Will Robots and AI Revolutionize Productivity Growth?

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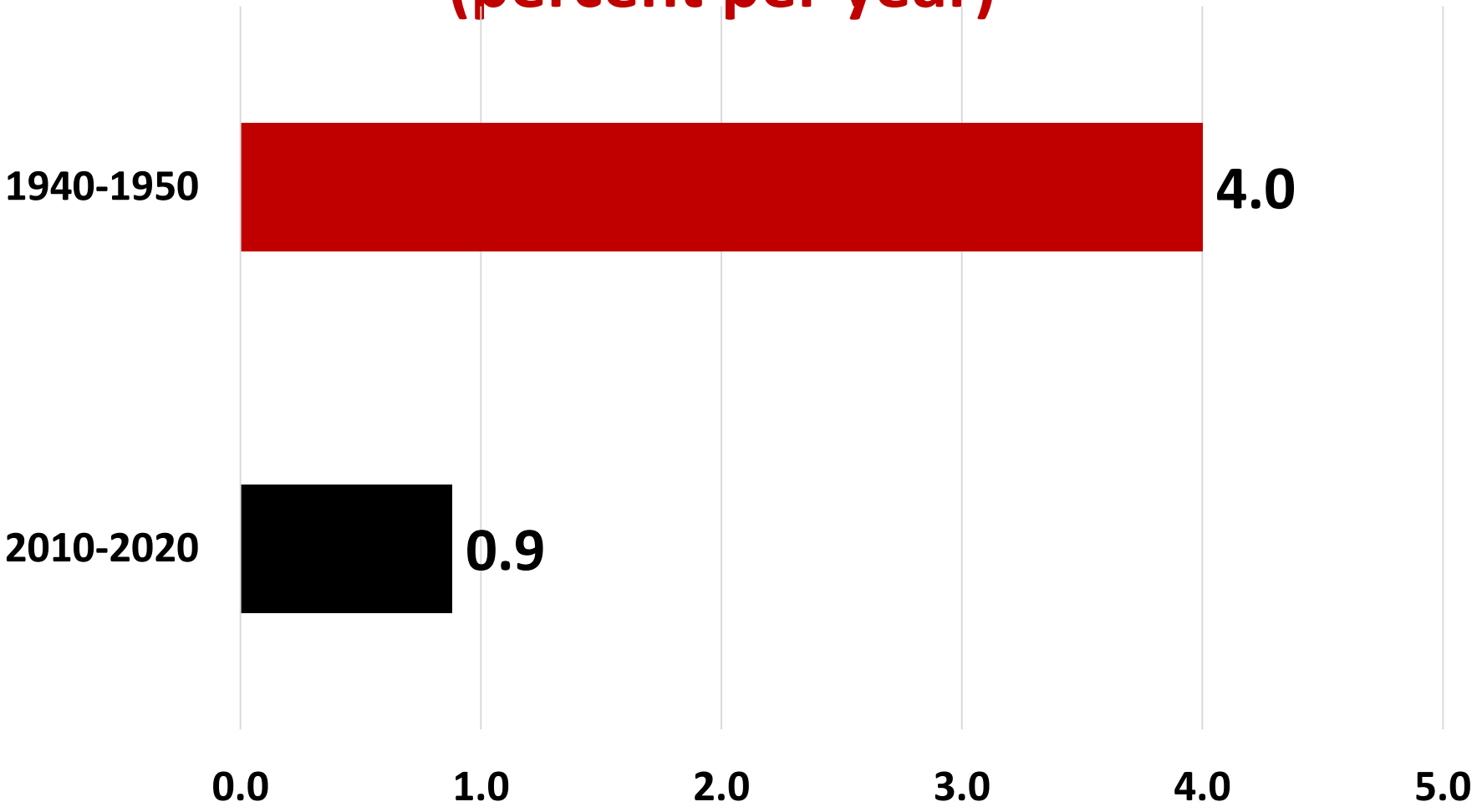
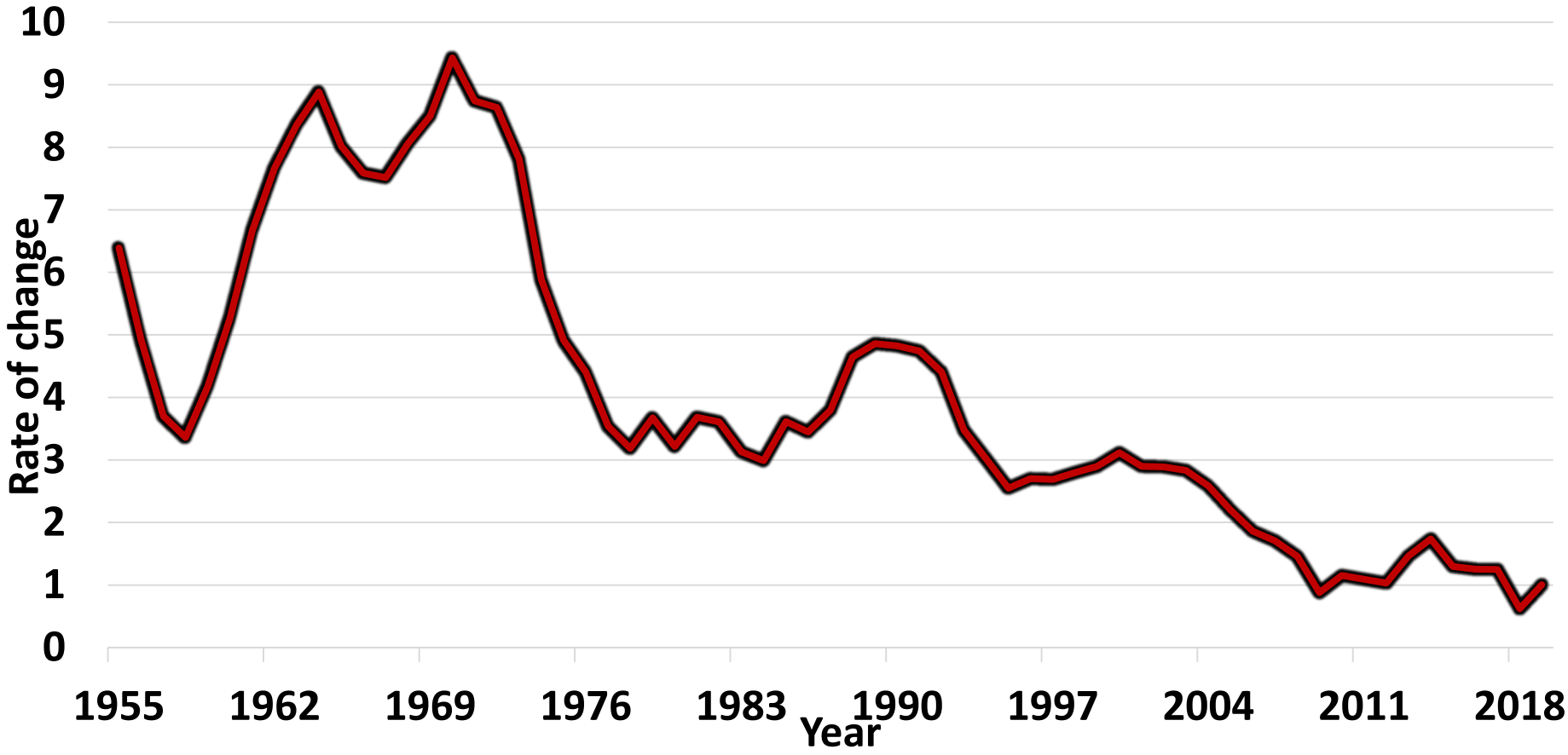
AI and the 4th Industrial Revolution

