The end of innovation?

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Fuqua School of Business, Duke University and NBER

TIM Plenary Session, AOM, 2023

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Outline

- **The end of innovation?**
- **The symptoms of the malaise**
  - Excessive investment in innovation? – *If ideas are harder to find, why are we trying so hard to find them?*
  - From Bohr to Pasteur – *most university research difficult to apply*
  - Biases in the direction of innovation? – *missing middle*
- **A partial diagnosis: a division of innovative labor.**
  - Big firms – more R&D, more incremental
  - University and firm gap bigger
  - Startups : value capture problem
  - Govt policies
  - Other stuff
- **What is to be done? The burning questions of the moment**

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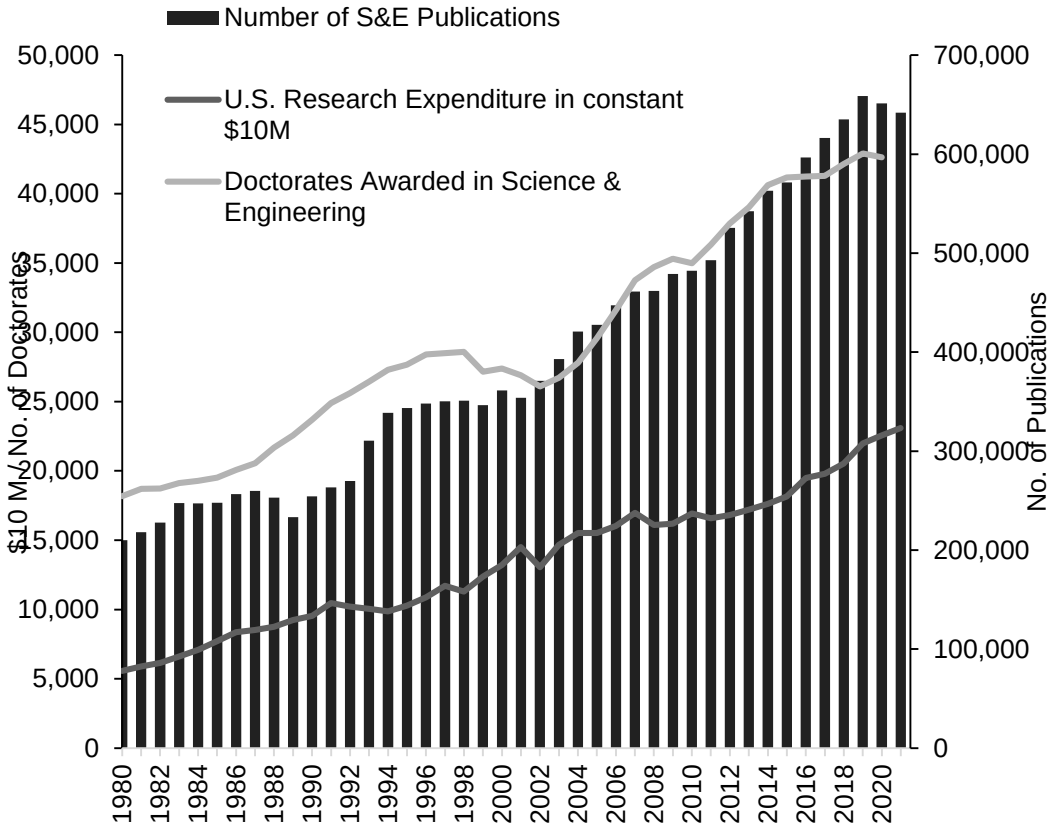
The end of innovation?

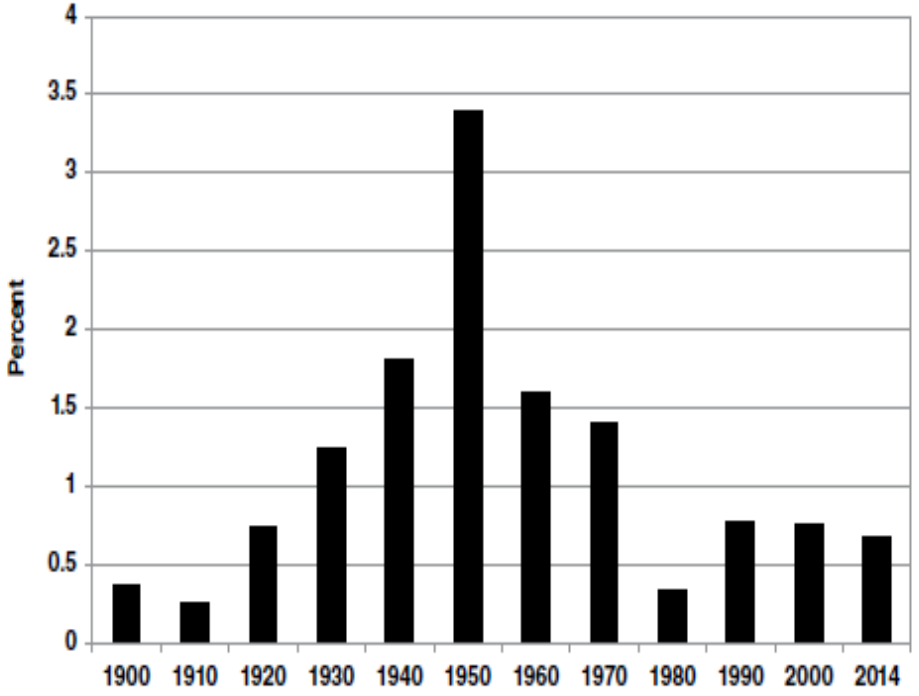
U.S. Scientific Investment and Output (1980-2021)



Sources: NSF, Web of Science

Figure 16–5. 10-Year Average Annual Growth in Total Factor Productivity, 1900–2014

Note: The average annual growth rate is over the ten years prior to year shown. The bar labelled 2014 shows the average annual growth rate for 2001–14.



Source: Gordon (2016)

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On the other hand …

The fruits of technological progress are coming forth at an undiminished rate

COVID mRNA vaccine

CRISPR

ChatGPT

Renewable energy

STAT News

In early work, researchers turn to CRISPR to treat Alzheimer's

4 hours ago

Science

Multiplex CRISPR editing of wood for sustainable fiber production

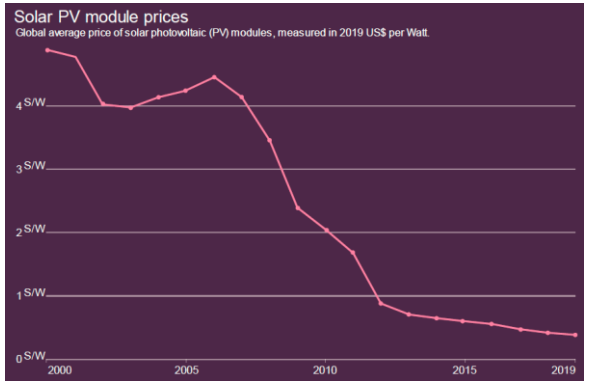
2 days ago

Fierce Pharma

ICER updates cost-effectiveness threshold for bluebird, Vertex and...

