

*AI and the Modern
Productivity Paradox:
A Clash of Expectations and Statistics*

FEDERAL RESERVE BANK OF ATLANTA
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based on work with
Erik Brynjolfsson and Daniel Rock

Technological Optimism

“The speed of innovation has never been faster.”

- Paul Polman, CEO Unilever

“Innovation is moving at a scarily fast pace.”

- Bill Gates, Founder, Microsoft

“the beginnings of...[a] rapid acceleration in the next 10, 15, 20 years”

- Vinod Khosla, Founder, Khosla Ventures

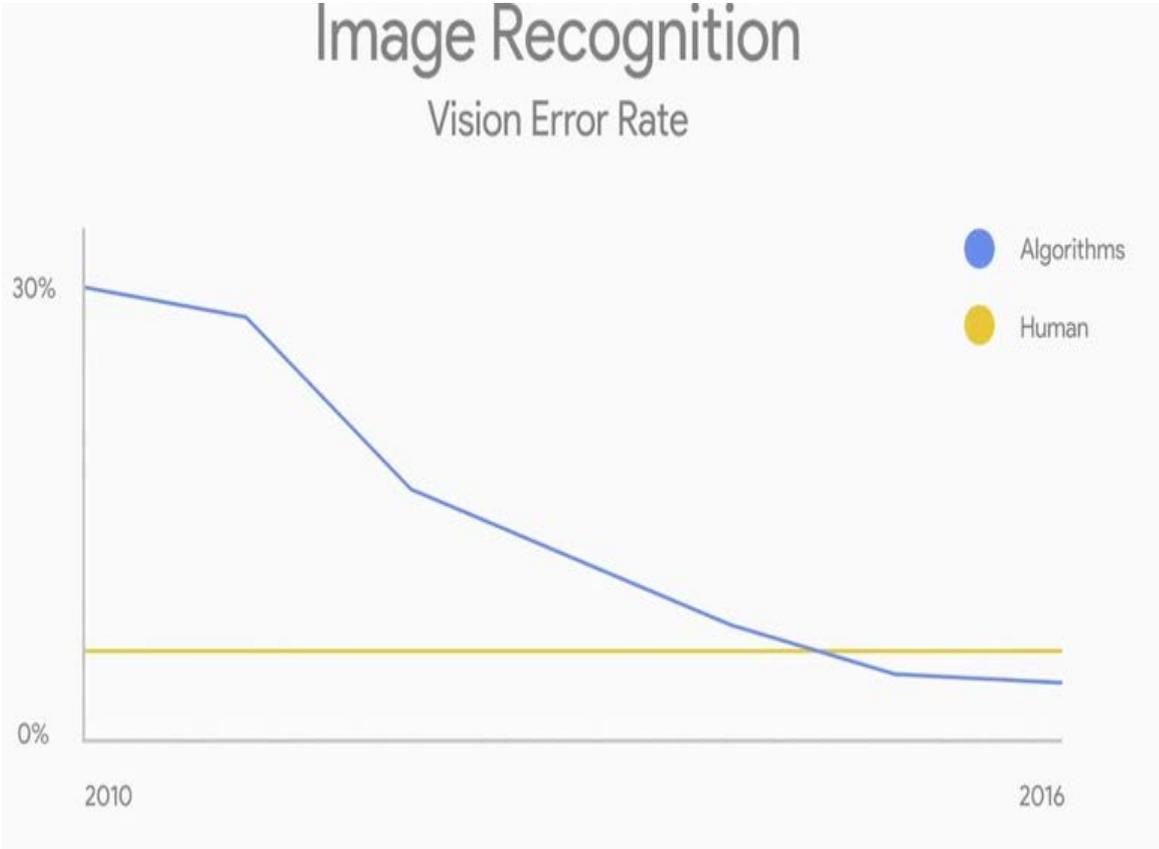
“We’re entering...the age of abundance [and] during the age of abundance, we’re going to see a new age...the age of intelligence”

- Eric Schmidt, Former Chairman, Alphabet

“The Singularity is near”

