The American Innovation System needs a new social compact to revitalize corporate research

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Corporate investment in research sustains American technological leadership and economic prosperity

- **The United States is losing its historic lead in innovation**
  - Asian rivals are quickly catching up in R&D investments and R&D intensity
  - Rivals have taken the lead in key industrial segments where established American corporations have cut investment in scientific research
  - America leads in science-intensive industries where American corporations invest in scientific research
- **Corporate research is vital for preventing further erosion**
  - It is large-scale, mission-driven, and inter-disciplinary
  - Vital third-leg of the stool in the American Innovation System
- **The social compact between leading firms and society that supported investments in research by corporation needs to be renewed**
  - More investment in long-term, upstream research by leading firms
  - More forbearance and support by government

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Corporate research was a vital part of the American Innovation Ecosystem 1940-1980

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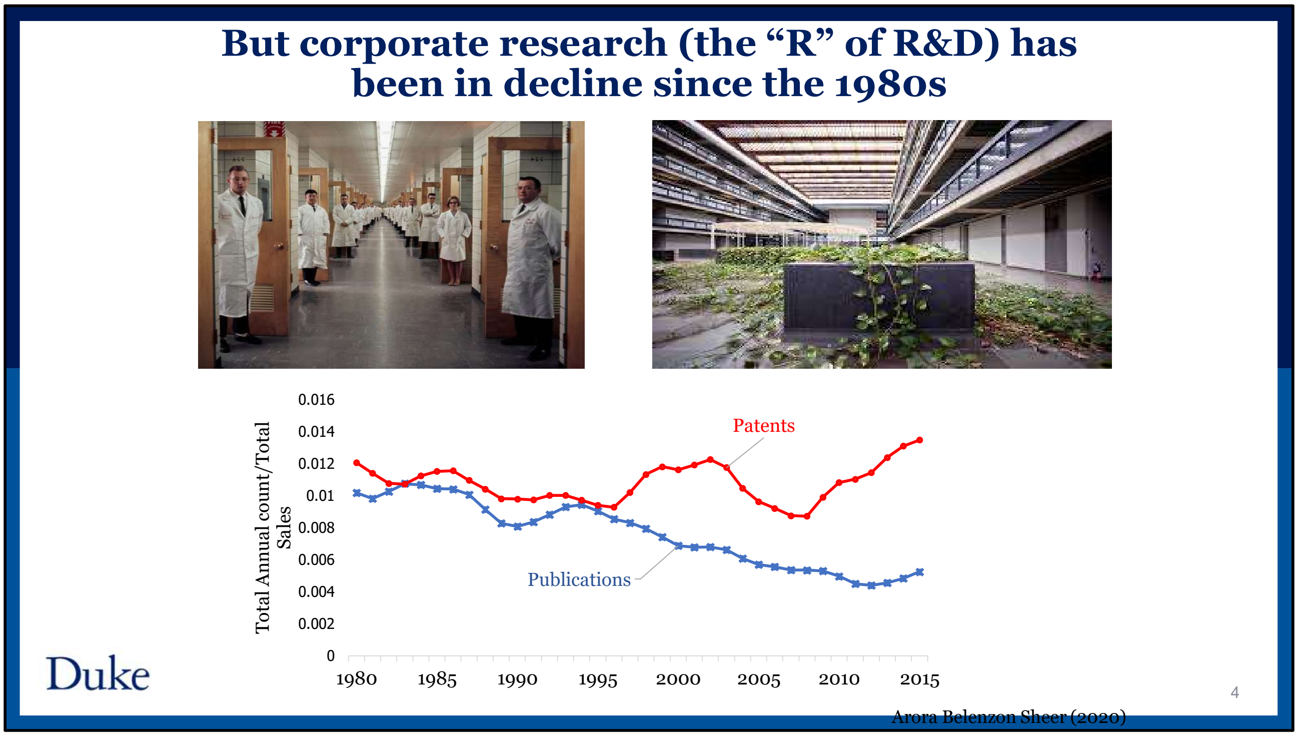
The post WWI era was marked by large corporate labs. Not just Bell Labs, but also IBM, GE, TI, Xerox, Kodak, Du Pont, and Standard Oil. Corporate researchers made substantial contribution to advancing scientific knowledge. There were nine nobel prizes (and 14 nobelists) awarded for research at Bell Labs alone. But by 1980s, the era was ending.

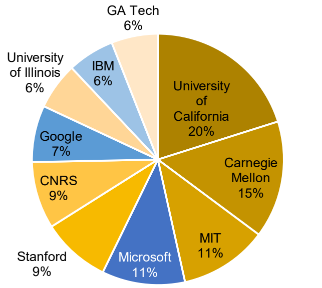


This is the story of how the American innovation ecosystem has changed. I am going to begin neither in the beginning nor at the end, but in the middle: And that is that large American corporations have been withdrawing from scientific research.

Anecdotal evidence shows that famed corporate labs such as Xerox PARC, AT&T Bell Labs and DuPont's Central Research Lab have been either spun off or closed.
NSF data show that the share of basic and applied research in business R&D has steadily declined. This is confirmed by a recent paper which shows that the number of scientific publications per dollar of sales has approximately halved between 1980 and 2015. By comparison, patenting has not declined.

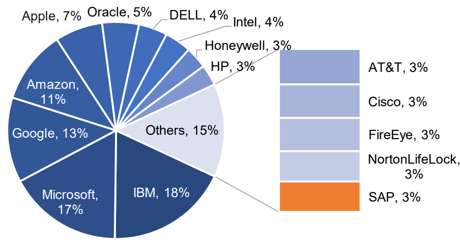
Corporate Research Underpins America's Leadership in AI & ML, but rivals are closing in

Leading AI Research Organizations, by Number of Papers in Top 10 AI Conferences



Science

Top 15 Patenting Organizations in AI, by Quality Adjusted Patents (2006-2020)



