than in other high-tech (Pharma).
- The incumbency effect is smaller than in Pharma, there is more turbulence at the top.
- We see no trend of increasing concentration.
- But more recently, concentration of R&D spending in the top 1 percent of spenders has risen and turbulence at the top has cooled.
- As the new and young leading R&D firms in digital sectors are all from US and Asia (particularly China), Europe has lost out in terms of top R&D shares.
The evidence of declining concentration is a positive sign, but its high incumbency characteristic, its slow downward pace and particularly its losing momentum more recently, requires further monitoring and analysis to understand its implications for overall corporate R&D and growth performance; Especially in digital technologies

Especially in new digital technologies (AI)

With the US, and more recently China, hosting most of the new R&D leaders, especially in digital sectors but also in other sectors, the weaker creative-destruction power of the EU corporate R&D system could contribute to a shifting regional R&D pattern to Europe’s detriment.
Policy implications

- For **innovation policy**, it is important to recognise that overall corporate R&D performance depends on a handful of firms.
  - Understanding the innovation advantages and barriers incumbent leaders and/or new leading firms might enjoy will matter for assessing the power of innovation to generate growth.

- For **competition policy**, it is important to understand the impact of a highly concentrated R&D landscape.
  - Are trends therein associated with leading R&D firms enjoying innovative advantages, how contestable are existing leading positions are, do leading firms use their dominant R&D positions to raise entry barriers against more efficient new innovators, how R&D leaders can turn their R&D weight into market power?
Thanks for your attention!

- Reinhilde.Veugelers@kuleuven.be
- https://feb.kuleuven.be/reinhilde.veugelers
- Reinhilde.Veugelers@Bruegel.org
- bruegel.org/author/reinhilde-veugelers/