- Ray Kurzweil, National Medal of Technology Laureate

ML Has Crossed an Important Threshold



Google Home Speech Recognition

Speech Recognition Word Error Rate



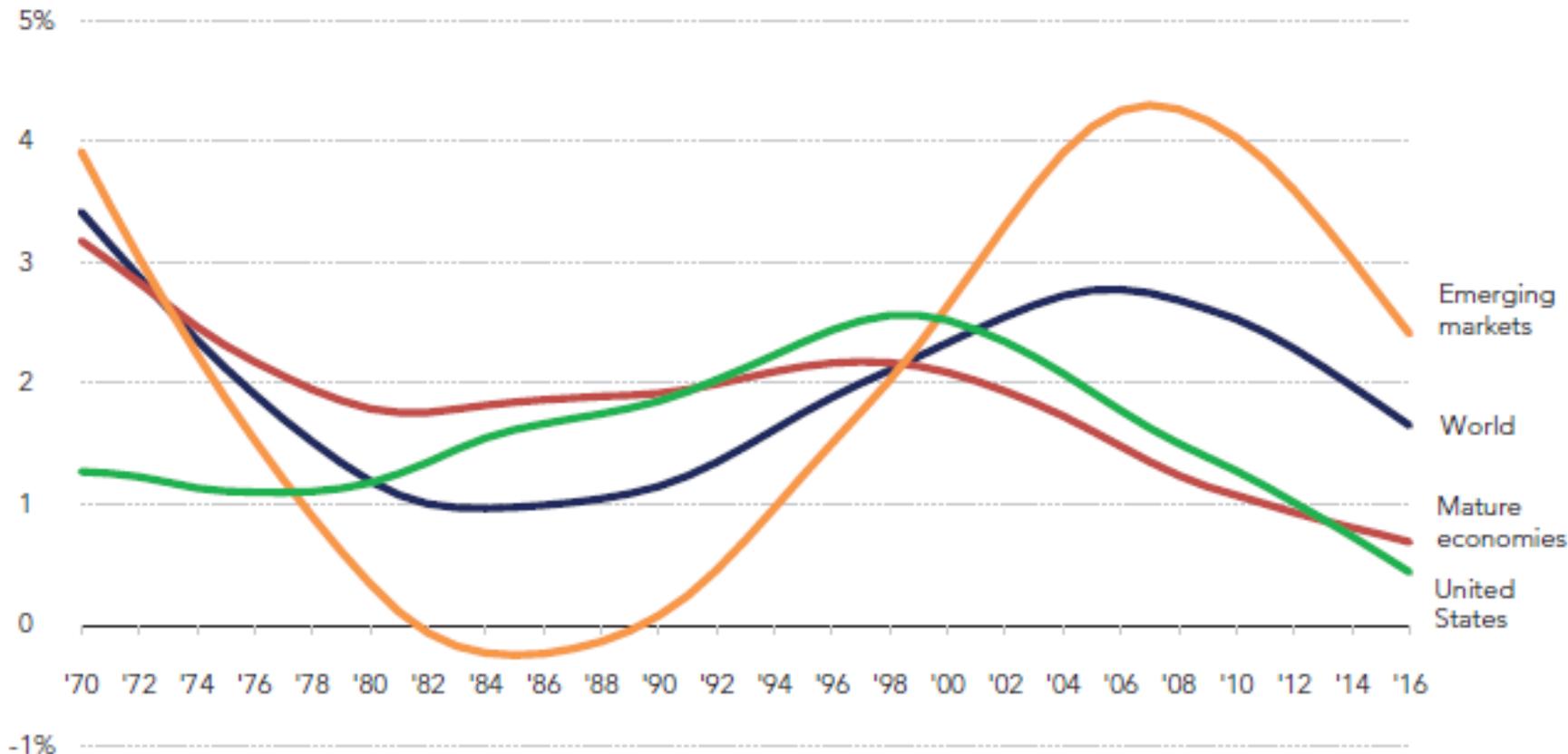
US English only.

The Disappointing Recent Reality

- Productivity growth has slowed everywhere
 - We are more than one decade into a slowdown in the U.S. and OECD countries
- United States:
 - 1995-2004: 2.9% per year
 - 2005-2017: 1.3% per year
- OECD: 29 of 30 countries saw similar-sized slowdowns after 2004
- Emerging markets experienced slowdown around Great Recession (U.S. and OECD slowdowns began earlier)

The Disappointing Recent Reality

Trend growth of global labor productivity (output per person), 1970-2016



Note: Trend growth rates are obtained using HP filter, assuming $\lambda=100$.

Source: The Conference Board Total Economy Database™, May 2016. Data for 2016 is based on projections by The Conference Board.

Why Does Slow Productivity Growth Matter?