Technology

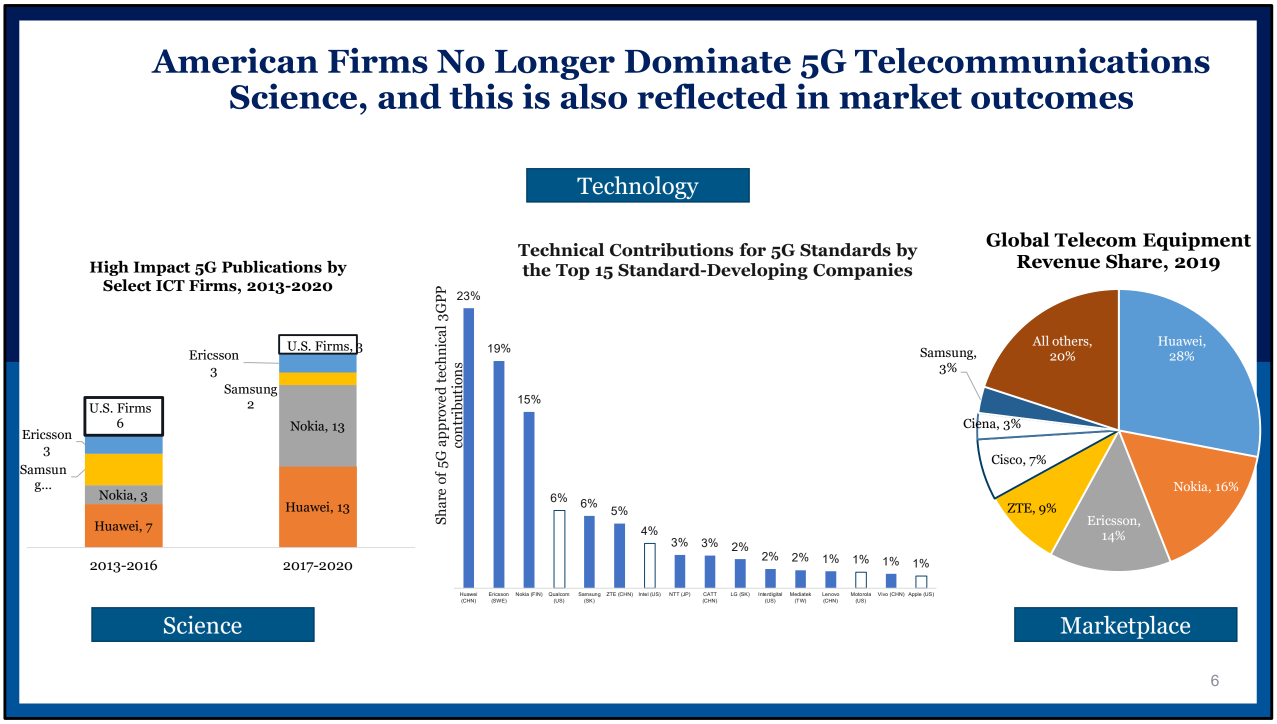
Firms that publish and patent in AI also pioneer marketplace applications

- Google search uses deep learning algorithms
- Amazon Echo uses Alexa virtual assistant
- IBM Watson for Health uses AI for medical diagnoses
- Microsoft 365 uses AI apps to improve writing, design, visualizations

Marketplace

Notes: Figure a is based on the largest publishers in the Top 10 AI conferences (by saliency to the topic of "artificial intelligence," according to Microsoft Academic Graph). Figure b is based on the papers published by **firms** included in the Top 50 organizations in the leading AI conferences. Figure c presents scientific publications on the topic of "artificial intelligence" published by authors affiliated with select IT firms, by 4-year cohorts. Sources: Microsoft Academic Graph.

However, Chinese firms and universities are making rapid progress in AI science, technology, and commercial applications, helped by large-scale government support.


American Firms No Longer Dominate 5G Telecommunications Science, and this is also reflected in market outcomes
Technology
High Impact 5G Publications by Select ICT Firms, 2013-2020
U.S. Firms 6
Ericsson 3
Samsun g...
Nokia, 3
Huawei, 7
U.S. Firms, 3
Ericsson 3
Samsung 2
Nokia, 13
Huawei, 13
2013-2016
2017-2020
Science
Technical Contributions for 5G Standards by the Top 15 Standard-Developing Companies
Share of 5G approved technical 3GPP contributions
23%
19%
15%
6%
6%
5%
4%
3%
3%
2%
2%
2%
1%
1%
1%
1%
Huawei (CHN)
Ericsson (SWE)
Nokia (FIN)
Qualcom (US)
Samsung (SK)
ZTE (CHN)
Intel (US)
NTT (JP)
CATT (CHN)
LG (SK)
Interdigital (US)
Mediatek (TW)
Lenovo (CHN)
Motorola (US)
Vivo (CHN)
Apple (US)
Global Telecom Equipment Revenue Share, 2019
Huawei, 28%
Nokia, 16%
Ericsson, 14%
ZTE, 9%
Cisco, 7%
Ciena, 3%
Samsung, 3%
All others, 20%
Marketplace
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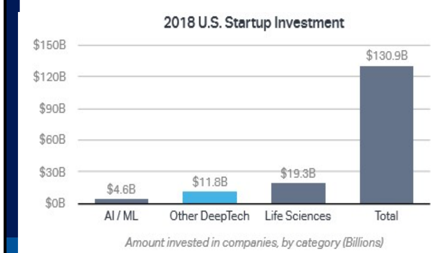
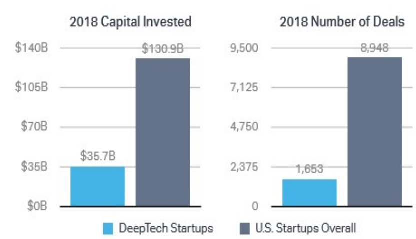
The American Innovation System needs corporate research

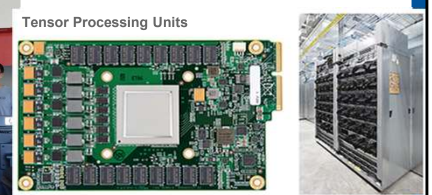




- No shortage of innovation but the American Innovation Ecosystem is unbalanced
- Direction: "deep-tech" e.g., materials, energy, environment
- Impact: Corporate research is mission oriented, multidisciplinary, and larger in scale and scope

Google Brain's "Cat Paper" Team

Tensor Processing Units



Google's first Tensor Processing Unit (TPU) on a printed circuit board (left); TPUs deployed in a Google datacenter (right)

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Although the new innovation ecosystem has many advantages, the decline of corporate research is leaving two types of gaps. The first is in terms of sectors. The new system seems to have left a gap in some sectors, particularly in what has been called "hardtech" or, as some prefer, in "deep tech". These include quantum computing, new semiconducting materials, energy storage, biofuels, agtech, etc.

The second gap is related. Corporate research cannot easily be replaced by universities. Corporate research is often mission oriented – it is greater in scale, architectural in scope, and multi-disciplinary. Let me give you an example.