- **Techno-optimists since a decade ago have predicted a 4th industrial revolution as robots and AI replace human workers**
  - **Brynjolfsson and McAfee back then in *The Atlantic*:**
    - **"Because the exponential, digital, and recombinant powers of the second machine age have made it possible for humanity to create two of the most important one-time events in our history: the emergence of real, useful artificial intelligence (AI) and the connection of most of the people on the planet via a common digital network. Either of these advances alone would fundamentally change our growth prospects. When combined, they're more important than anything since the Industrial Revolution.**
  - **Brynjolfsson's testimony before a congressional committee on AI in 2019:**
    - **"I think that with the right policies, AI can be harnessed to make the next decade the best decade in US history"**

The Best Decade in U.S. History? Compare 2010-20 with 1940-50 (percent per year)



Five-Year Change in Output per Hour, Japan, 1955-2019



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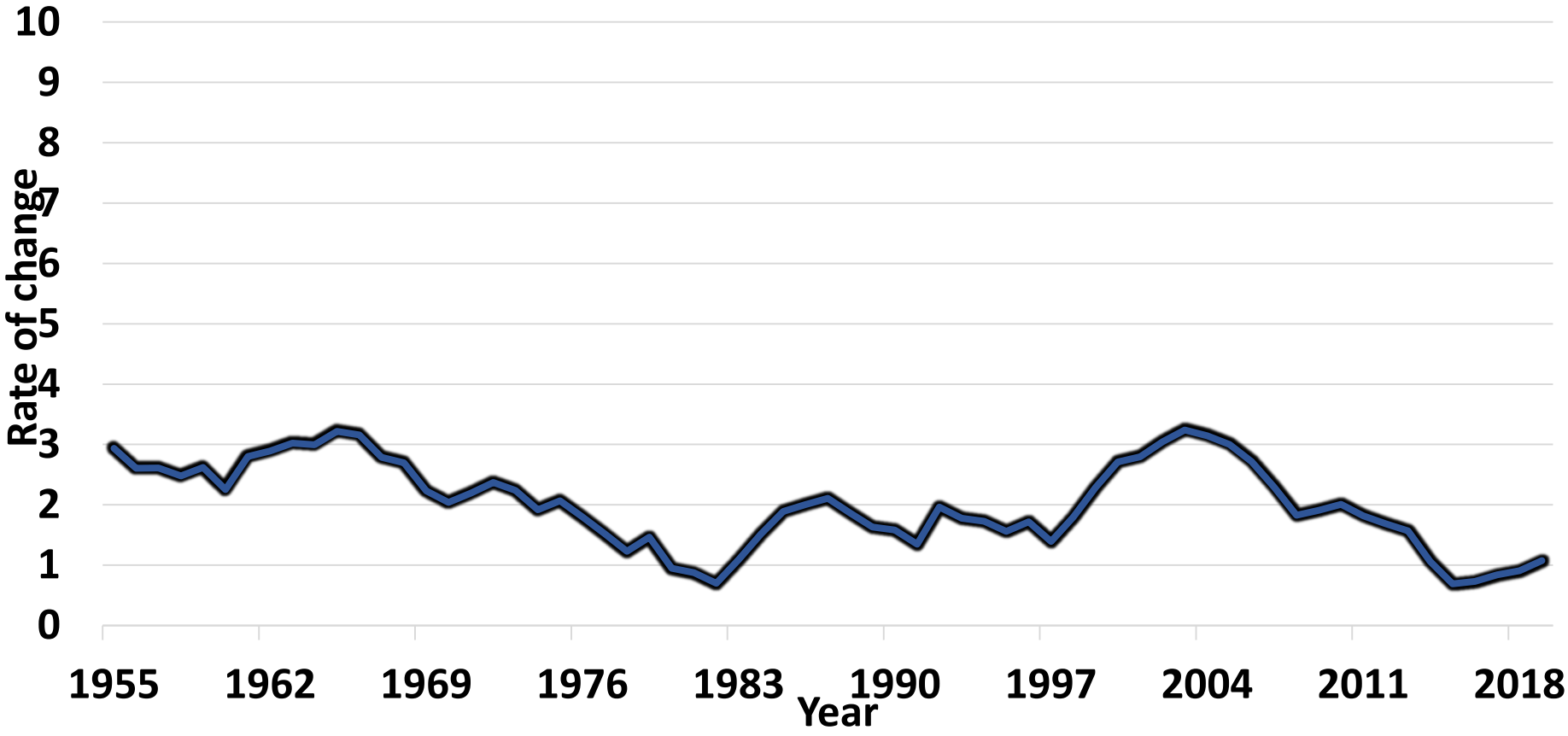
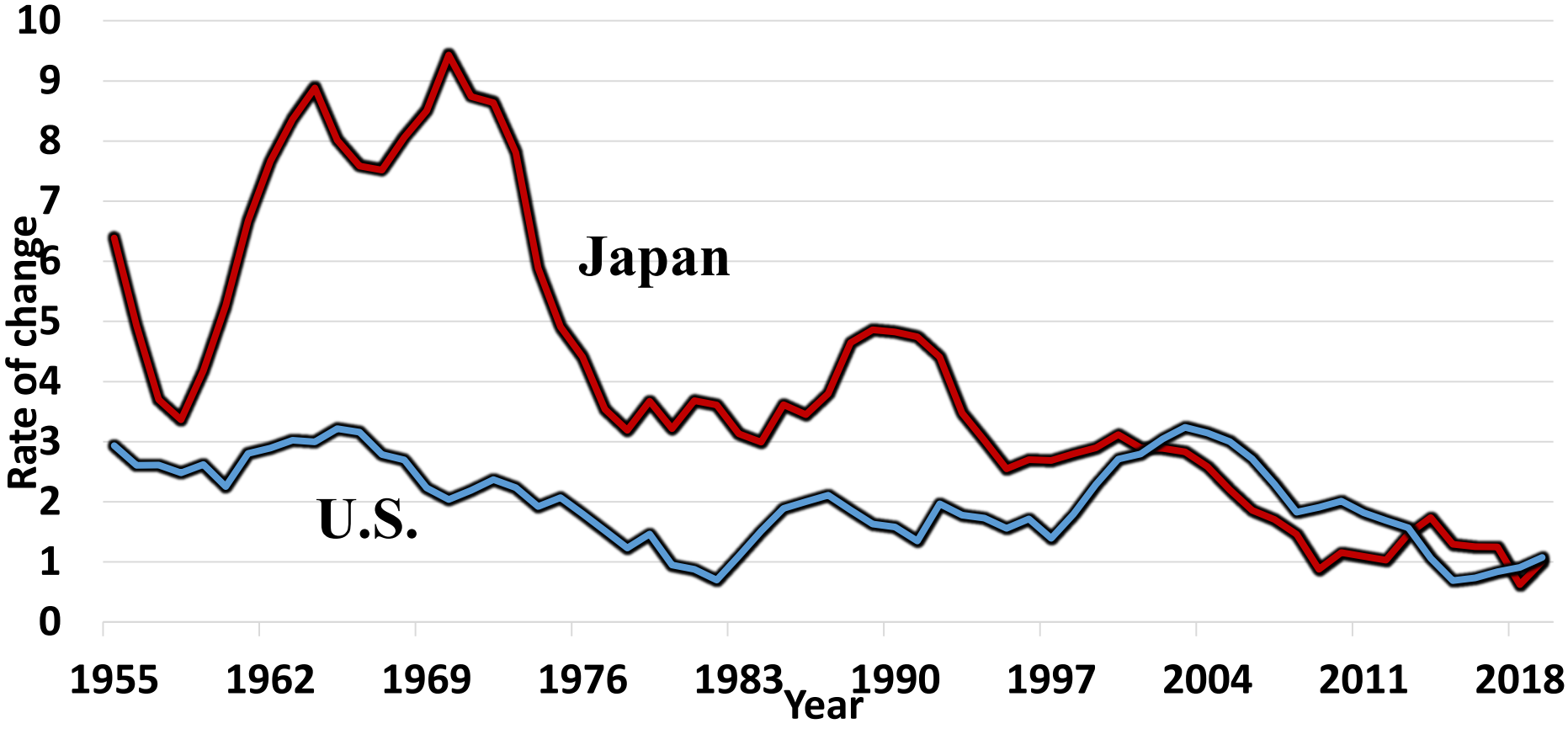