- Productivity is the “speed limit” on economic growth
- Even small changes in growth rates add up
- Had productivity growth not slowed after 2004:
 - GDP would now be (conservatively) \$3 trillion higher per year
 - \$9200 per capita
 - \$24,000 per household
- If this slowdown continues another 10 years, we will be “missing” over one-third of GDP

A Paradox: Potential Explanations

1. False hopes
 - Technological optimism unwarranted; future productivity acceleration won't happen
2. Mismeasurement
 - Reality better than measured; no current slowdown
3. Distribution and dissipation
 - Technological benefits are real but concentrated; large dissipative efforts to grab or guard benefits
4. Implementation and restructuring lags
 - Technology is real, but benefits take time to emerge

Explanations for the Paradox

1. False hopes: Certainly some past technologies have disappointed
 - But not hard to estimate large productivity gains from existing technologies
2. Mismeasurement: Reasonable prima facie case
 - But lots of recent work indicating this isn't the story
3. Distribution and dissipation: Consistent with more skewed/concentrated company and worker outcomes
 - But hardly dispositive, and implies huge amounts of dissipative activity

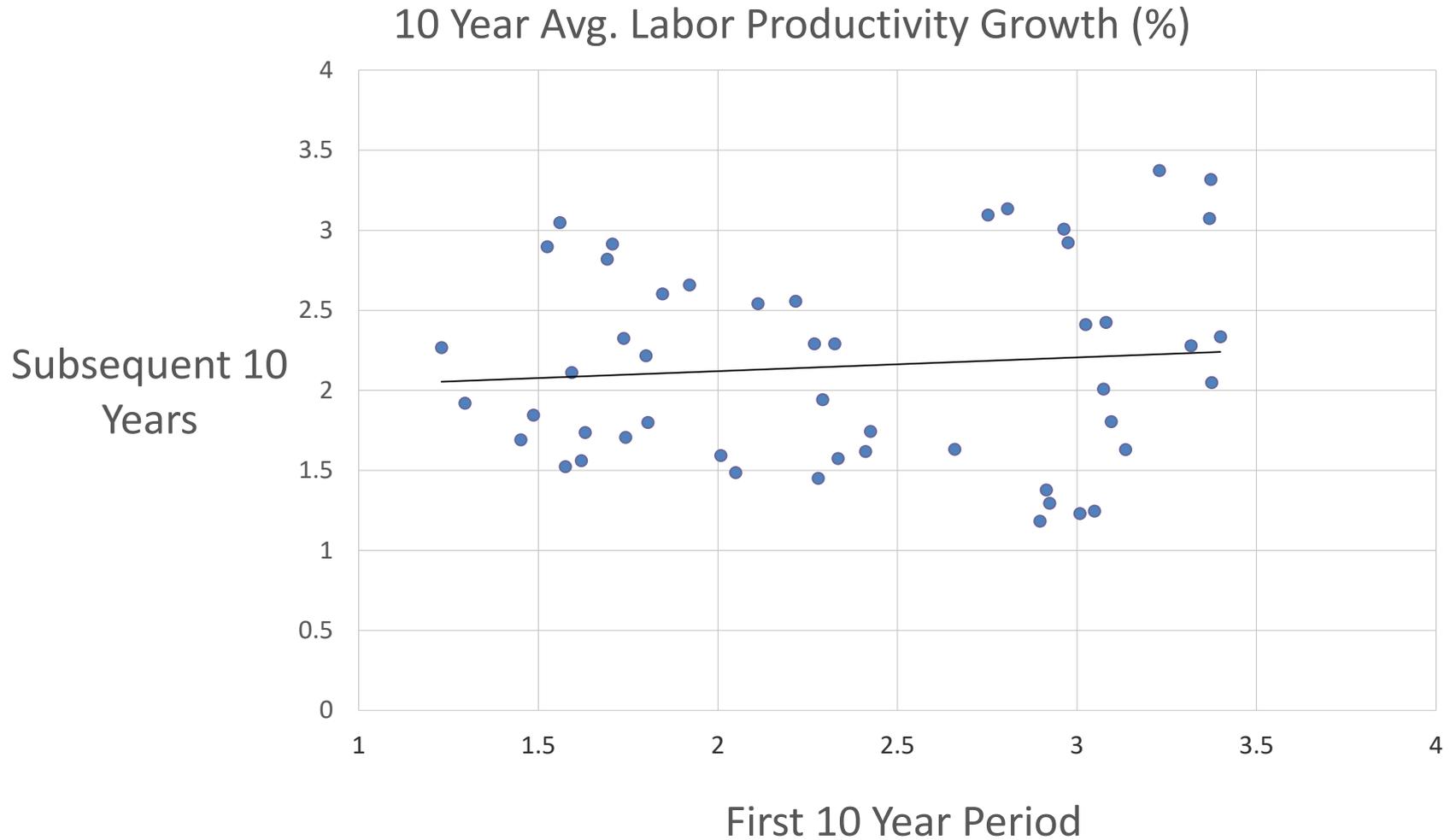
Explanations for the Paradox

4. Implementation and restructuring lags
 - Technology is real, but benefits take time to emerge
- AI Paradox is not a contradiction:
 1. Optimists are looking to future impacts of current technologies, but GDP and productivity data reflect past and present
 2. General purpose technologies (GPTs) take time to have an impact
 3. GPTs may *reduce* measured productivity initially
 - Current slowdown tells us little about future

