Living in an Ocean of Knowledge
Deflating Intangible Investment: Some New Ideas and Estimates

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** The views expressed today are my own and not necessarily those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.*

Introduction: A Rapidly Rising Ocean of Knowledge

- We are in an extraordinary time for innovation and therefore for R&D, the quintessential intangible
  - Innovative firms are rapidly expanding our capabilities
    - Apple, Google, Tesla, SpaceX, Netflix, Spotify, Illumina, Moderna, and Amazon
    - Creativity is at the heart of the modern corporation
  - Extraordinary innovation in all dimensions of human endeavor
    - Software, statistics, data, art, travel, entertainment, biology, global culture, chemistry, education, sensing, imaging, electricity, communication, neurology, health, and markets.
  - When we study intangibles, we venture into the very heart of creativity.

Difficulties in understanding intangibles and their impact on productivity

- We have great difficulties measuring the economic impact of innovation
- A large and increasing literature shows that much of the growth impact of new products is missed in measures of real GDP
- Less attention has been paid to the deflation of investment in innovation: that is, the measurement of real intangible investment
- This makes the productivity measurement puzzle worse

Intangibles differ from tangibles on many dimensions

- We are trying to tame intangibles. We try to view intangible investments as very similar to tangible investments.
  - But can we? Should we?
- Dimensions along which intangibles differ from tangibles
  - Nonrival and nonlinear—zero cost of reproduction
  - IP protection (sometimes refused); open source
  - No physical deterioration, no geographical ties
  - Not arm's length and very risky with fat tails
  - Never the same from period to period

Example: Pharmaceuticals

- Pharmaceuticals industry has negative productivity growth over past 15 years
- Yet pharmaceuticals industry produced mRNA vaccines.
  - Which have saved millions of lives: worth $1 trillion plus
  - But this real value of vaccines not included in output
- Value of new pharmaceuticals not captured as new goods
  - And the savings from generics are not included in GDP (produced in China and India)

Pricing intangibles from their outcomes?

- In this paper, I focus on the deflation of research and development
  - By and large, we deflate R&D by deflating input costs for capital and labor and add back in an overall estimate of productivity.
- Generally, we do not observe transaction prices for R&D
  - We observe transaction prices for the products that are created
  - The key innovative products we study are both outputs of and inputs into innovation
- Tangible investments like a computer or communication equipment can fall rapidly in price
  - why not intangible investment?

Do intangibles help account for growth?

- The rapid improvements we have seen in microprocessors have been an important source of growth
  - These improvement are due to spending to improve the technology that produces microprocesors, in intangible investments
- The rates of improvement in the technology should be reflected in the intangible investments
- Because many R&D projects fail, it is the sum total of all the expenditures that should be so deflated.

Evidence of rapid improvement in R&D from depreciation rates

- R&D does not deteriorate physically over time
- Instead, it loses private value because of obsolescence or because it loses intellectual property protection
- Either way, obsolescence arises from technological progress, which remains permanent
- R&D depreciates fairly rapidly, often 16 % annually or more
- This is one set of evidence that progress is fast in intangible investment and perhaps intangibles prices are deflating

Depreciation rates of R&D are often faster than 16 percent (modal rate of depreciation for R&D)

Table 1. Domestic Research and Development, 2018, Total and Selected Groupings, National Center for Science and Engineering Statistics (NCSES)

Business Activity	Industry codes	Billions of dollars	Percentage	Depreciation rate spread in percent
Total		441.0	100.0	
Medical and chemical	32500,33910,62150	98.7	22.4	9 to 16
Machinery and electronic	33300	103.4	23.4	25 to 40
Transportation machinery	33600	49.1	11.1	7 to 31
Information	51000	94.7	21.5	16 to 33
Professional, scientific and tech	54100	47.2	10.7	16
Subtotal of selected groupings		393.1	89.1	7 to 40