Five Year Change in Output per Hour, Japan vs. US, 1955-2019



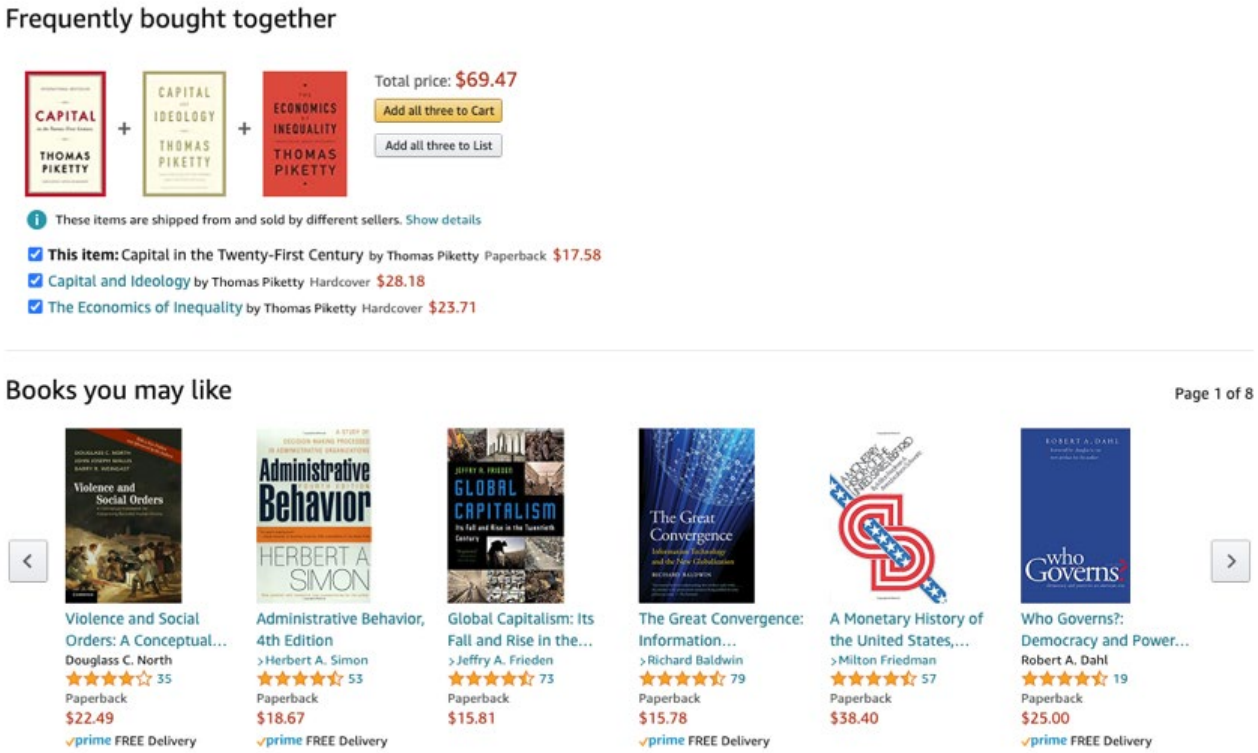
Google Chief Pinchal: "AI More Profound than Fire or Electricity"

