Lessons from Past Productivity Research and Implications for the Future: Discussion

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April 11, 2023

Prepared for "Seminar on Productivity in a Time of Change"
at The Brookings Institution.[1]

[1] *The views expressed here are not represented to be the views of the Federal Reserve Board of Governors.*

Summary of Baily

Summary of Baily: A helpful encapsulation of what we know about productivity and, especially, what we don't.

- What caused the slowdown in the 2000s? [and the 1970s!]
- Why haven't economies converged?
- How can industries not converge across countries even when the diffusion of ideas seems fairly free?
- Which technologies will underpin growth going forward?

Summary of Baily (continued)

The breezy answer to all these questions is "intangible capital," but, what kind of intangibles matter?

Intangibles includes
(Corrado-Hulten-Sichel taxonomy)

- Economic competencies: organizational capital, brand equity
- Innovative property: R&D, artistic originals
- Computerized information: software, databases, and data

Also, human capital is, in a sense, intangible capital held by workers.

Baily emphasizes what separates leading firms from mediocre ones

- Economic competencies: Management, from strategic management down to project management. Marketing.
- Innovative property: What do firms send to to China/Taiwan/Vietnam for contract manufacturing?
- Human capital: Here, again, management is key. Supervision of diverse specialties.

I'll spend some time on computerized information

Regulation, competition, and scale

Regulation, competition, and scale matter as well.

- Are firms operating at the frontier? Is that by choice?
- Does multinational scale allow for transmission of best practices within the boundaries of the firm when they cannot be exchanged at arm's length?
- What role is there for regulation and public policy generally?

We'll return to these issues.

What's going on with computerized information?

Productivity in a time of change ...
What's changing in computerized information?

Key dimensions of change

- Technology
- Market Structure
- Geopolitics

I'll focus on tangible capital, specifically electronics.

The Electronics Sector

Electronics is foundational for the production of computerized information. Importantly, though, data and information are not the same thing.

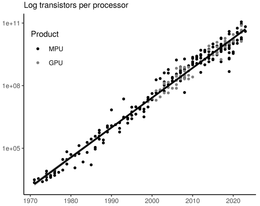
The electronics sector ==
production of equipment for

- collection,
- storage,
- transformation,
- transmission,
- and presentation of data.

What is going on with each of these five components of electronics?

Microprocessor performance,
continues to climb far faster than prices.

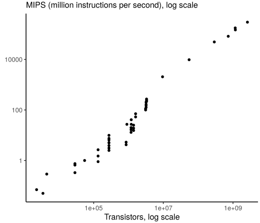
Fig. 1: Moore's Law



Note: Moore (1975) predicted that transistors per processor would double every two years. The average increase for the models shown is 92% every two years.
Source: Wikipedia, accessed 4/7/2023.

MPU transistors double every *two* years.

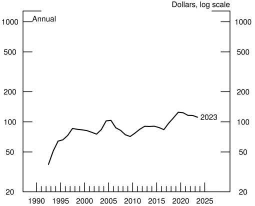
Fig. 2: Performance



Note: Intel microprocessors released from 1971 to 2014.
Source: Intel, Inc.; Wikipedia; Computer History Museum.

Performance is tightly related to transistor count. (Correlation = 0.98)

Fig. 3: MPU Average Price



Source: Semiconductor Industry Association.

MPU price seems to double every *twenty* years.

Storage and transmission prices continue to plumb new depths and data volume climbs in response.

Fig. 4: Storage and Transmission Prices

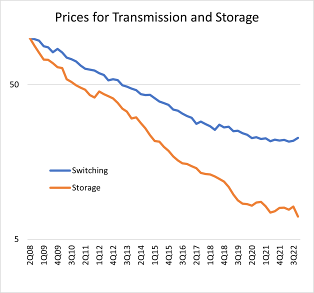
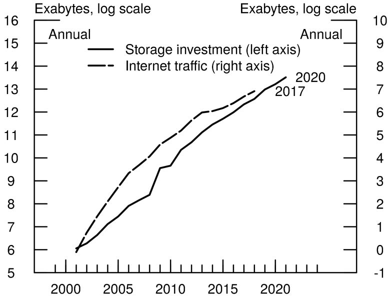


Fig. 5: Global Data Volume

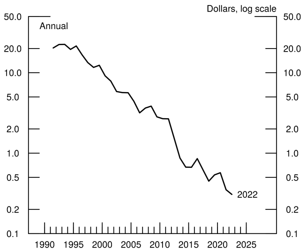


Source: Cisco, Inc. and IDC, Inc.

Collection and presentation is harder to measure, but innovation is swift.

Collecting analog signals (sound, images) and converting to digital for processing.

Fig. 6: Price of CCD Image Sensors



Source: Semiconductor Industry Association.

Natural Language Processing revolutionizing presentation (ChatGPT)

Beware the lump of labor fallacy.

Fig. 7: Human Calculators

Source: NASA/JPL-Caltech.

Market Structure: Competition for the Leading Edge

How much competition is there in the tech sector? Indicators include

- The supercomputing crown is regularly passed back and forth between the United States, Japan, and China. This is not just about weapons simulation. Firms from cloud providers (obviously) to potato chip manufacturers (!) use supercomputing.
- The competition for the bleeding edge of semiconductor technology is intense between the United States (Intel), South Korea (Samsung), and Taiwan (TSMC).
- More competition may mean faster deployment of technology to production (e.g. AMD vs. Intel), but whether it means more or less R&D is less clear.

Market Structure: Capacity by Country

Table 1: Semiconductor Capacity for Key Economies

Economy	Fabs	Wafers	Transistors	Specialty
United States	73	7%	9%	MPU, Analog
Taiwan	82	18%	34%	Foundry
South Korea	37	18%	43%	Memory
PR of China	143	28%	6%	Optoelectronics, Memory
Japan	108	16%	5%	Optoelectronics, Memory
Planned Expansions				
United States	11	12%	46%	Foundry
Taiwan	8	5%	28%	Foundry
South Korea	6	29%	22%	Foundry, Memory
PR of China	18	30%	1%	Foundry
Japan	6	15%	2%	Memory

Note: Transistors is wafers divided by geometry squared. Geometry is company-reported—typically the distance between features on the chip.
Source: SEMI (Semiconductor Equipment and Materials International)

Planned new capacity would increase the size of the industry by 23% by 2025.

Geopolitical developments seem negative, on balance.

- How bad is the trade war with China? We already restricted their access to advanced electronics and semiconductor technology. Even with the technology in hand, they struggle to produce advanced chips for lack of engineers.
- How bad would a disruption of Taiwan be? Samsung and Intel are just a whisker behind TSMC. Whether TSMC would continue to operate at the leading edge under PRC control is unclear.
- Supply chain disruption from COVID-19 was surprisingly persistent. Regional disruptions from climate events (e.g. flooding in Thailand) can be consequential as well and will be more frequent.
- The modal expectation matters, but uncertainty matters too, perhaps more, for investment decisions.

Solving the Productivity Puzzles

- Emphasize global nature of productivity developments. (See recent work by Fernald and coauthors. World Input-Output Database is a major advance.)
- We need three-fold consistency in the measurement system: across countries, products, and time. Productivity developments unfold over decades and are global. These issues are known to, but not a top priority for, national statistical agencies.
- Emphasis on measuring intangibles. Especially with non-traditional data sources.