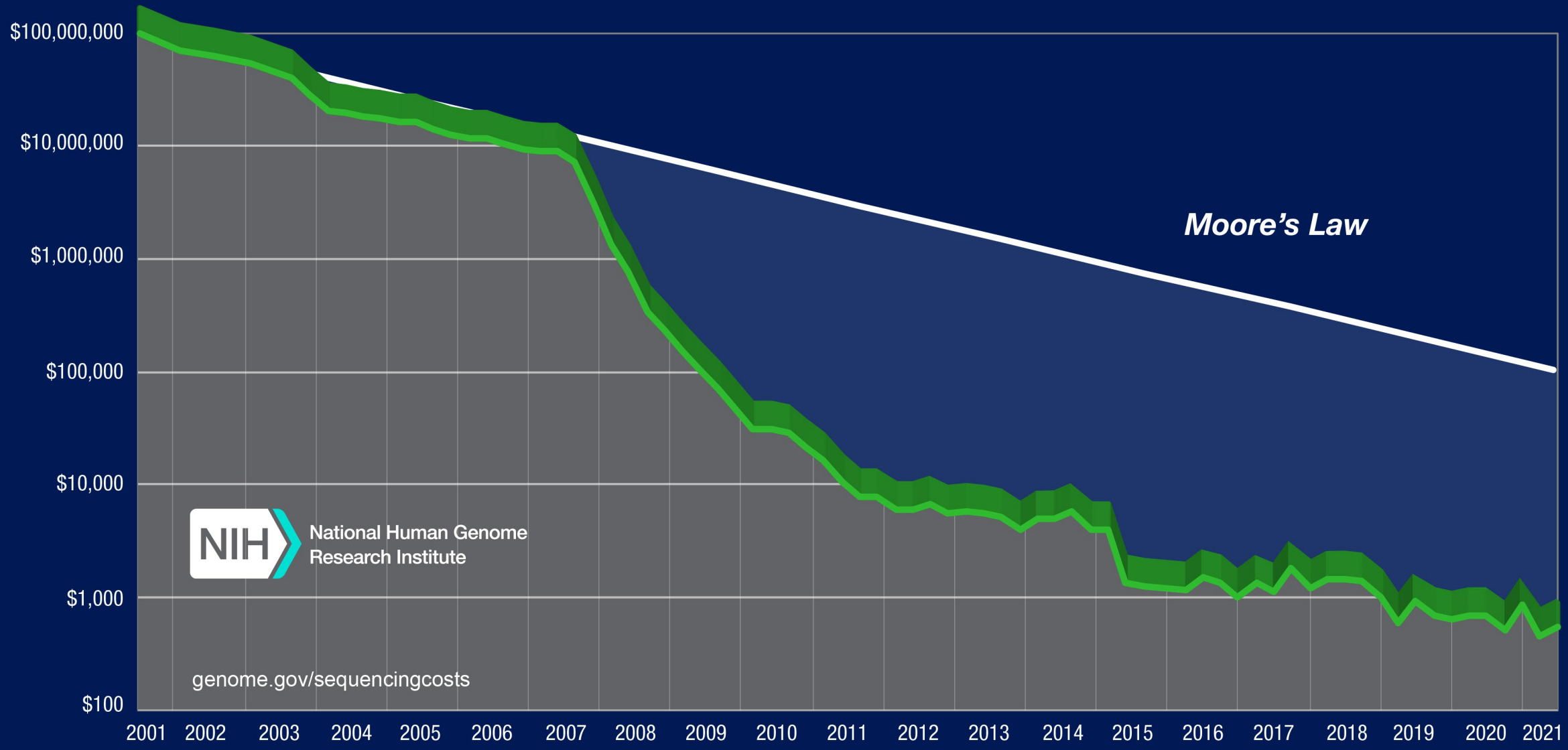
Rapid price declines for experimentation

- The cost of performing an experiment has fallen dramatically in many key instances:
- Space launches, robot scientists, cloud computing, neurology, biochemistry, sensors, AI, and on and on.

Examining central drivers of innovation we see very fast rates of price decline

- Central dogma of biology:
  - DNA instructs RNA how to create proteins, proteins fold into 3 dimensional shapes to function
- DNA sequencing of one human genome:
  - 2005: $10 million each; 2018: $1000 each; 47 % annual rate of price decline
- DNA manipulation:
  - 2012 to 2018: fall in price 150 fold; even faster than DNA sequencing
- New Deep Mind AI technology solves protein folding for 2/3 of all proteins!

Cost per Human Genome



Other examples

- Moore's Law: 29 % rate of price decline
- Cloud computing prices: 7 % price decline
- Rocket cost per flight fell by 3 times: 13 %
- LEDs: 21 %
- Batteries: 20 %
- Lidar (laser equivalent of radar): 22 %
- Internet per byte: 28 %
- Cellular per byte:45 %

Rapid rates of price decline characterize central innovative products

- Price declines to outputs of R&D include input prices as well as output prices:
  - Computation, data storage, DNA sequencing, DNA manipulation, protein folding, communications, rockets, robots, AI, sensors, imaging
- Both depreciation rates and direct measures of price declines suggest that many areas of R&D are experiencing deflation
- If the outcomes of R&D fall in price rapidly, is that deflation of R&D
- Do we need better measures of price changes in intangible investment as we do in consumer products?

Conclusion

- There has been rapid progress in some areas of intangible investing
  - some areas of research and development are deflating at double digit rates
  - If we want to draw a strong parallel with tangible investing, perhaps we should deflate intangibles
  - If we want to understand the sources of growth, we must deflate intangibles
- However, doing so makes making sense of productivity data even harder