Phys.org

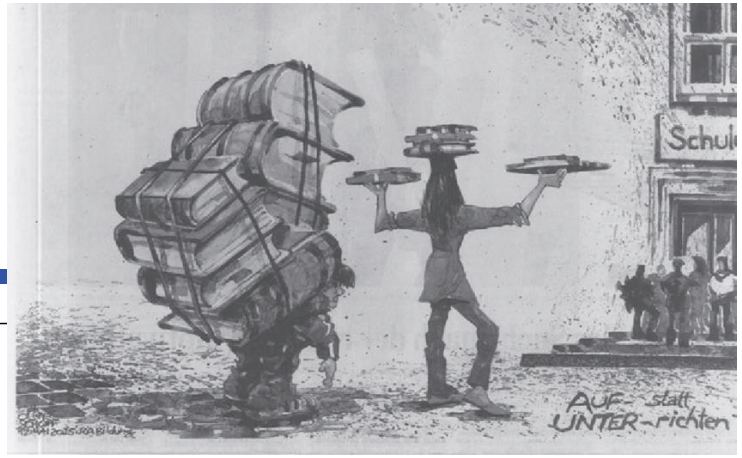
Building a better forest tree with CRISPR gene editing



Lilly's Donanemab Significantly Slowed Cognitive and Functional Decline in Phase 3 Study of Early Alzheimer's Disease

May 3, 2023

More incremental?
Papers and patents are becoming less disruptive?



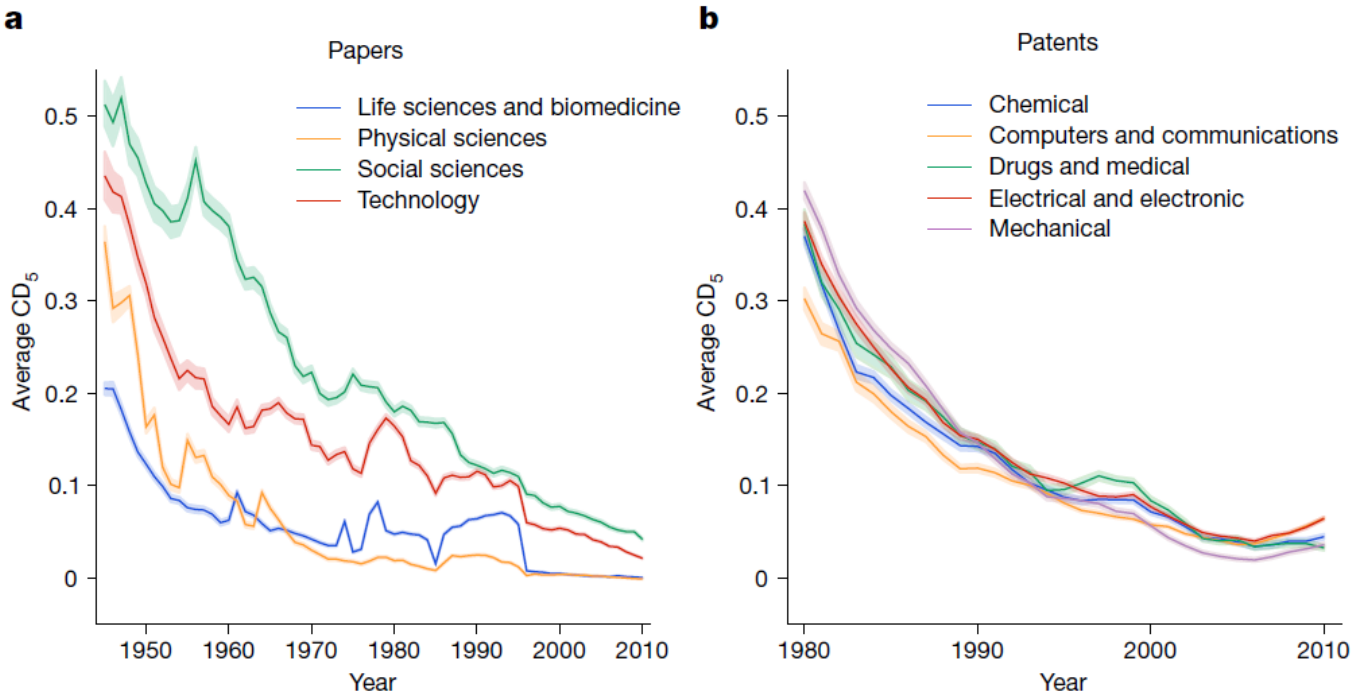


Fig. 2 | Decline of disruptive science and technology. a,**b**, Decline in CD_5 over time, separately for papers (**a**, $n = 24{,}659{,}076$) and patents (**b**, $n = 3{,}912{,}353$). For papers, lines correspond to WoS research areas; from 1945 to 2010 the magnitude of decline ranges from 91.9% (social sciences) to 100% (physical sciences). For patents, lines correspond to National Bureau of Economic Research (NBER) technology categories; from 1980 to 2010 the magnitude of decline ranges from 93.5% (computers and communications) to 96.4% (drugs and medical). Shaded bands correspond to 95% confidence intervals. As we elaborate in the Methods, this pattern of decline is robust to adjustment for confounding from changes in publication, citation and authorship practices over time.

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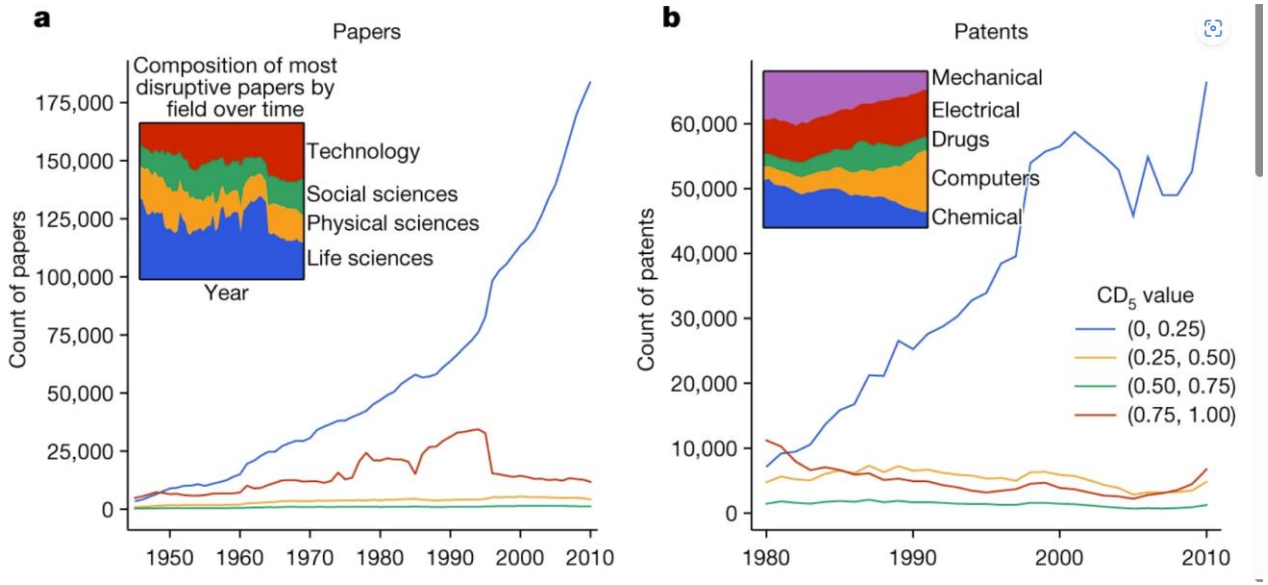
Park, M., Leahey, E. & Funk, R.J. Papers and patents are becoming less disruptive over time. *Nature* **613**, 138–144 (2023)