And revitalizing corporate research needs a new social compact

- **Leading firms must commit to invest in long-term, upstream research**
  - Furthering national interest as well as shareholder value
- **In return, they should be able to expect support and forbearance from policy makers**

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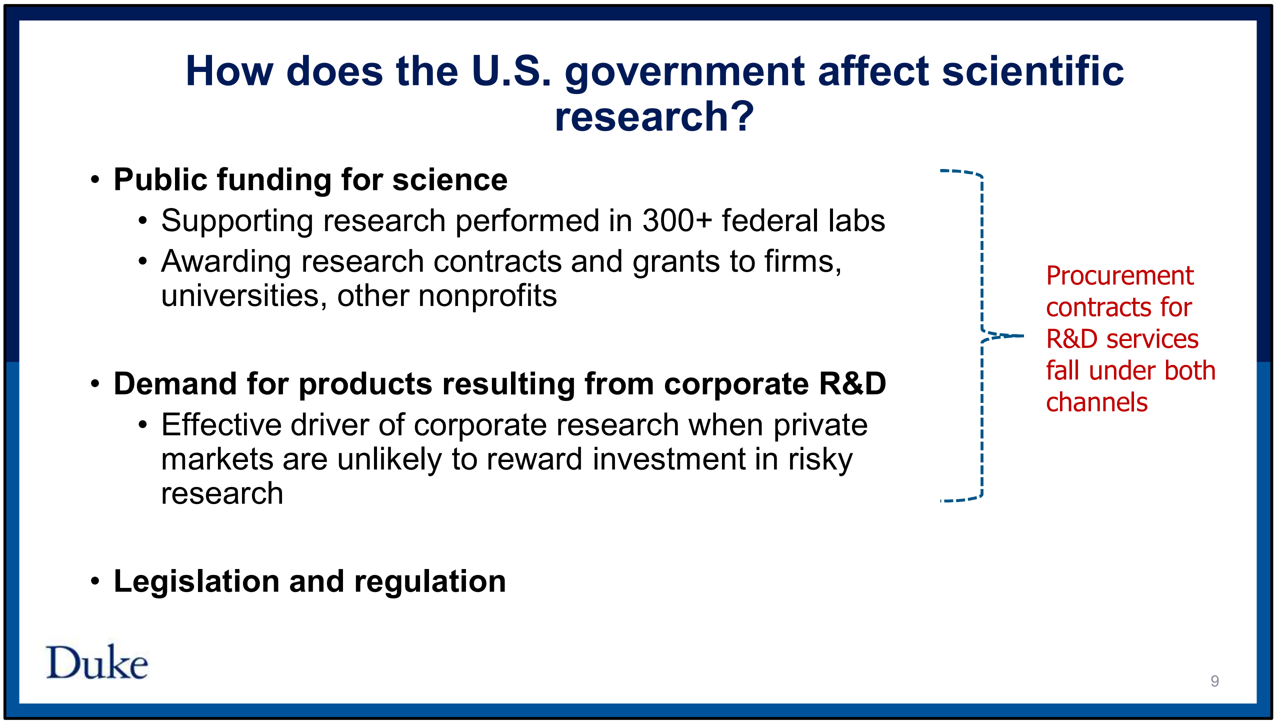
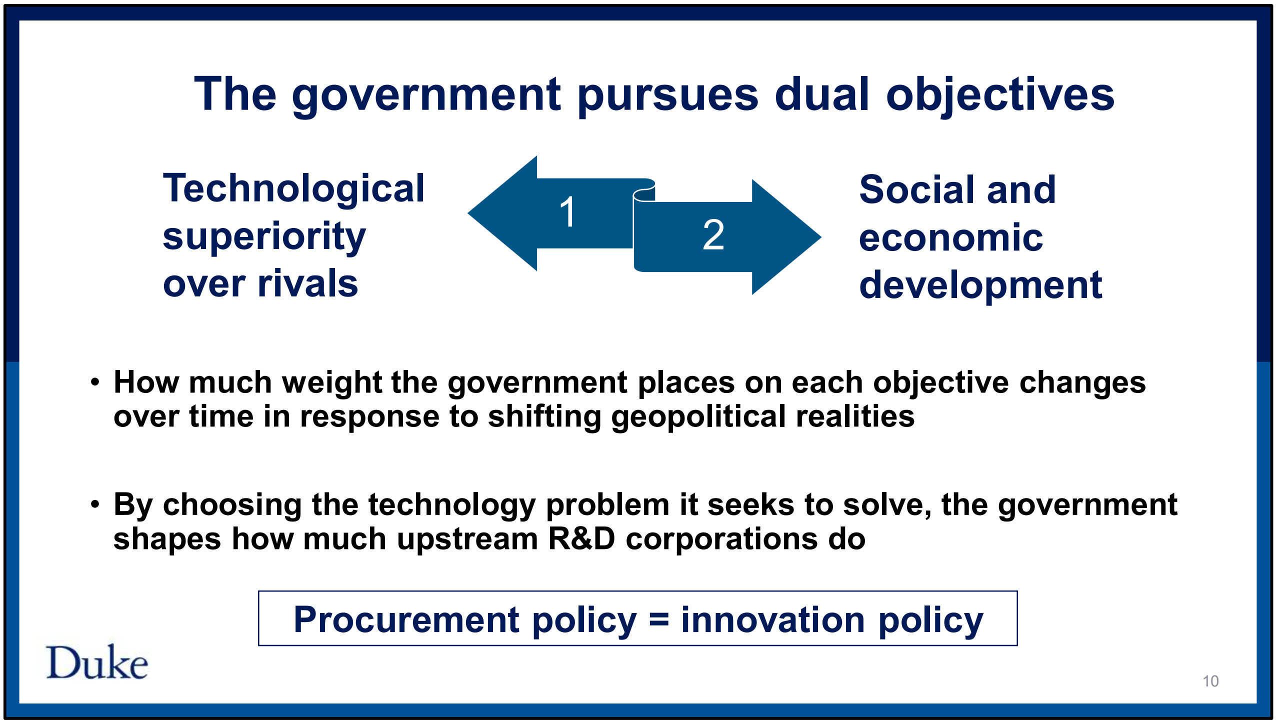


- The U.S. government affects research through three main channels:
  - By providing public funding for science,
  - By creating demand for products resulting from corporate R&D through procurement contracts, and
  - Through legislation and regulation, though I won't touch upon this channel

- The public funding channel includes:
  - Supporting intramural research performed in more than 300 federal labs, and
  - Awarding research contracts and grants, and other forms of financial assistance to corporations, universities, and other nonprofits.
  - This channel has been well researched.

- In contrast, the demand channel has received little scholarly attention, which is surprising because procurement contracts can, theoretically, be an effective driver of corporate research when private markets are unlikely to reward corporate investment in science.

- In this study, we focus on the impact of procurement contracts for R&D services, which fall under both channels, because winning a competitive R&D contract is typically how firms access guaranteed demand (i.e., noncompetitive downstream production contracts for technology-intensive products).