Case for Implementation Lag Story

- Current productivity growth does not predict future productivity growth
- Back-of-the-envelope examples of achievable productivity growth
- AI as a GPT

Past Performance Does Not Predict Future Results



Examples of Potential AI-Driven Productivity Growth

- Autonomous Vehicles
 - BLS reports 3.5 million “motor vehicle operators”
 - Suppose autonomous vehicles reduced that to 1.5 million
 - Private employment is 122 million
 - => ~ 1.7% increase in productivity
 - Over 10 years, perhaps an additional 0.17%/yr

Examples of Potential AI-Driven Productivity Growth

- Call Centers
 - 2.2 million employed in large call centers
 - If reduced by 60%:
 - => ~ 1% increase in productivity
 - Over 10 years, perhaps an additional 0.1%/yr

Google uses DeepMind AI to cut data center energy bills

The AI successfully reduced power consumption by 15 percent overall

By James Vincent on July 21, 2016 04:02 am @jvincent



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The amount of energy consumed by big data centers has always been a headache for tech companies. Keeping the servers cool as they crunch numbers is such a challenge that Facebook even built one of its facilities on the edge of the Arctic Circle. Well, Google has a different solution to this problem: putting its DeepMind artificial intelligence unit in charge and using AI to manage power usage in parts of its data centers. The results of this experiment? A 40 percent reduction in the amount of

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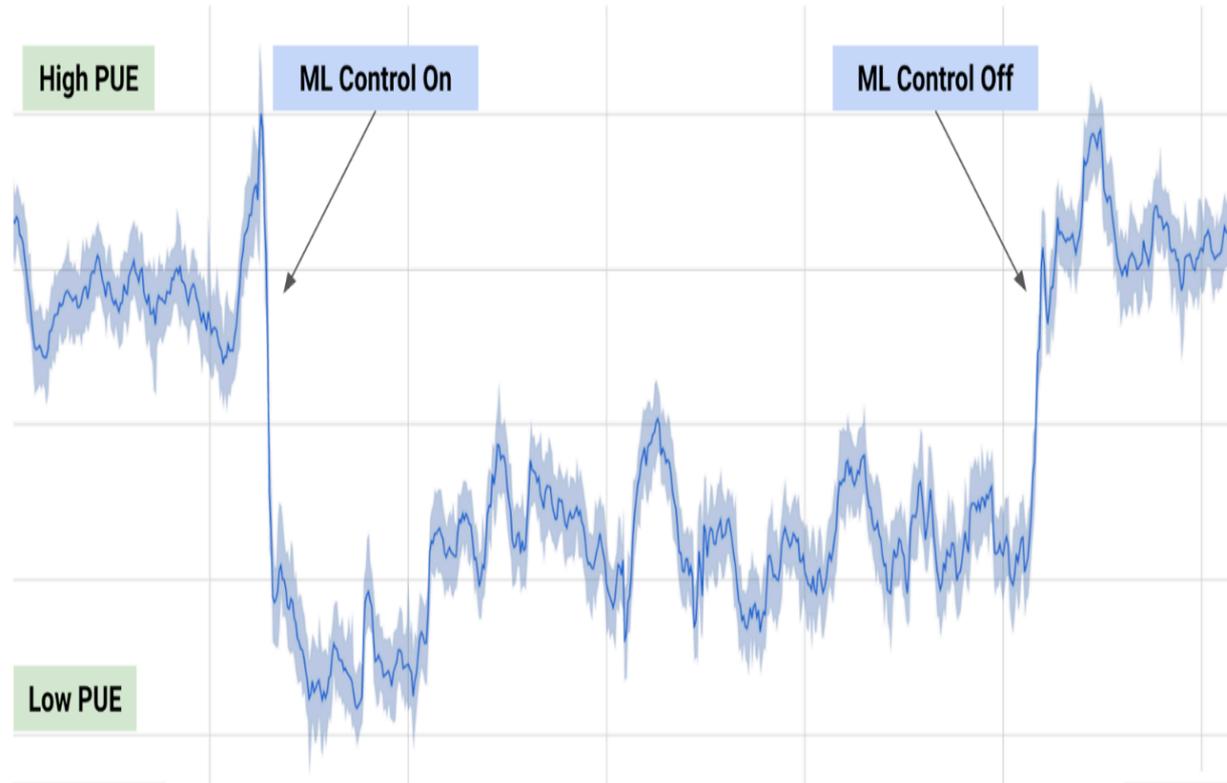


The Xbox One S heats up the HDR format war



Bitcoin exchange hit with \$61 million theft

We tested our model by deploying on a live data centre. The graph below shows a typical day of testing, including when we turned the machine learning recommendations on, and when we turned them off.