On the other hand …

Scientific progress continues at an undiminished rate



Park, M., Leahey, E. & Funk, R.J. Papers and patents are becoming less disruptive over time. *Nature* **613**, 138–144 (2023)

The number of disruptive paper and patents has NOT declined

nature

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NEWS | 14 June 2023

IBM quantum computer passes calculation milestone

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US scientists repeat fusion power breakthrough

Federal laboratory experiment produces more energy than during landmark test last year

The end of innovation? No, but there are problems

The symptoms of the malaise

- Innovation is incremental
- Ever increasing investments in universities are yielding less
- Innovation is lopsided – “we wanted flying cars, instead we got 140 characters”

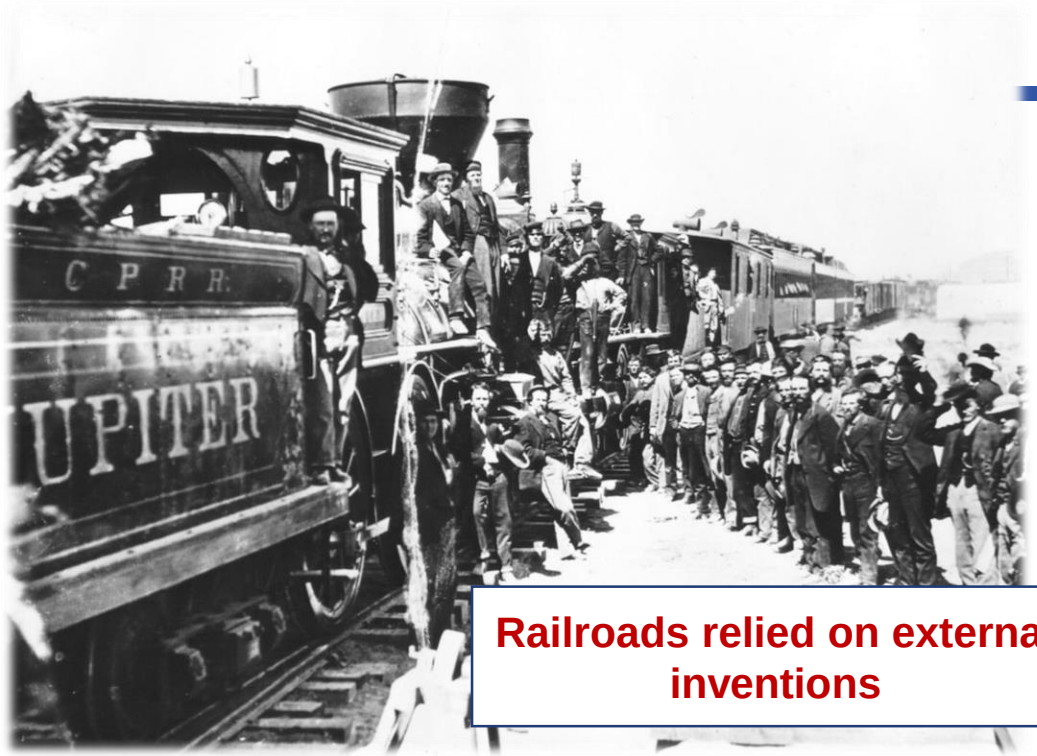
A partial diagnosis: Division of innovative labor

- Large firms produce more incremental innovations on average
- University research needs to be embodied for commercial application
- Startup innovations leave a missing middle

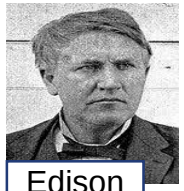
The division of innovative labor

A brief history of the last 150 years of innovation in 5 slides

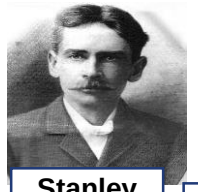
The division of innovative labor in America, 1850-1900



Railroads relied on external inventions

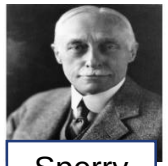


Edison



Stanley

Thompson



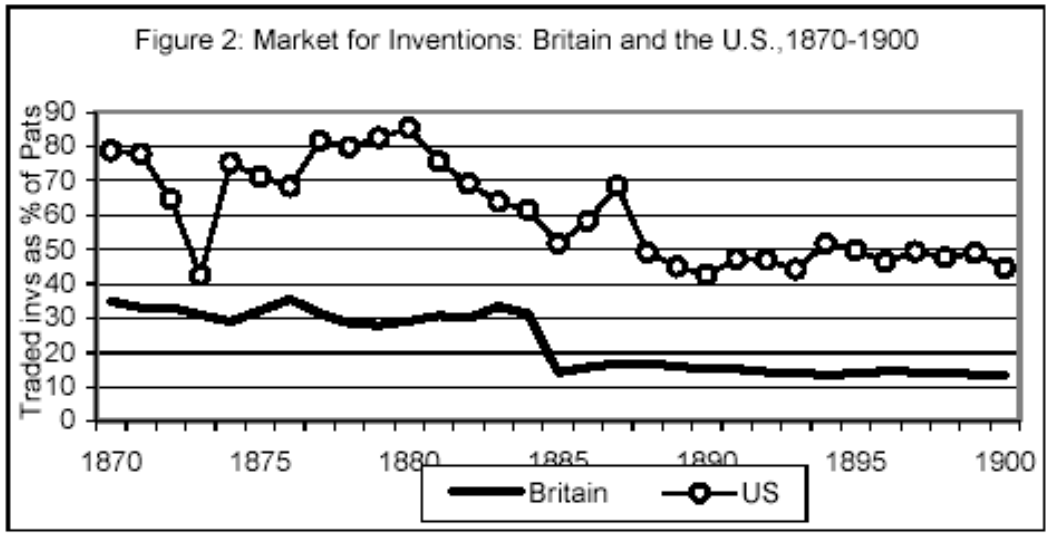
Sperry

Westinghouse

"I am fully convinced that it … never will pay commercially, to keep an establishment of professional inventors…