- Timeline of AI Progress
  - 1948 Alan Turing writes first chess playing program
  - 1955 First use of the term "artificial intelligence"
  - 1996 "Deep Blue" beats world chess champion
  - 2009 Waymo develops first autonomous vehicle
  - 2010 "Watson' beats world champion on Jeopardy
  - 2011 Apple introduces "Siri" voice-activated assistant
  - 2016 Alphago beats grandmaster at Go

Many Uses of AI Are Nothing New

- Current Applications of AI
  - Search engines
  - Facial recognition that unlocks smartphones
  - Voice recognition (Siri, Alexa, Netflix)
  - Language translation
- Pattern Recognition
  - Radiology diagnosis, brain tumors 10X faster
  - Astronomers search planets
  - Legal searches
  - Consumer credit ratings: assess credit risk

Example of AI – Machine Learning (Amazon Book Recommendation)



Example of AI – Speech Recognition (Alexa)

Amazon's Choice

All-new Echo Dot (4th Gen) | Smart speaker with Alexa | Charcoal

4.5 out of 5 stars 2,584

42% off Limited time deal

$28.99 ~~$49.99~~

Or $5.80/month for 5 months (no fees or interest)

prime FREE Delivery **Sun, Nov 29**

Climate Pledge Friendly

See 1 certification

Holiday Gift Guide

Echo Dot (3rd Gen) - Smart speaker with Alexa - Charcoal

4.5 out of 5 stars 772,099

53% off Limited time deal

$18.99 ~~$39.99~~

Or $3.80/month for 5 months (no fees or interest)

FREE Delivery for Prime members

New and used options from $16.71

Example of AI – Facial Recognition (iPhones)

Uber and Airline Booking Systems as Marvels of AI

- Uber matches customer location with available nearby drivers
  - Plots optimal routes based on real-time traffic conditions
  - Applies surge pricing in response to demand in busy hours
- Airline systems used to price seasonally
  - Now “hyperdynamic pricing,” price changes many times per day
  - Responds to news, weather, local events

Will AI Replace Human Authors?

- "Software writing software," eliminates tedious and repetitive aspect of coding
- Teaching computers to write by analyzing millions of pages of text
  - Program uses 175 billion parameters, all of which can be individually tweaked
- Program can write a mystery story in the style of Harry Potter
- Correct grammar doesn't guarantee meaning:
  - "It takes two rainbows to jump from Hawaii to Route 17."

AI is Based on "Deep Learning" -- How Does It Work?

- **Deep Learning powers every application**
- **Deep learning is called "deep"**
  - **It uses multiplie layers in a neural network between the input layer (cat images) and the output layer ("this is a white cat")**
  - **"Backward propagation algorithm invented in 1986 showed how to go from a few layers to many layers ("backprop")**
  - **Algorithm sat idle for decades until exponential hardware progress allowed an exponential increase in number of layers**
- **Not human intelligence, instead narrow and limited**
  - **Backprop not based on human intelligence, but rather trial-and-error animal conditioning and training**
  - **Result: "this is a pizza" not what a pizza is for**

General Limitations of AI

- **“Flexibility in dynamic environments is a key human attribute that machine learning is finding it very hard to duplicate.”**
- **“Inability to adapt to entirely new situations is still an enormous challenge for AI**
- **AI typically perform only a limited set of tasks rather than the full range of tasks that define a typical human occupation**
- **Problem #1, never enough data (Covid contact tracing)**
- **Problem #2, bias (identifying black faces vs. white faces)**
- **Problem #3, defined options (win at “Go”) vs. ill-defined options common on customer service (cancalled flights)**

Is AI a General Purpose Technology?

- Didn't invent prediction; helps deal w/new data
  - Feed enough legal data, it can outdo human searches
- Less of a GPT than computers
  - Once you have a computer, you can do many tasks
  - But every AI application has to be custom-built with unique deta and algorithms by skilled engineers
- This makes building AI applications more costly than building computers

Limitations of AI Illustrated by Autonomous Vehicles

- Elon Musk proclaimed in 2015 that a Tesla would be “fully autonomous” by 2017
  - But in 2019 a Tesla AV crashed into a truck, killing its driver
  - In 2021 we’re still waiting for fully autonomous cars
  - AVs now limited to controlled environments
- AV based on pattern recognition; weakness is inability to deal with “edge cases”
  - An escaped horse running down the road
  - Snow covering up lane markings
  - Stickers on a stop sign interpreted as “45-MPH Zone”

Stickers on a Stop Sign Misread as “Speed Limit 45”

More on Autonomous Vehicles

- **One research team reported that**
  - "they are able to fool a Tesla Model S into switching lanes so that it drives directly into oncoming traffic. All they had to do was place three stickers on the road, forming the appearance of a line."
- **Avs don't "know", they are just following examples**
- **Harder than pattern recognition because AV must predict where each identified object will move next**

Unimportance of AI Based on Spending

- Total U.S. fixed equipment spending 2018 $2T
- For entire world must be at least $8T
- Total expenditures on AI in 2018 = $35B
- Of this, $10B was on autonomous vehicles
- About AVs
  - "The first 90% was easy, the last 10% is 10,000 times as hard"