Our machine learning system was able to consistently achieve a 40 percent reduction in the amount of energy used for cooling, which equates to a 15 percent reduction in overall PUE overhead after accounting for electrical losses and other non-cooling inefficiencies. It also produced the lowest PUE the site had ever seen.

AI as a General Purpose Technology

- Defining properties of GPTs
 1. Pervasive
 2. Able to be improved upon over time
 3. Able to spawn complementary innovations

AI as a General Purpose Technology

- Defining properties of GPTs
 1. Pervasive
 - **Prediction**, including diagnosis, classification, and labeling, is core to broad range of tasks, occupations and industries
 2. Able to be improved upon over time
 - Essence of machine **learning** is (self-)improvement
 3. Able to spawn complementary innovations
 - **Perception** (esp. vision, voice recognition) and **cognition** (problem solving) are building blocks enabling massive combinatorial innovation
 - Cloud robotics amplifies this impact

If AI Is So Great, Why a Slowdown?

1. Enough new capital stock must be accumulated to affect aggregates
2. Complementary assets need to be invented, built, and installed

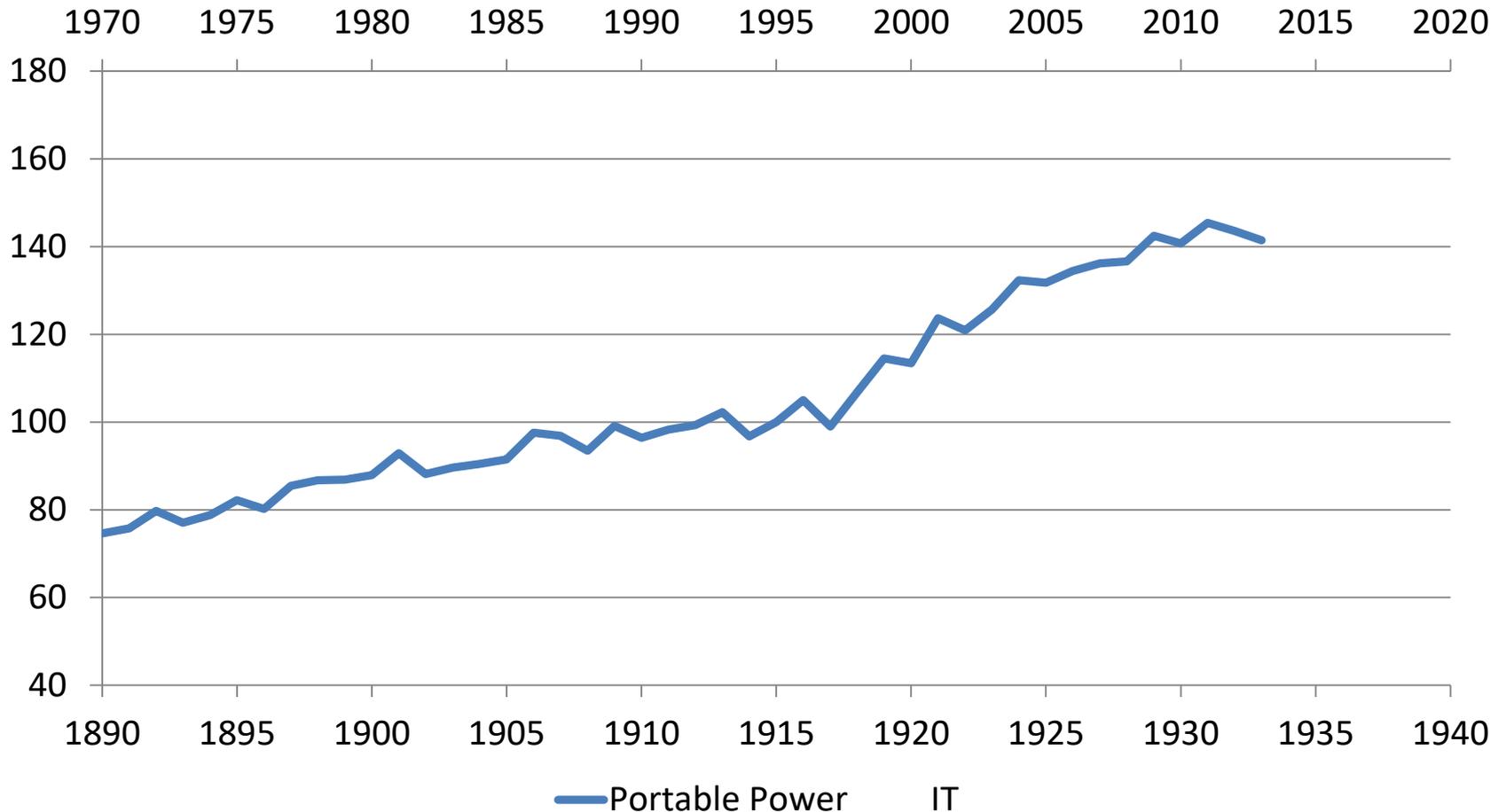
These processes can take years or decades