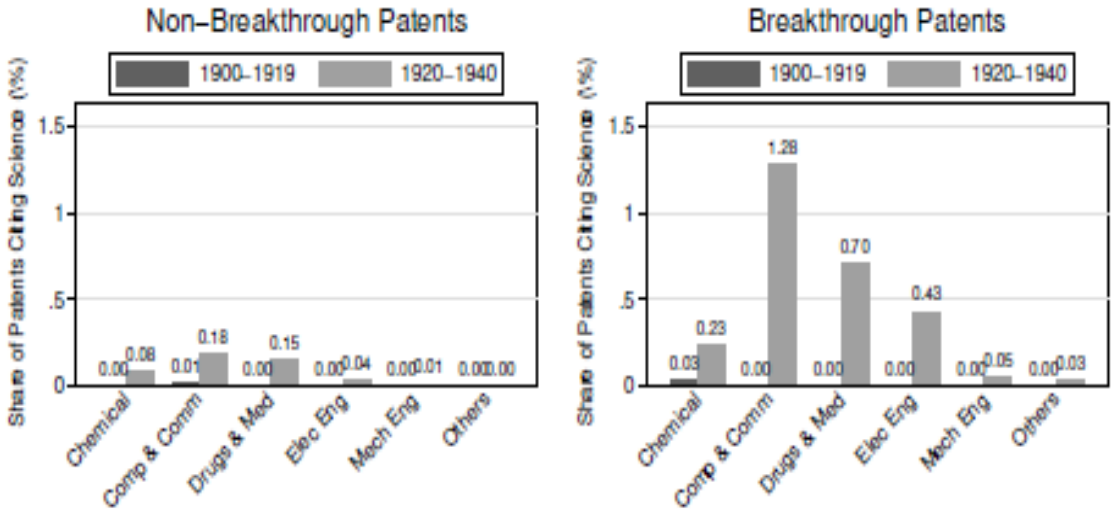
The duties of the patent department … (should be)
… examining patents or inventions submitted by the public for consideration and
… examining descriptions of inventions forwarded by the company's employees."

T.D. Lockwood, on the "Duties of the patent department", AT&T, 1885
(cited by Lamoreaux & Sokoloff, 1999)

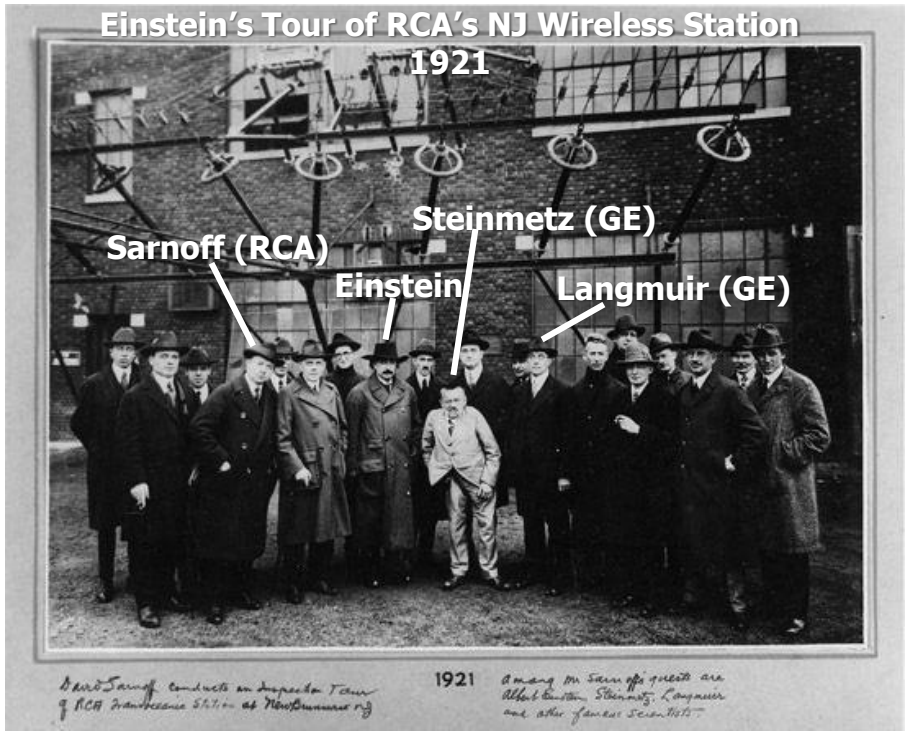


Notes: The figure shows the ratio of all assignments to patents issued in the U.S.; whereas for Britain, the ratio comprises assignments and licenses relative to patents issued.

The rise of industrial research (Arora, Belenzon, Kosenko, Suh, Yafeh, 2023)



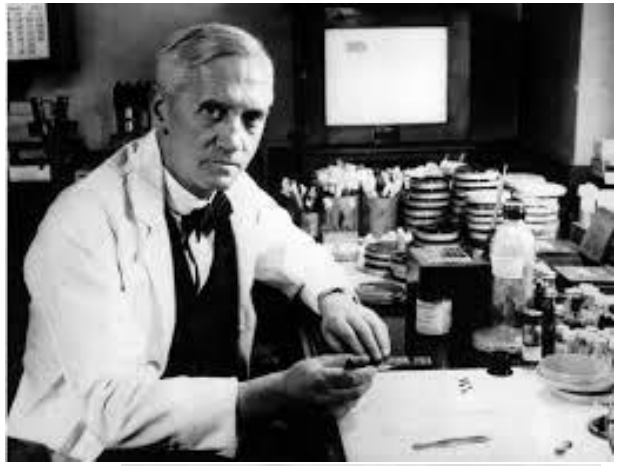

Barn used by GE's Steinmetz as Private Laboratory in 1900, 1901

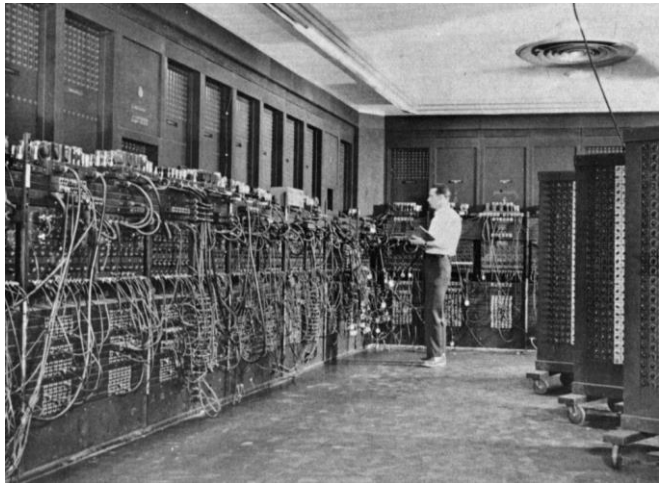


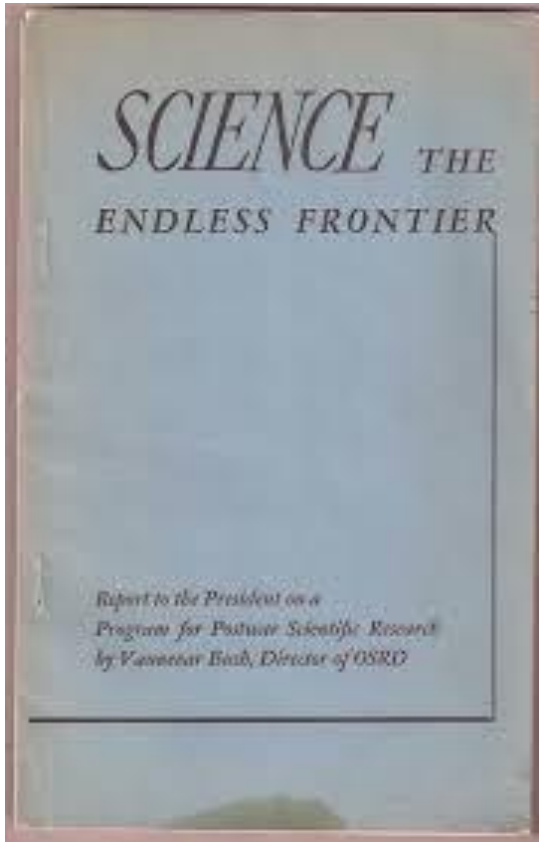
Breakthrough innovations in 20th century need science

American universities unwilling to unable to supply … but do train the required human capital

World War II: The practical applications of science reinforced (both govt and private investment!)