When choosing which technology problems to solve by specifying procurement requirements, the government pursues dual objectives:

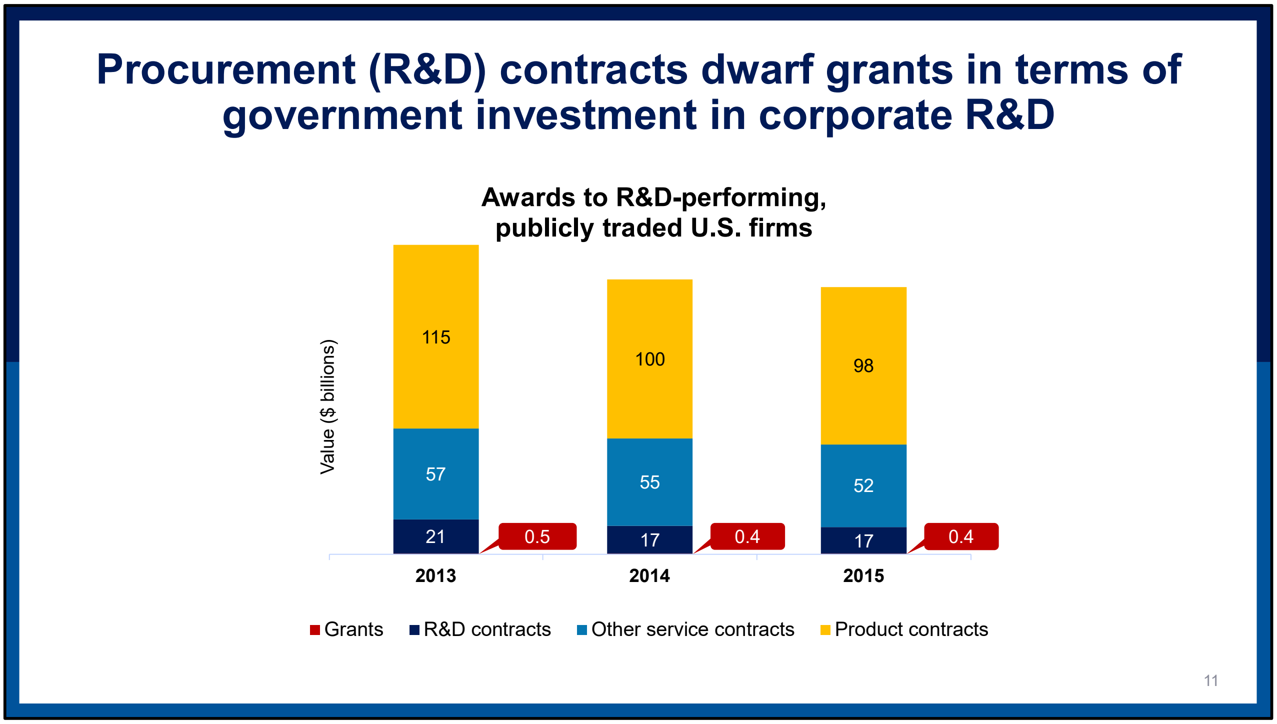
- The first is to **secure technological superiority over rival nations**, and
- The second is to **promote social and economic development**.

While these objectives are related, they are not the same. Achieving technological leadership is critical for national defense, but may not lead to economic benefits and competitiveness in global markets. Similarly, a higher level of economic development may not produce the advanced technologies needed for national defense and geopolitical influence.

How much weight the government places on each objective changes over time in response to **shifting geopolitical realities**.

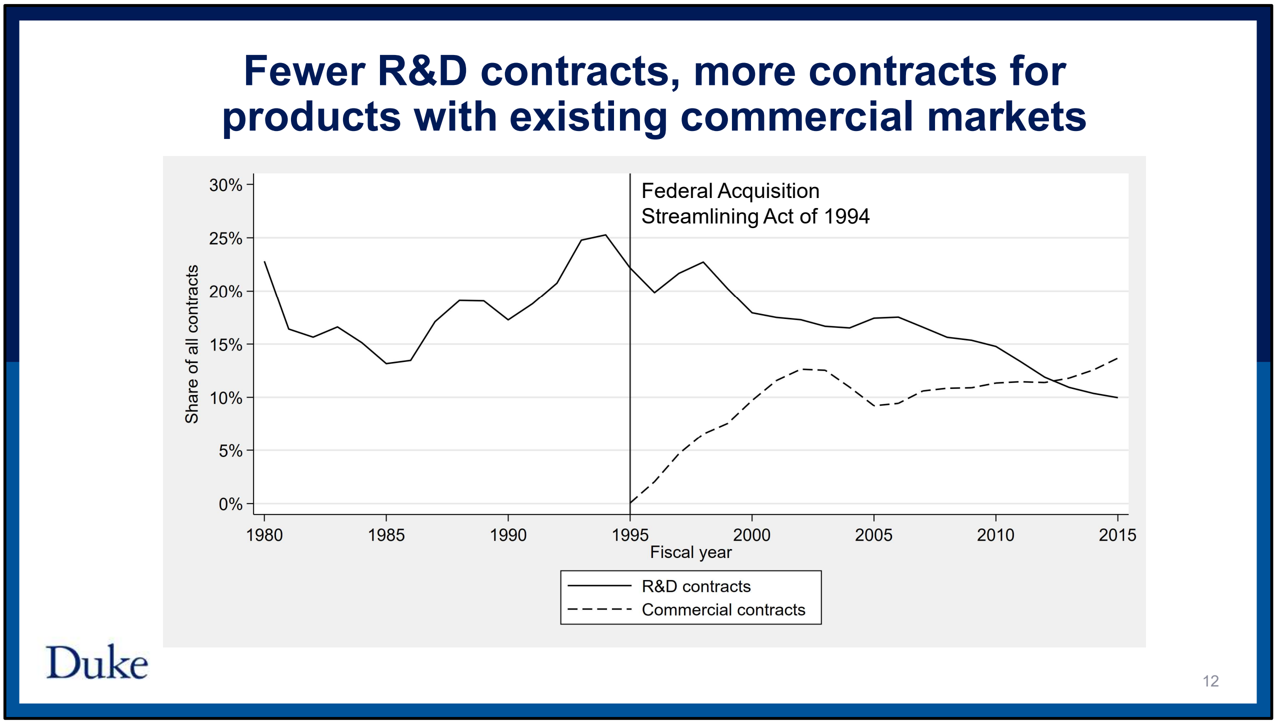
- The 1957 Sputnik shock---the start of the space race between the United States and the Soviet Union, when the Soviets successfully launched the world's first artificial satellite---is an example of a moment in history when the objective of ensuring technological superiority at all cost came to the forefront. The government sought solutions to ``extreme quality'' problems (e.g., putting a man on the Moon by the end of the 1960s), even when those solutions had little to do with practical civilian applications, at least at the time.