If AI Is So Great, Why a Slowdown?

- It can take a long time for enough GPT stock to be accumulated to show up in aggregates
 - Computer capital in U.S. topped off at about 5% of total nonresidential equipment capital by late 1980s
 - 25+ years after invention of integrated circuit
 - Only half that level 10 years earlier
 - Over half of U.S. manufacturing establishments unelectrified in 1919
 - 30 years after AC systems standardized

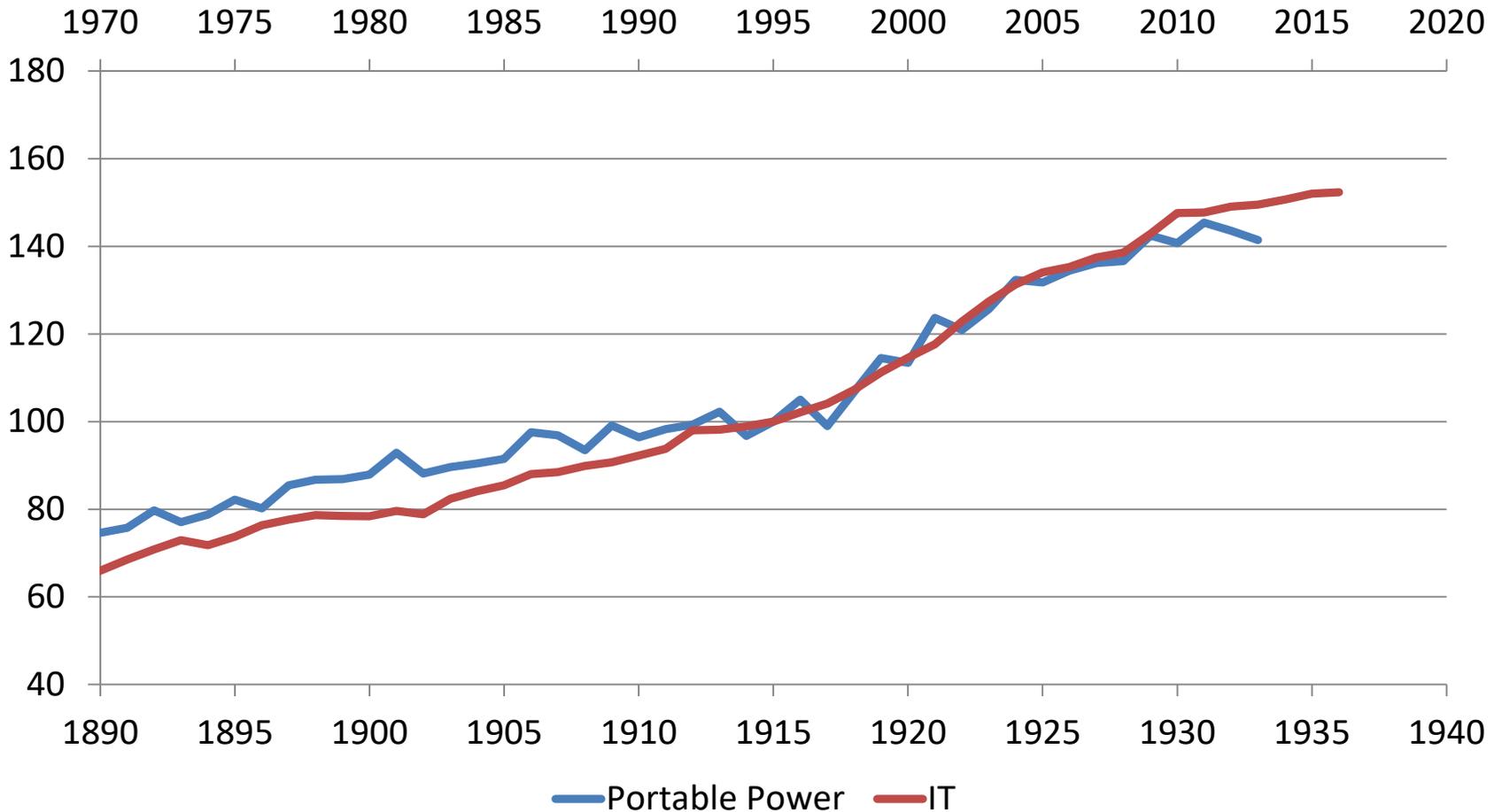
History's Lens on Today's Paradox

Labor Productivity in the Portable Power and IT Eras



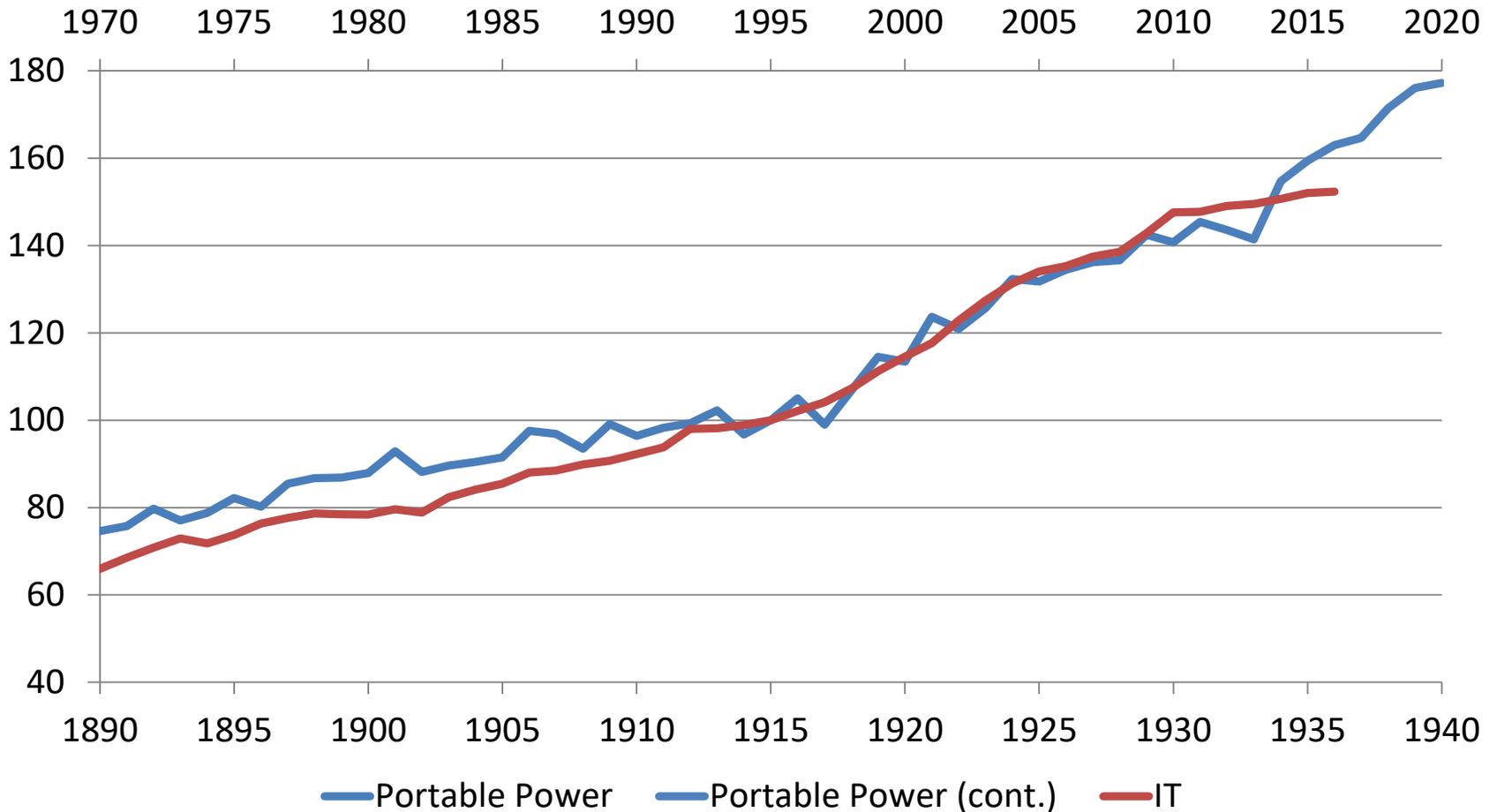