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The Golden Age, 1940-1980:
The American innovation ecosystem rested on **industria**l research


Arno Penzias, Bell Labs (1978, Physics)


Clinton Davisson, Bell Labs (1937, Physics)

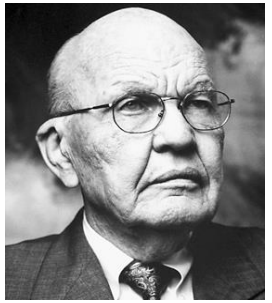

Phil Anderson, Bell Labs (1977, Physics)

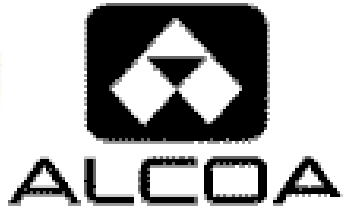

Leo Esaki, IBM (1973, Physics)


Irving Langmuir, GE (1932, Chemistry)


Walter Brattain, Bell Labs (1956, Physics)


William Shockley, Beckman Instruments (1956, Physics)


Jack Kilby, Texas Instruments (2000, Physics)



Post 1980s: Most companies withdraw from research, but *Some* American firms continue to invest in research…

DuPont Shutting Central Research

Corporate R&D: Firm's restructuring of storied labs comes before its merger with Dow

by **Alexander H. Tullo**
January 4, 2016 | A version of this story appeared in **Volume 94, Issue 1**

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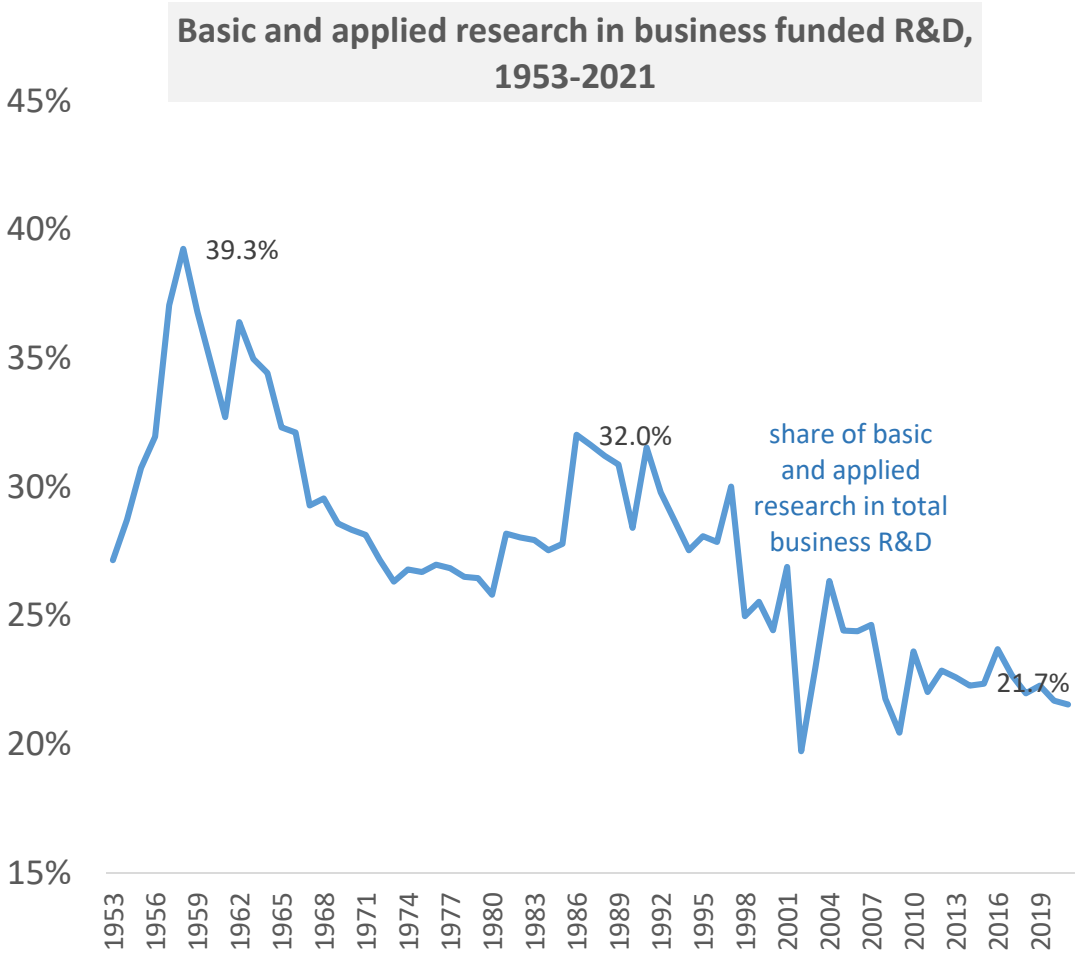
Credit: DuPont

Bell Labs Holmdel Complex, 2010s



Science

IBM casts doubt on Google's claims of quantum supremacy

Google Brain's "Cat Paper" Team

The division of innovative labor and the implications for the rate and direction of inventive activity