AI and the Future of Work

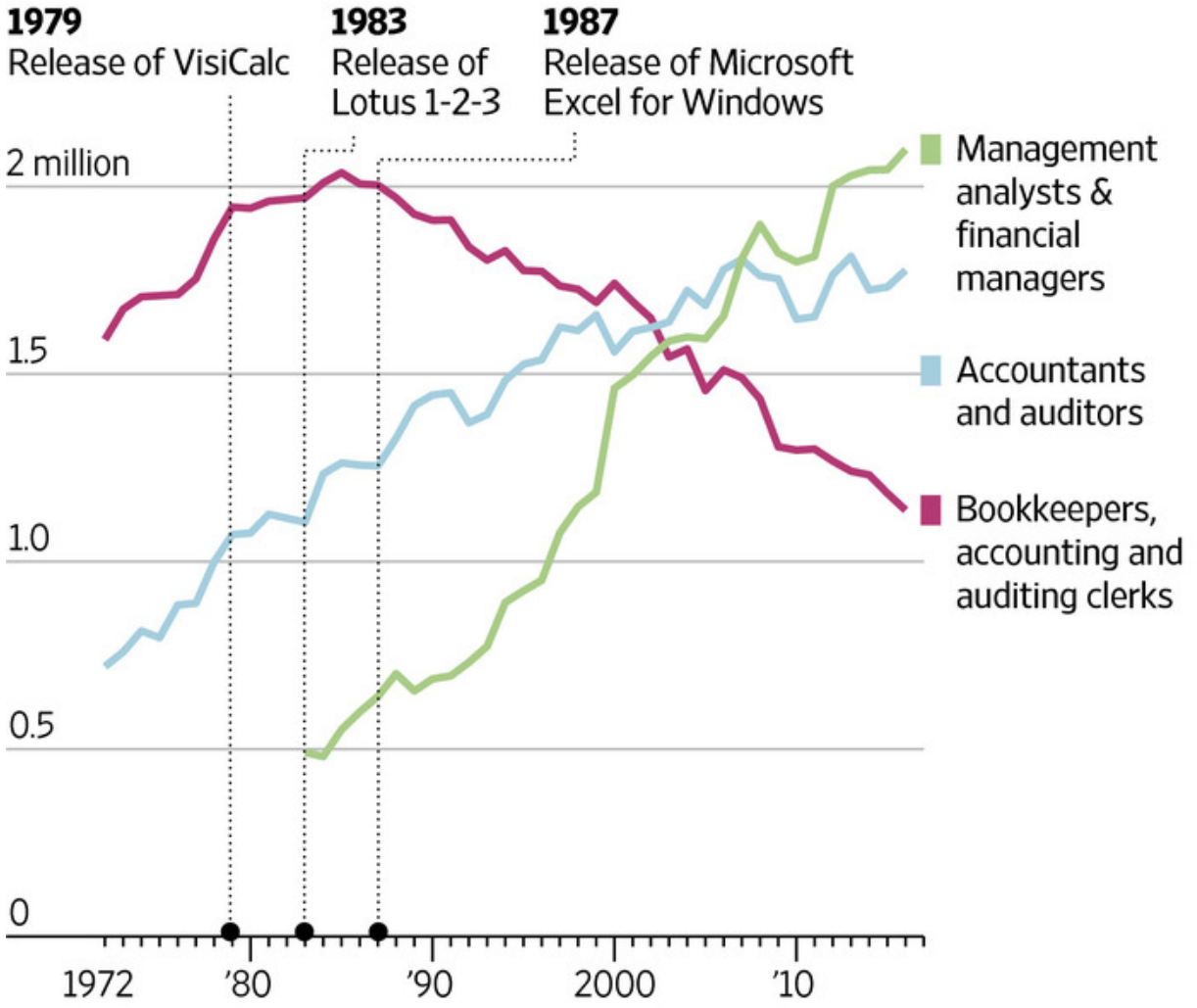
- **Machines have replaced humans for 250 years, but the U.S. unemployment rate in early 2020 was the lowest in 52 years**
- **MIT 2019 report on "Future of Work":**
  - We anticipate that, due to slowing labor force growth rates, rising ratios of retirees to workers, and increasingly restrictive immigration policies, over the next two decades industrialized countries will be grappling with more job openings than able-bodied adults to fill them."

The Problem is Not Jobs, But the Types of Jobs

- **Polarizatiion – shrinking middle skill occuptions**
  - **From 38% in 1970 to 23% in 2016**
  - **Sales, office, production workers**
  - **Due to both automation, digitization, and offshoring**
  - **AI will continue this trend**
- **44% of jobs are low-paid manual occupations require physical dexterity and face-to-face communication.**
  - **Retail sales, cooks, food-beverage servers, janitors, housekeepers, personal care and service workers**
  - **Earning average $11 per hour, source of rising inequality**
  - **Outside the capabilities of AI**
  - **Why haven't these jobs been eliminated by robots?**

The Spreadsheet Apocalypse, Revisited

Jobs in bookkeeping plummeted after the introduction of spreadsheet software, but jobs in accounting and analysis took off.



Notes: There is no data for 1982. Changes in occupational definitions in 1983, 2000 and 2011 mean that data is not strictly comparable across time. There was no category for management analysts or financial managers prior to 1983.