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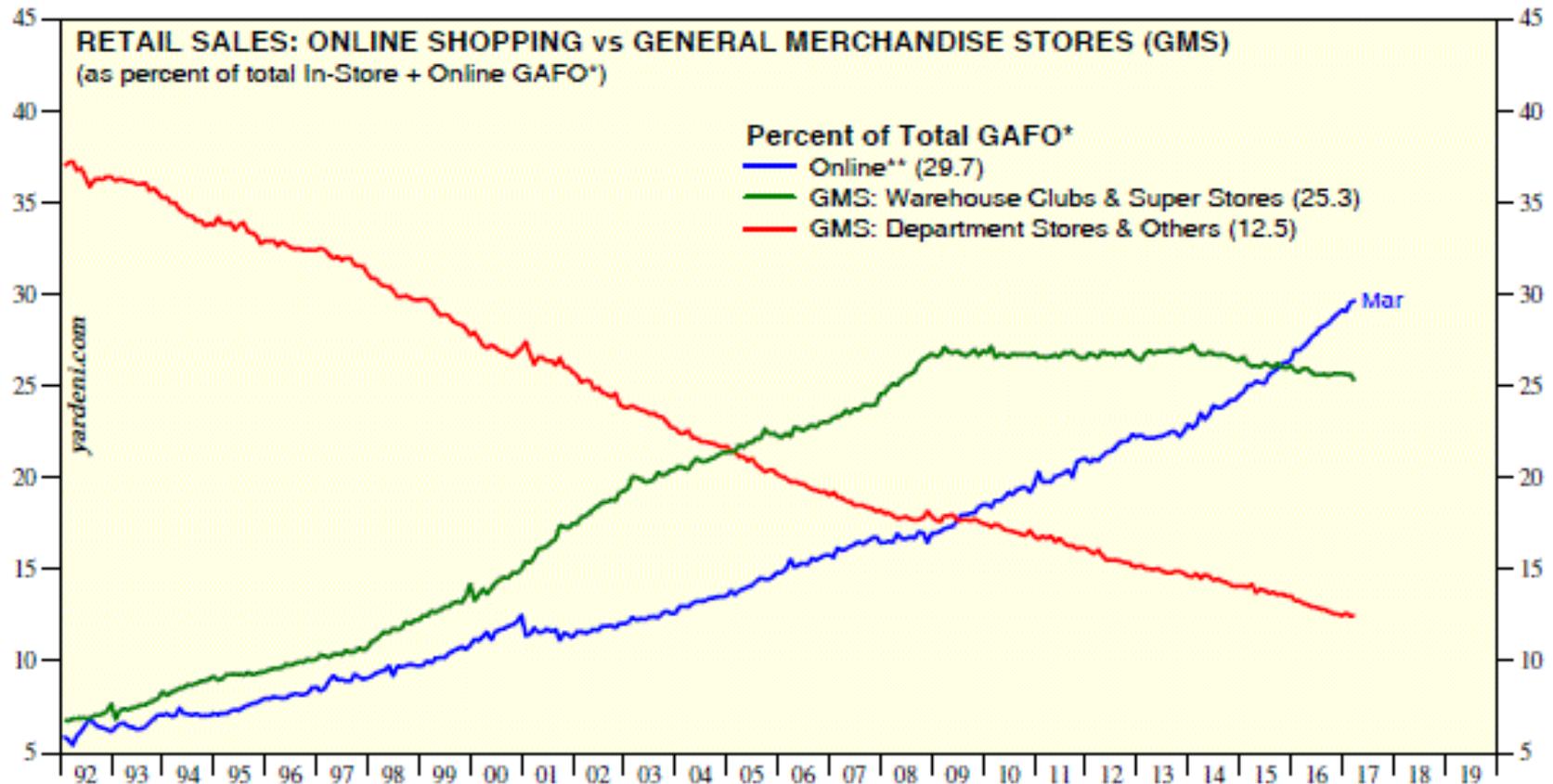


History's Lens on Today's Paradox

Labor Productivity in the Portable Power and IT Eras



Ecommerce Wasn't Finished in 1999



* GAFO (general merchandise, apparel and accessories, furniture, and other sales) includes retailers that specialize in department-store types of merchandise such as furniture & home furnishings, electronics & appliances, clothing & accessories, sporting goods, hobby, book, and music, general merchandise, office supply, stationery, and gift stores.

** Electronic shopping and mail order houses.
Source: Census Bureau and Haver Analytics.

Conclusion

- Implementation and restructuring lags story a plausible resolution to the current paradox of technological optimism and disappointing current empirical reality
- The story says these two things not in conflict
- Indeed, it implies they are an internally consistent and necessary result of GPT invention and diffusion
- But realizing benefits of AI will not be automatic
 - Workers, organizations, and industry institutions do not change quickly
 - Dynamism is important, yet there has been a long-term downward trend