- In other moments, economic considerations loomed larger. This was the case at the end of the Cold War. The so-called ``peace dividend'' allowed issues of national competitiveness (especially vis-a-vis Japan in such important industrial sectors as semiconductors) to feature prominently in U.S. policy-making. The government sought to reduce cost and increase efficiency and transparency in procurement by prioritizing the development of dual-use technologies, acquiring commercial-off-the-shelf (COTS) products, and using ``full and open competition'' in procurement.
- As the primary objective of government procurement changes, so do the types of problems it is trying to solve and how to incentivize businesses to solve those problems.
- In this respect, **procurement policy is innovation policy**



- So yes, there is a gap in the literature. And, examining the effect of R&D contracts is important because they dwarf grants in terms of government investment in corporate R&D.

- For example, in 2013, the federal government awarded $21 billion in R&D contracts to publicly traded U.S. firms, compared to just half a billion in grants.



The solid line in this figure plots the share of R&D contract dollars in all contracts awarded to sample firms over time. It has fallen from a high of 24 percent in 1998 to 10 percent in 2015. At the same time, the share of commercial contracts (dotted line) has increased from 6 percent in 1998 to 14 percent in 2015.

What can explain these compositional changes?

- Numerous policy changes were made as a result of the end of the Cold War, increased global trade, constrained defense budgets, and the need to attract nontraditional, innovative suppliers from the much larger commercial markets, especially those in the growing IT sector.

- These policy changes culminated in the Federal Acquisition Streamlining Act of 1994, which enabled simplified acquisition procedures and established a statutory preference for government procurement of commercial items.

Over time, government procurement offered fewer R&D contracts and more contracts for products and services with existing commercial markets. The ability of public demand to substitute for private demand in incentivizing upstream corporate R&D should have eroded.

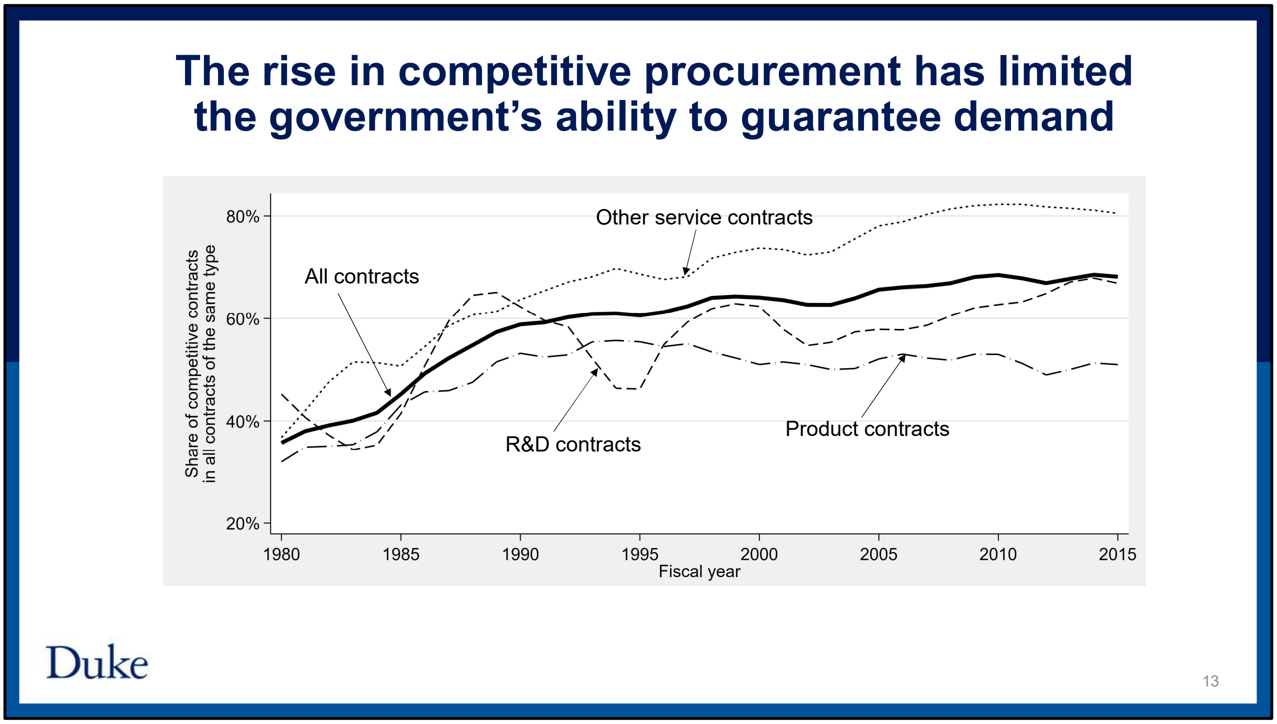
Commercial contracts use special (usually simplified) requirements that resemble the commercial market.

The vertical line represents the passing of the Federal Acquisition Streamlining Act in October 1994, which occurred during fiscal year 1995 (the U.S., government uses a fiscal year that starts on Oct. 1 and ends on Sept. 30).

The decline in the importance of R&D contracts relative to commercial contracts occurred across a wide range of industries:

- Electronics saw its share of R&D contract dollars in all contracts drop from 17 percent in 1998 to just 3 percent in 2015.
- Conversely, Drugs had the largest increase in the share of commercial contracts, from 14 percent in 1998 to 77 percent in 2015.