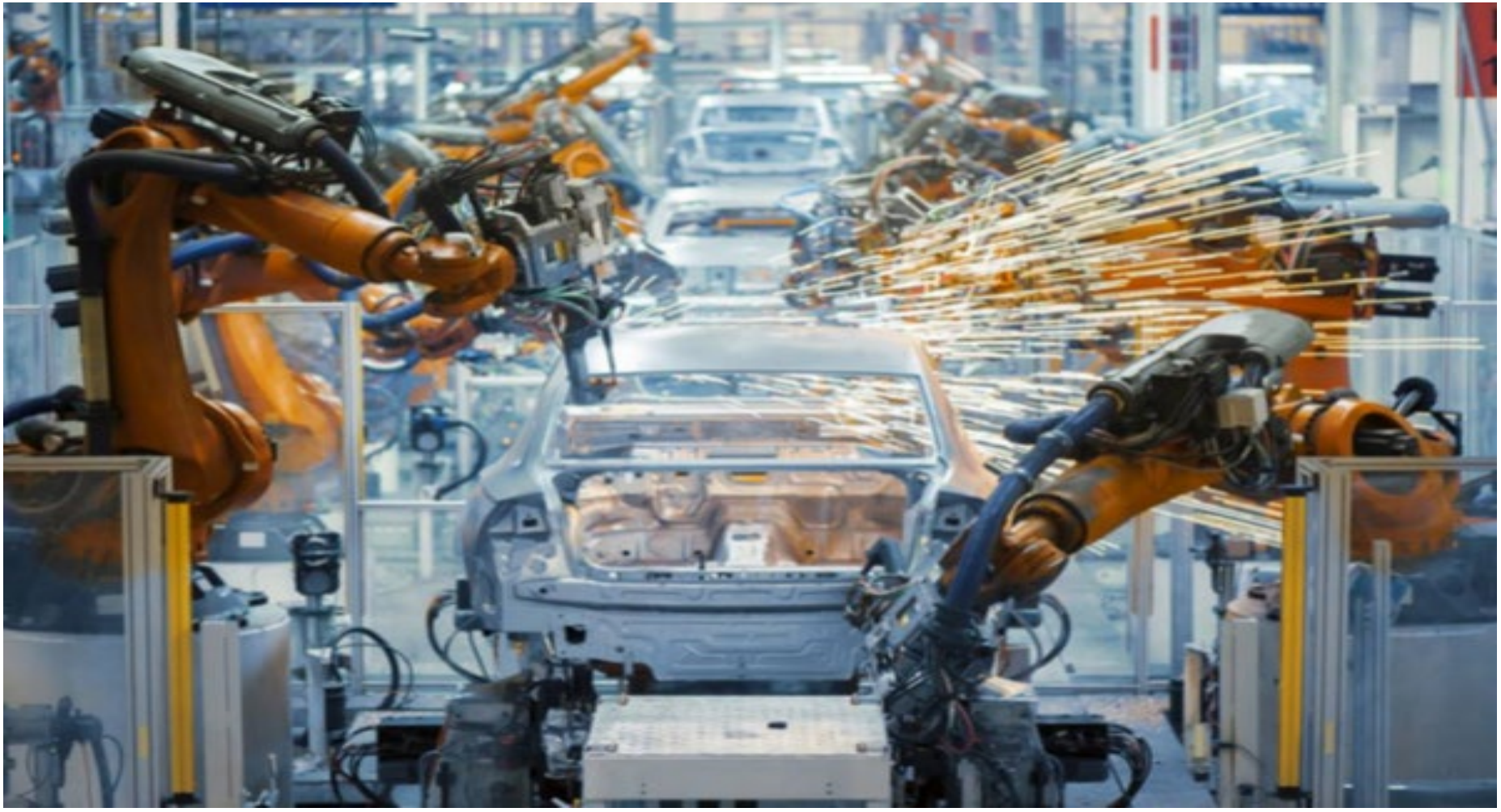
Source: Bureau of Labor Statistics

THE WALL STREET JOURNAL.

Robots as Part of the 4th Industrial Revolution

- Robots like AI are programmable and work w/out a human operator but w/ moving parts
- Robots are old news, invented in 1961
  - By 1990 robots had taken over welding and painting in auto factories
- Robot responses, unlike humans, are limited to what is in the program
- Robot responses are limited compared to humans
  - how to pick up a paper cup of water, hold with right degree of tightness
  - We don't drop the cup or squeeze out the water