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TEL AVIV UNIVERSITY

The division of innovative labor has enhanced innovation

Perelman School of Medicine University of Pennsylvania

But

changes in industrial structure increase value of marginal innovation

Incumbent firms have less absorptive capacity to use university research

Startup innovations leave gaps

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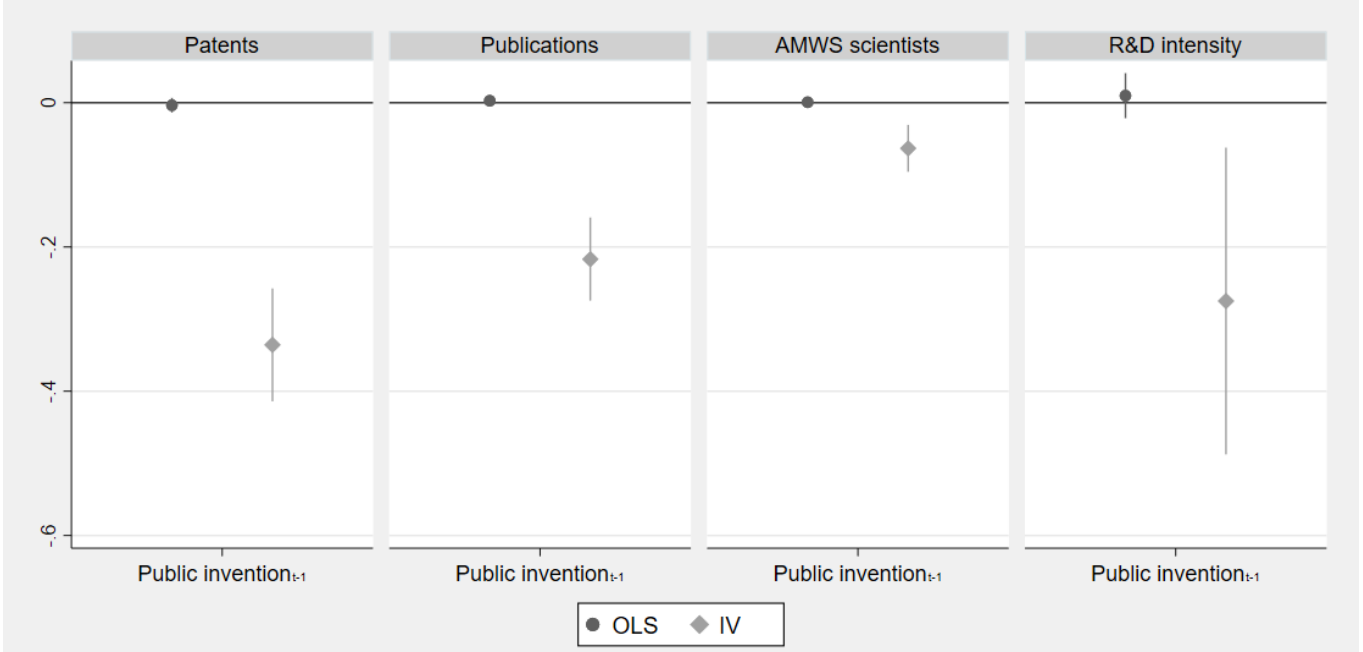

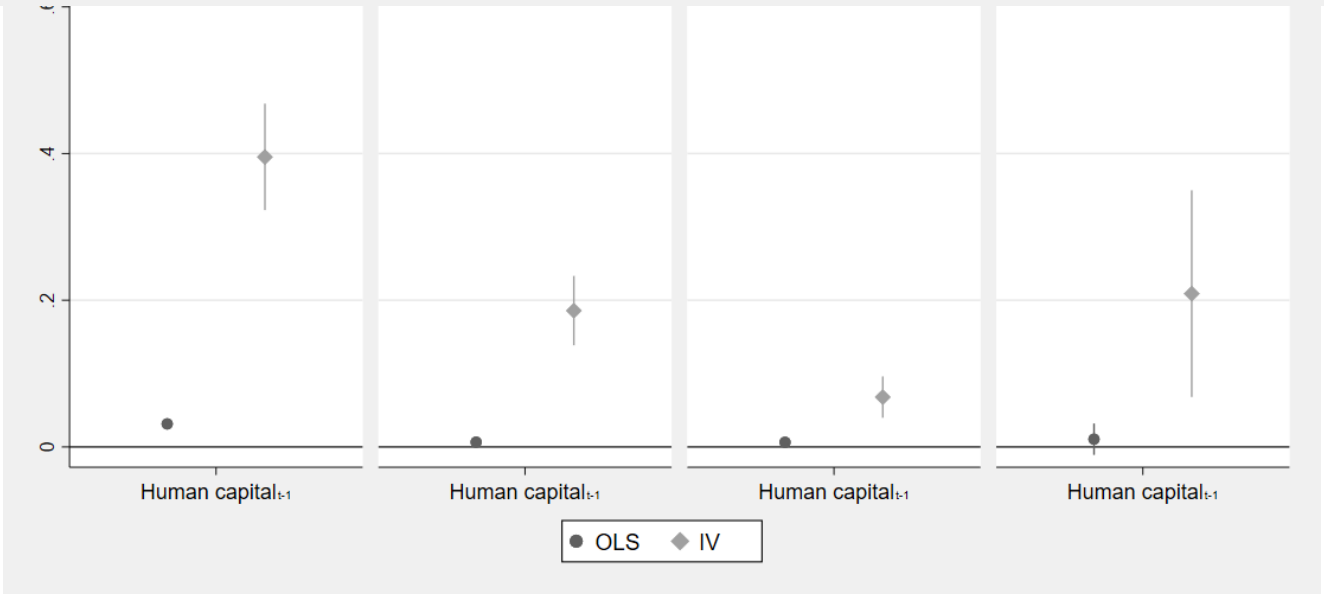

The decline of R in corporate R&D – lower ability to absorb university science unless embodied in people or developed into inventions

Human capital increases corporate patents and publications (*complement)*

University Invention reduces corporate patents and publications (*substitute)*

University knowledge has no effect

Arora, Belenzon, Cioaca, Sheer, Zhang. *In progress*

Less to show from more science?

A longer distance from Bohr to Pasteur

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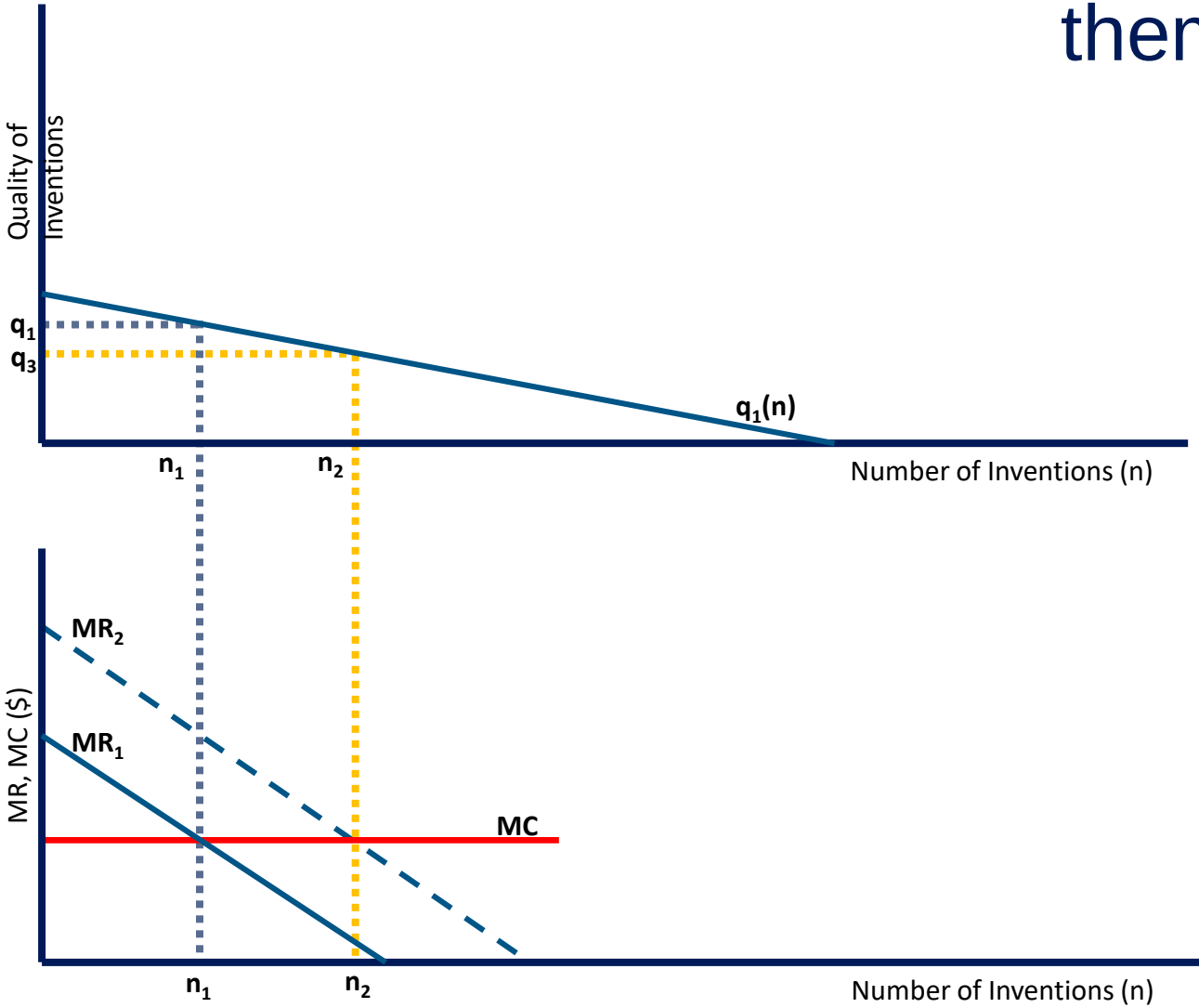
Incrementalism:

If ideas are hard to find, why are we trying so hard to find them?



Increase in private value of innovation

➔ Increase R&D investment

➔ More incremental innovation

➔ Average quality of innovation falls

Looks like ideas are harder to find

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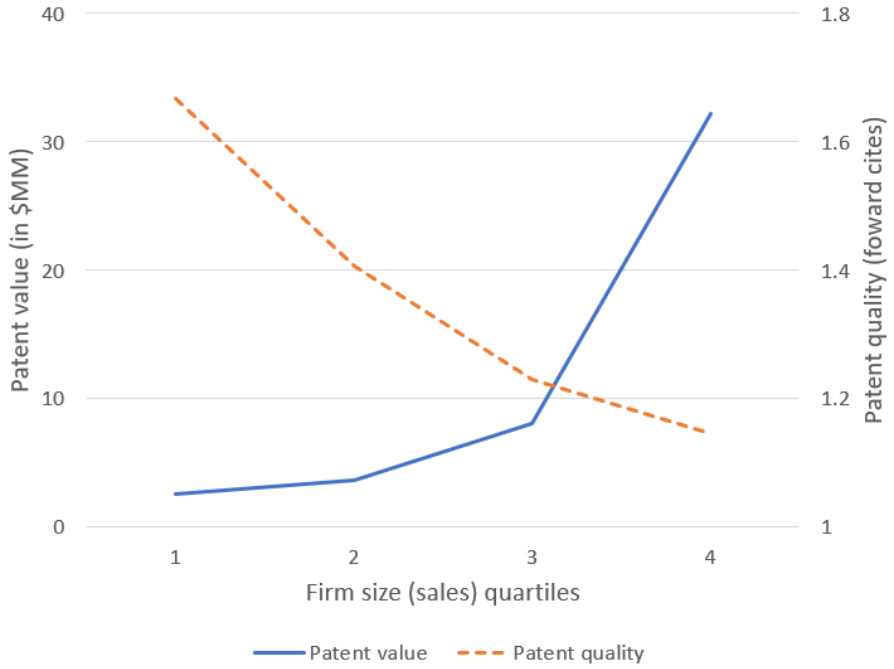
Innovations in larger firms:

- higher private value but average lower quality
- similar top quality



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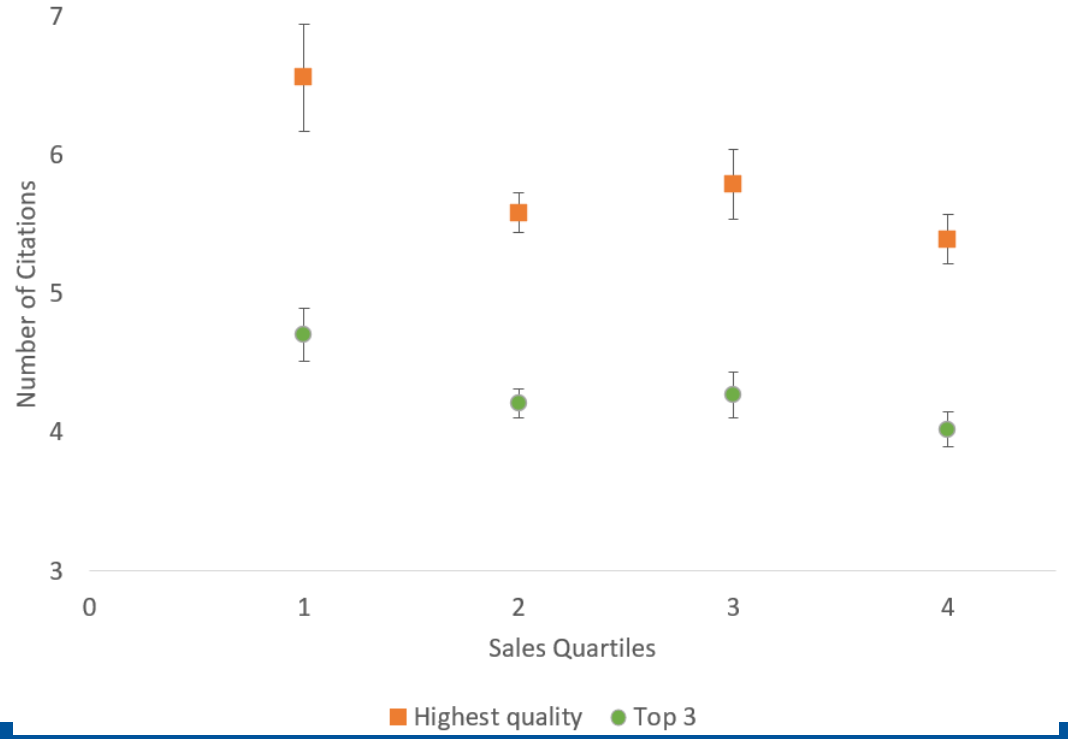
ELSEVIER