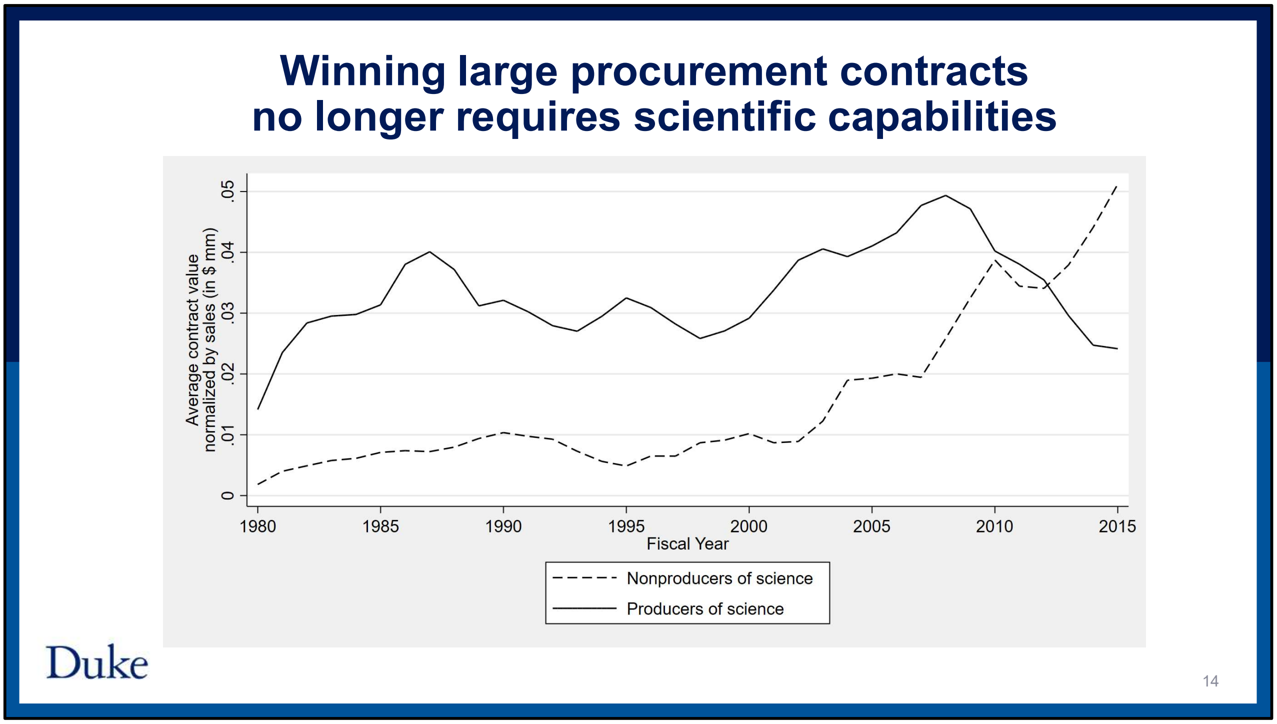
- The Bayh-Dole Act of 1980 and its extensions allowed contractors to retain ownership of inventions made with federal funding.
- The Stevenson-Wydler Technology Innovation Act of 1980 and its extensions gave businesses access to technologies developed in federal laboratories.
- The Goldwater-Nichols Department of Defense Reorganization Act of 1986 reworked the military command structure and implemented shared procurement across the military branches.



Moreover, the rise in competitive procurement has arguably limited the government's ability to guarantee downstream demand.

- Historically, the government awarded most procurement contracts noncompetitively to firms that were able to demonstrate strong technical capabilities.
- Over time, pressures to reduce cost and increase efficiency and transparency led to legislation such as the Competition in Contracting Act of 1984, which mandated that all procurement contracts be awarded based on full and open competition unless certain exclusions applied.
- As a result, the share of competitive contracts in all contracts (by dollar value, thick solid line) increased from 36 percent in 1980 to 68 percent in 2015, while the share of noncompetitive product contracts dropped from 78 percent in 1980 to 49 percent in 2015.

Competitive contracts are awarded using full and open competition.



As a result, the importance of scientific capabilities for contract value has fallen over time.

- In this figure, the solid line plots the average contract value awarded to producers of science, which has remained relatively stable over time.

- The dotted line plots the average contract value awarded to nonproducers of science, which has increased sharply -- from less than $2,000 per $1 million in sales in 1980 to $51,000 per $1 million in sales in 2015.

These patterns also hold in regression analysis, showing that winning large procurement contracts no longer requires scientific capabilities.

All dollar values have been adjusted using the GDP Implicit Price Deflator to reflect 2012 dollars (U.S. Bureau of Economic Analysis, 2020).

We classify a firm as a producer of science if its annual number of publications over annual sales is above industry median value. Other firms are classified as nonproducers of science. Average contract value normalized by sales is the ratio of total contract value and total sales. Number of publications per $1 million in research contracts is the ratio of total number of corporate publications and total value of research contracts.

Conclusion

- **Government procurement policy is innovation policy**
  - By choosing the problems it seeks to solve, the government shapes how much upstream R&D corporations do
- **To revitalize corporate science policy makers should consider returning to the practice of rewarding firms that demonstrate technological superiority**
  - Guaranteed public demand in the form of noncompetitive contracts for the resulting products
- **Doing so would be beneficial to U.S. national security and geopolitical influence in the short term, and later on to consumers as new commercialize applications emerge**

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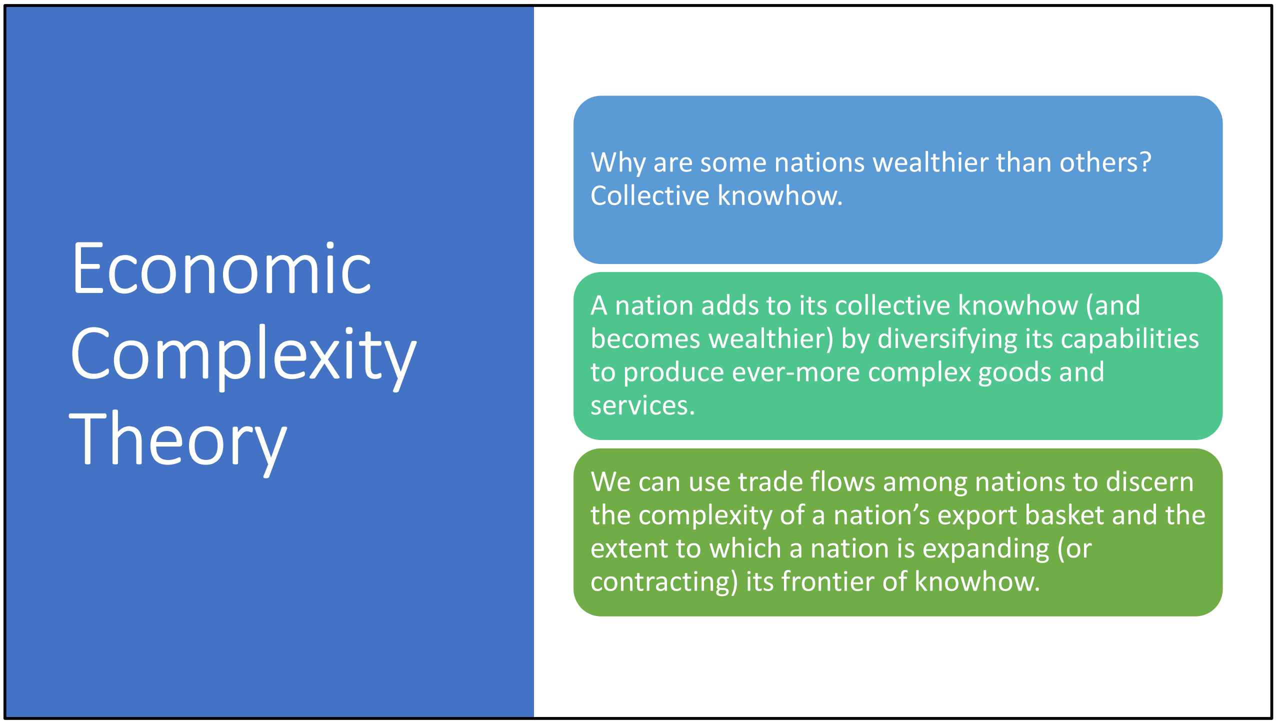
To conclude: we show that government procurement policy is indeed innovation policy.