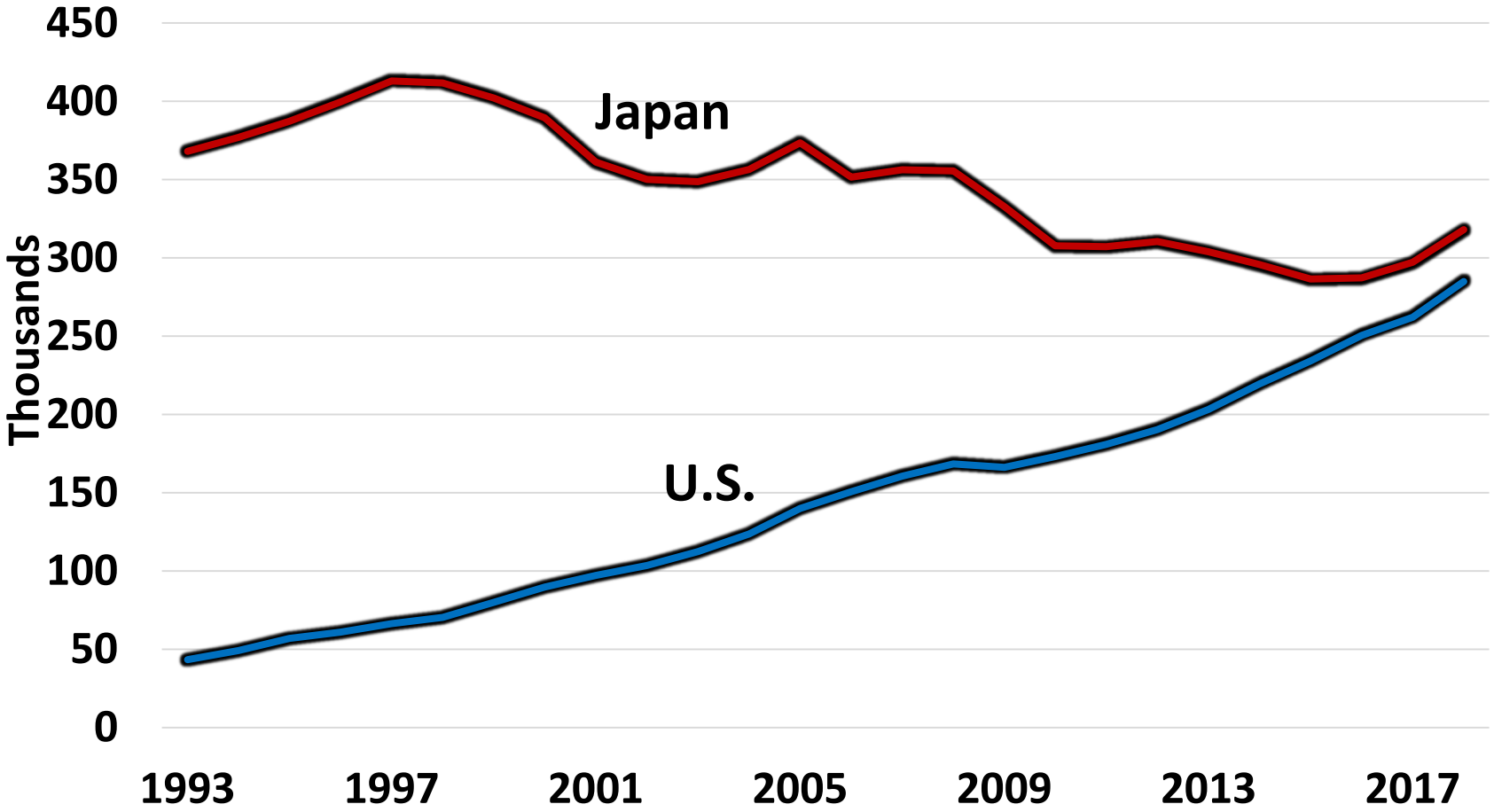
Welding Robots in An Auto Factory



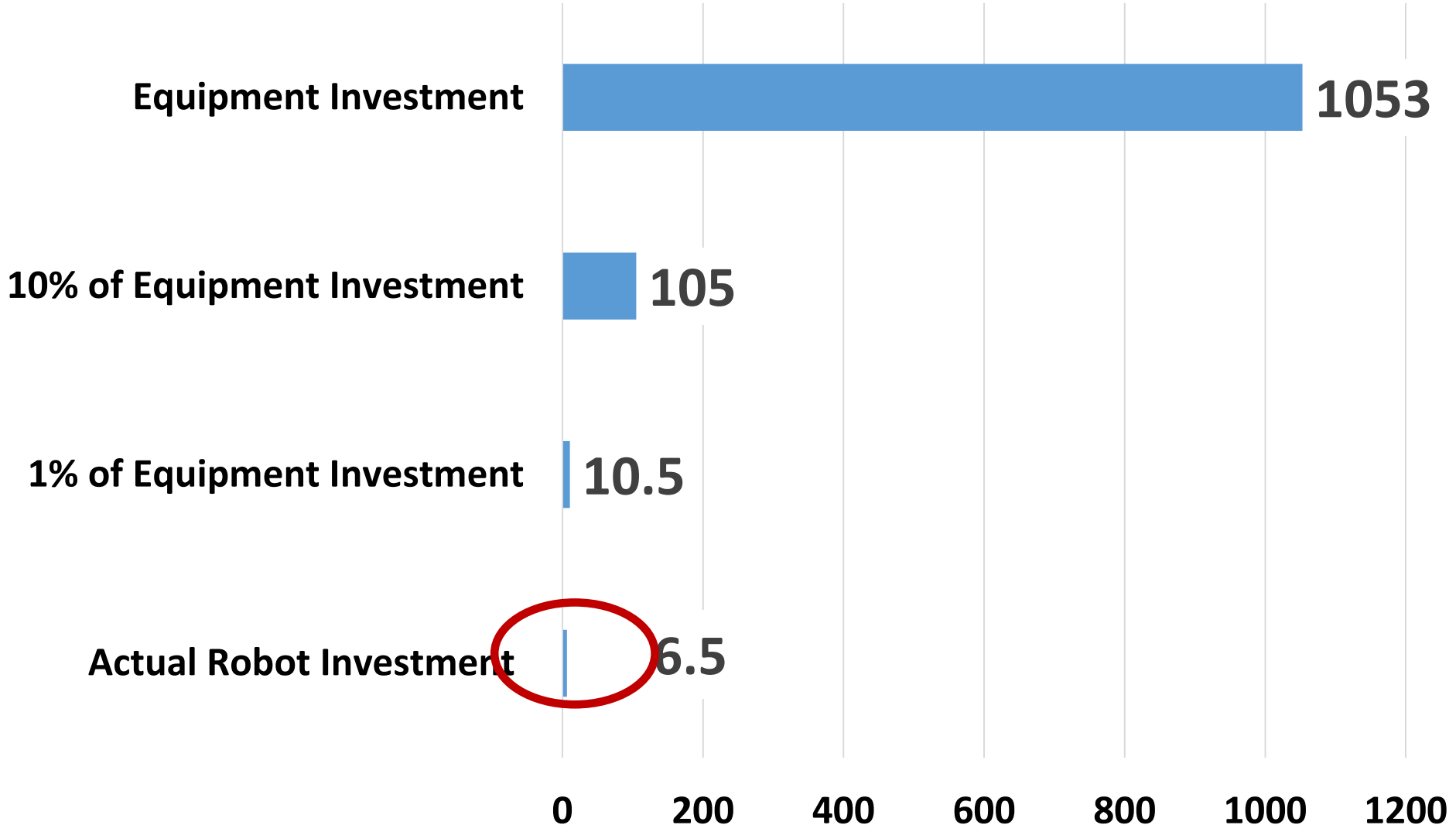
More on Limitations of Robots

- Amazon is at the technological frontier
  - But in Amazon warehouses robots only move shelves around
  - Humans still pick objects off shelves and pack them
- A Singapore team taught a robot to assemble an IKEA chair
  - Much time taken to program the robot and store images
  - Robot took 20 minutes, human took 5
- Outside of factories, robots are bad at anything that requires a human hand

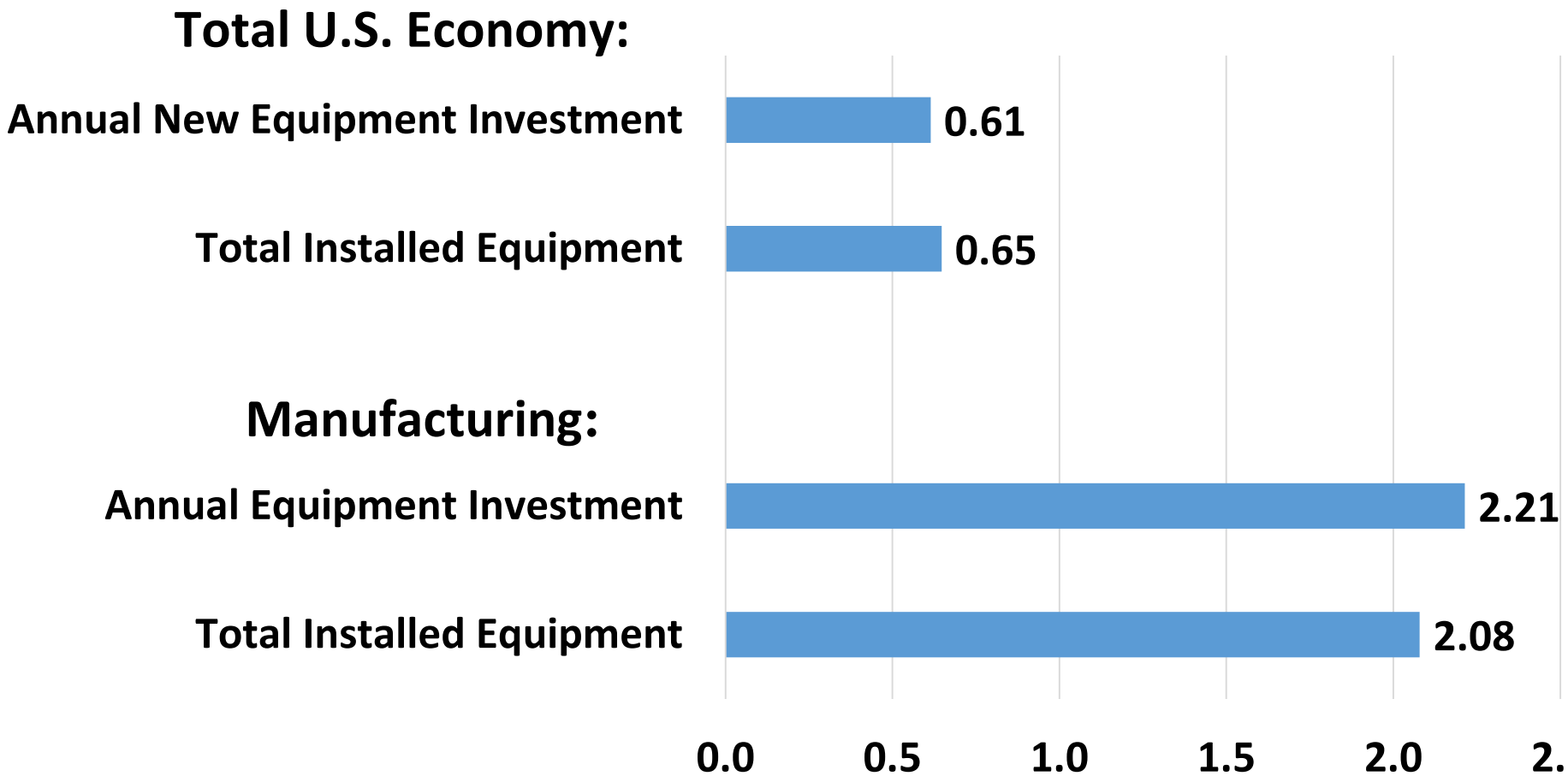
Installed Robots, Japan and U.S., 1993-2018