Research Policy

Volume 52, Issue 1, January 2023, 104650

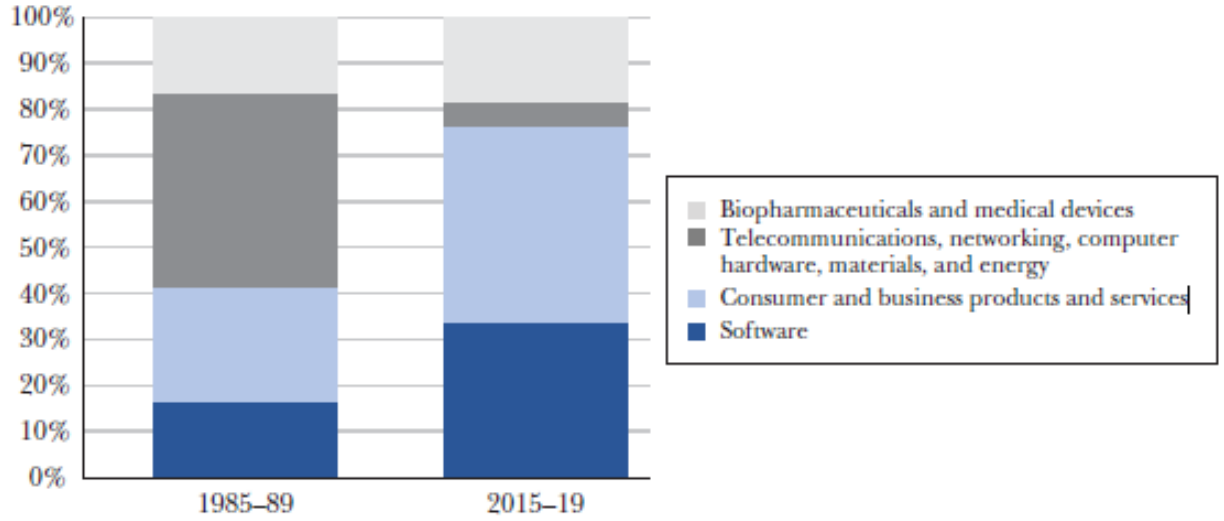
Invention value, inventive capability and the large firm advantage ☆

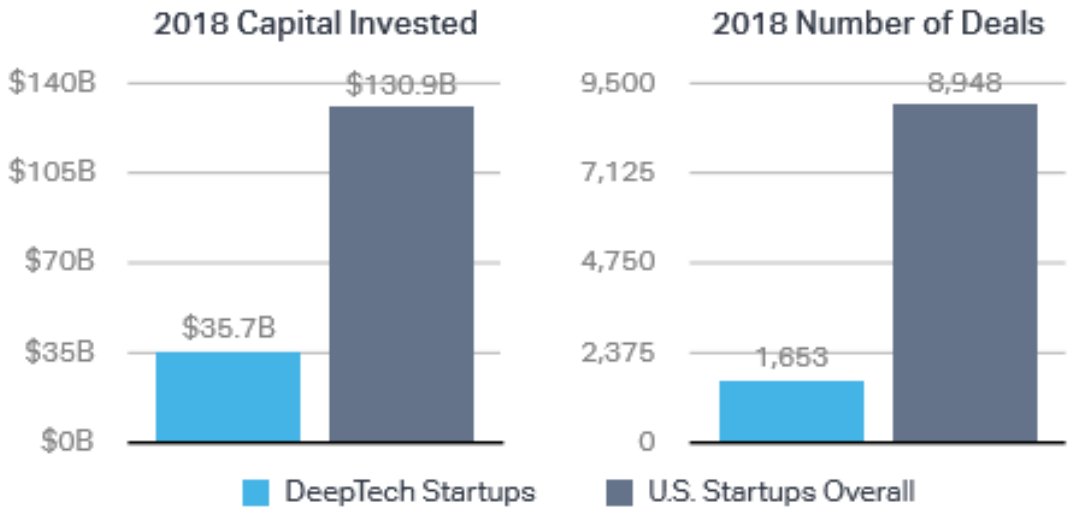
Ashish Arora [a b 1], Wesley Cohen [a b 1], Honggi Lee [c 1], Divya Sebastian [a 1]



Mind The Gap
140 characters but no flying cars?

Figure 2
Venture Capital Investment into US Startups between 1985 and 2019, by Sector





Innovation Ecosystem is unbalanced
(Lerner & Nanda, 2020)

VC investment is narrowly focused by sector

Two potentially important gaps

<u>Direction:</u> "deep-tech" e.g., materials, energy, environment,

<u>Impact</u>: industrial research is mission oriented, and hence, multidisciplinary, and larger in scale and scope ➔ *disappointing productivity growth linked to decline in industrial research*

Impact: Corporate science is multi-disciplinary, mission-oriented

arXiv.org > cs > arXiv:1609.08144 Search or Arti (Help | Advanced

Computer Science > Computation and Language

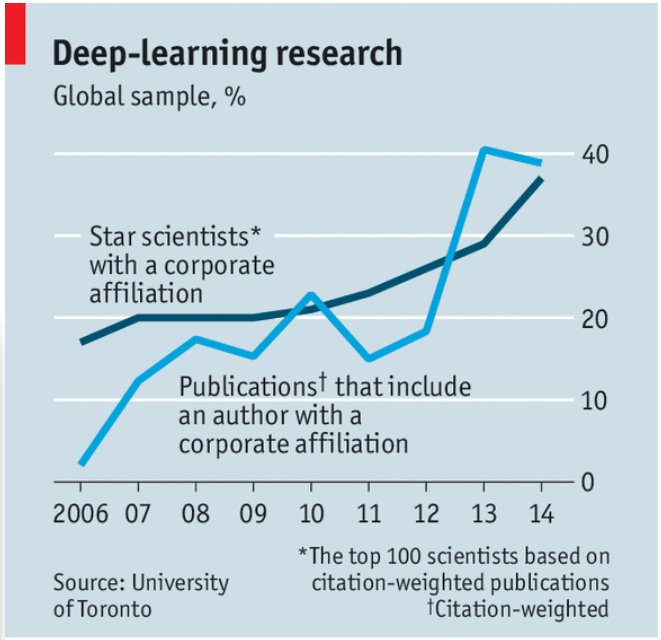
Google's Neural Machine Translation System: Bridging the Gap between Human and Machine Translation

Yonghui Wu, Mike Schuster, Zhifeng Chen, Quoc V. Le, Mohammad Norouzi, Wolfgang Macherey, Maxim Krikun, Yuan Cao, Qin Gao, Klaus Macherey, Jeff Klingner, Apurva Shah, Melvin Johnson, Xiaobing Liu, Łukasz Kaiser, Stephan Gouws, Yoshikiyo Kato, Taku Kudo, Hideto Kazawa, Keith Stevens, George Kurian, Nishant Patil, Wei Wang, Cliff Young, Jason Smith, Jason Riesa, Alex Rudnick, Oriol Vinyals, Greg Corrado, Macduff Hughes, Jeffrey Dean

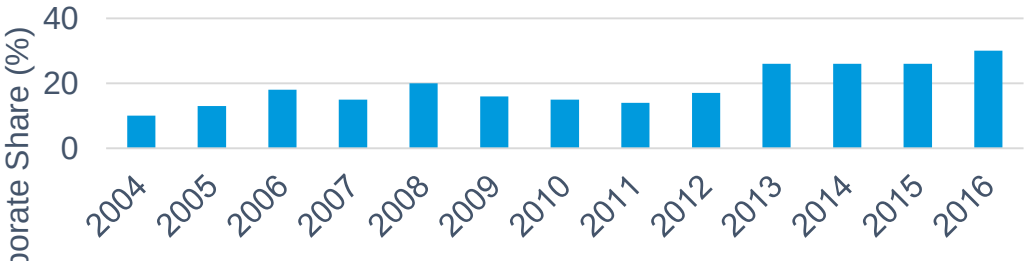
(Submitted on 26 Sep 2016 (v1), last revised 8 Oct 2016 (this version, v2))

Google Brain's "Cat Paper" Team

Corporate Labs remain at the forefront in some key emerging technologies … the loss of corporate research in other sector hurts



Share of Corporate Publications in ICML (Hartmann & Henkel, 2019)



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What is to be done? Where to begin?

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