This is important given the use of procurement contracts to boost domestic economic activity and support targeted geographies or industries. President Biden's Buy American Executive Order from January 25, 2021 is just the most recent example of using contracts as a policy lever. We show its implications for corporate R&D.

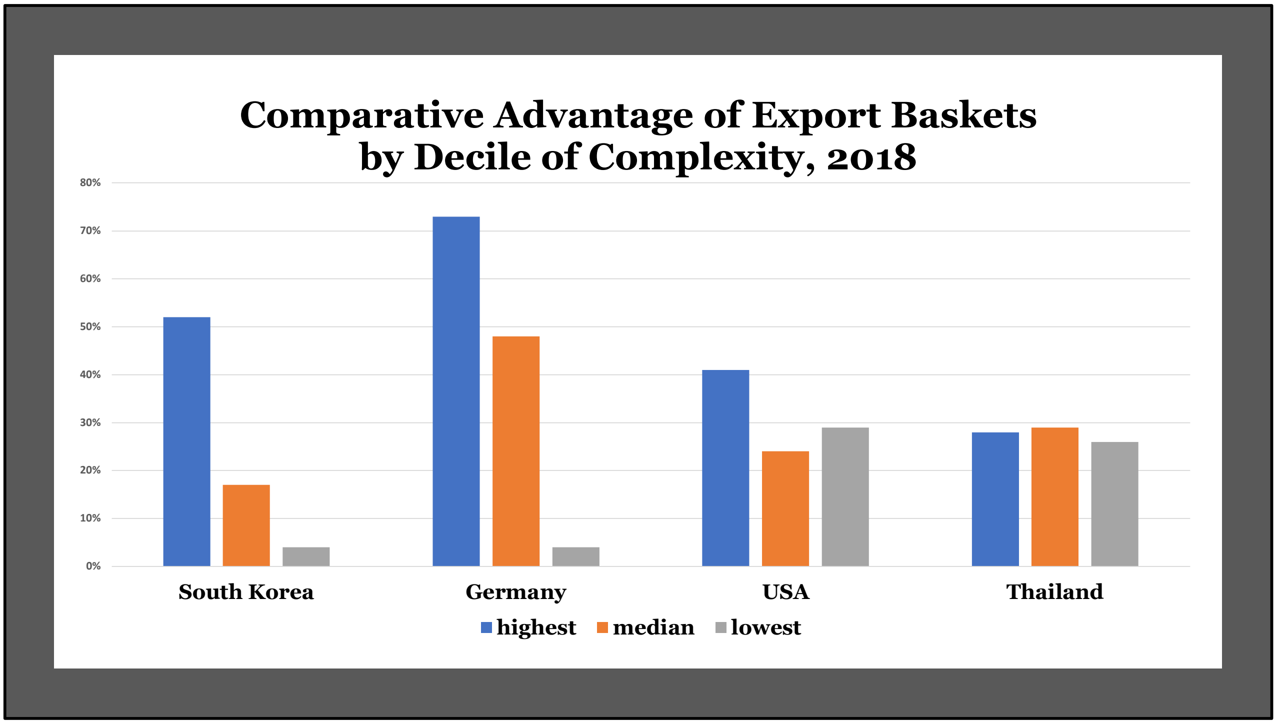
We provide the first systematic evidence in support of the government's role in driving corporate scientific research through the guaranteed demand mechanism.

Finally, we show that the changing composition of government procurement helps explain why corporations have been withdrawing from performing scientific research in recent decades.

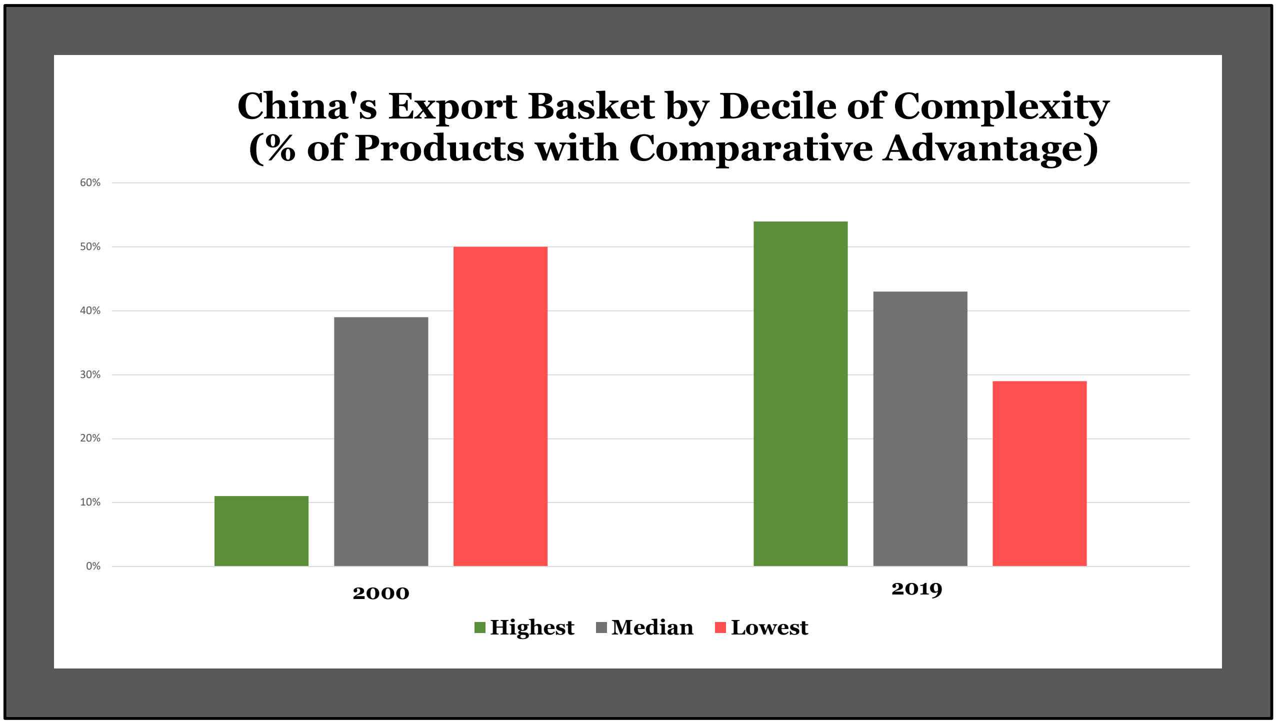
Firms choose to invest in research to win contracts. Since the government began competing with the commercial market for commercially proven technologies, corporations have had fewer incentives to perform risky upstream scientific research, and more incentives to invest in downstream development of commercially viable products and services.



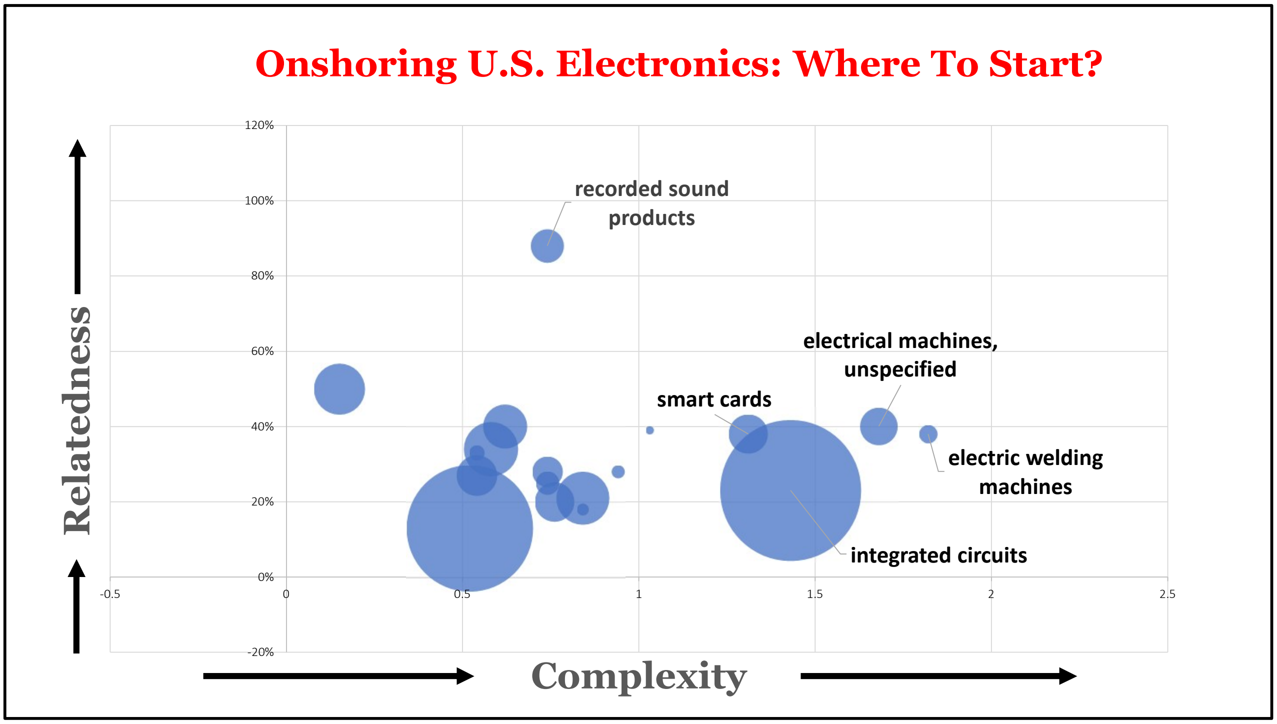
I want to start with an observation—that despite political divisions, US elected officials have, in recent years, expressed bipartisan concern about the loss of US manufacturing capabilities—and they are willing to do something about it—especially if the capabilities relate to making advanced technology, R&D-intensive products, or high value-added goods. These policy makers intuitively understand something called economic complexity theory, which says that nations grow faster and become wealthier if they expand the frontier of their collective knowhow. Recently, I wrote a paper for PPI where I used international trade data to look at the frontier of knowhow across nations. It turns out that, in the 21st century, the United States is not doing very well. But other nations, like China, are. And this provides an opportunity for US policy makers.



This chart looks at the export basket of a few selected countries by decile of complexity. I should first explain that all traded goods can be ranked in terms of complexity and nations can be ranked in terms of the complexity of their export baskets. In 2018, South Korea and Germany were near the top in terms of complexity ranking, the US was 12th, and Thailand was 22nd. This chart suggests that this ranking is driven largely by goods in the highest decile of complexity. The take-away here is that the US resembles Thailand more than it does Germany or South Korea. And this is worrisome. Even more worrisome is the fact that the US has seen its comparative advantage in the highest decile of complexity fall from >60% in 2000 to just over 40% today. In other words, its frontier of knowhow is contracting. You might ask—How does this compare to China?



As it turns out, China has transformed its export basket in the 21st century. Its comparative advantage in the most complex traded goods has risen from just over 10% to well over 50%. The US is still ranked higher than China in terms of complexity, but China is catching up and, if current trends continue, within in ten years will surpass the US. What is the US to do? It can expand its frontier of knowhow. This is the BIG IDEA from complexity theory and has been understood for centuries. Our Founding Fathers understood this. Alexander Hamilton wrote about it. Abraham Lincoln promoted it. And given his SOTU address on Tuesday night, Joe Biden is pushing for it. The next slide provides an illustration.



For decades, global supply chains for electronics have migrated away from North America to Asia. Of the 51 categories of electronics that are globally traded, the US has a comparative advantage in just 8. This chart shows 18 categories of electronics where the US does not have a comparative advantage but are related to the 8 categories where the US has a comparative advantage. The size of each bubble reflects world trade in that product category. Ideally, we'd like to see a big, fat bubble in the northeast corner. Absent that, the best opportunities lie in the labeled products. When I look at this chart, I see opportunity, especially for integrated circuits—also known as computer chips. This is one of the reasons I like the House-passed COMPETES Act and the Senate-passed USICA. Both aim to build US capabilities in computer chips, especially the most advanced computer chips. And there are other provisions in the bills that comport with complexity theory.

Provisions in COMPETES/USICA Consistent with Economic Complexity Theory

- CHiPs Act to make the most complex semiconductors.
- MTB to eliminate tariffs on intermediate inputs to domestic manufacturers.
- New NSF Directorate to advance technology competitiveness.
- Outbound Investment Screening to prevent loss of critical capabilities.
- A chief manufacturing officer in the White House.
- Supply Chain Resilience Office at DOC.
- Immigration reform to attract and keep STEM Ph.D. graduates.
- International standard-setting. USA to engage strategically.
- Expand Manufacturing USA and the Manufacturing Extension Partnership.

Going through the two bills, I see the following provisions as consistent with the BIG IDEA—that nations should expand their frontier of knowhow. I would note that R&D is a critical ingredient and that there is a significant boost to R&D in some of these provisions.