The Unimportance of Robots, U.S., 2018



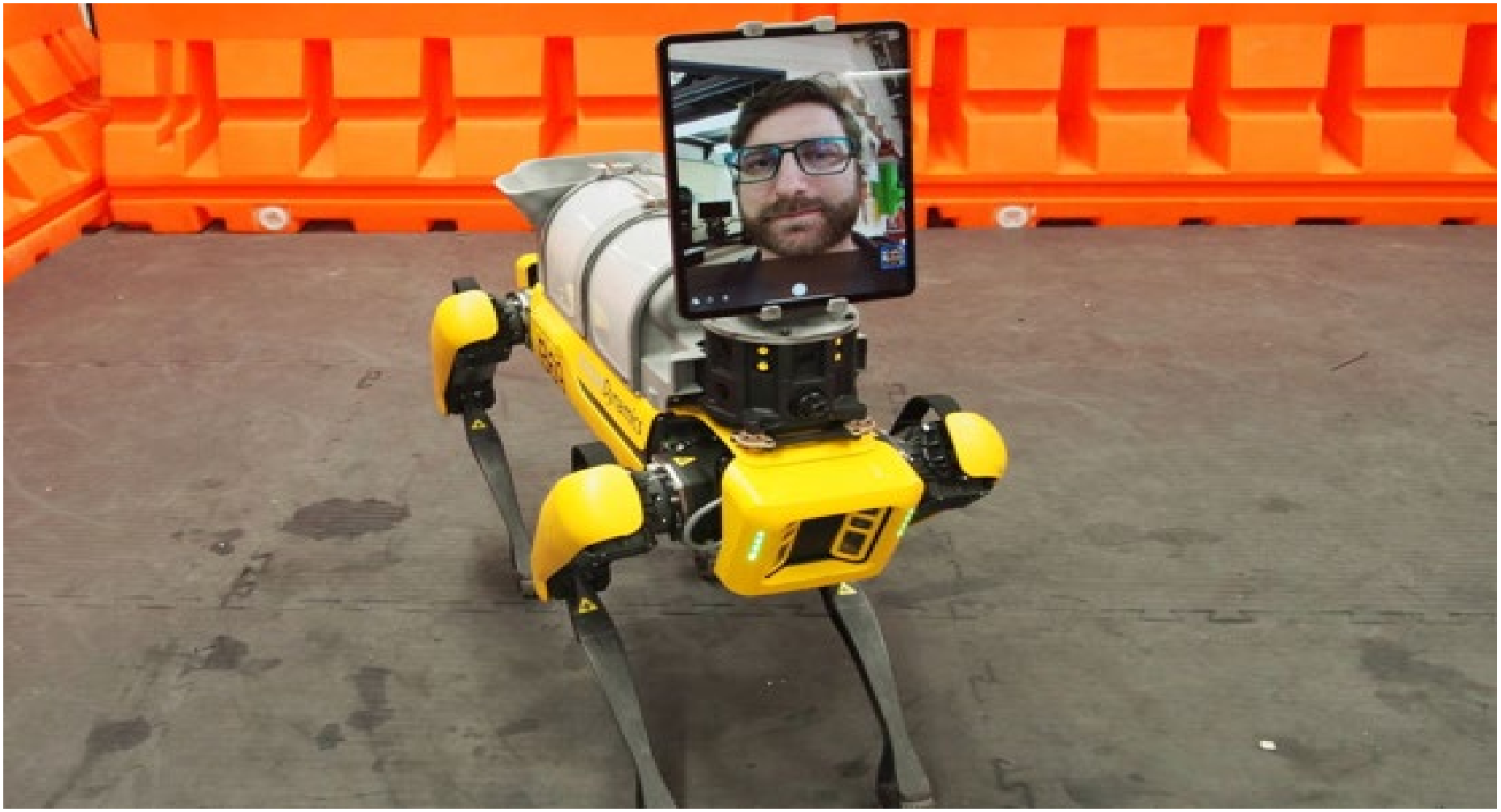
Total Economy vs. Manufacturing in U.S.



Robots and Work

- How much have robots reduced employment?
- Strange question
  - Why distinguish robots from other capital?
  - Why distinguish robots from outsourcing?
- Put in perspective
  - Total U.S. employment, 1979 to Feb 2020 +62m
  - Manufacturing employment -7m
- Acemoglu-Restrepo study, 3 workers per robot
  - 2018 300,000 robots x 3 employees = 900,000
  - 14% of lost manufacturing jobs since 1979
  - 1.5% vs. gain in total jobs since 1979

Still Waiting:
Robots in the Service Sector



Conclusions

- **Limitations of AI as Important as Its Benefits**
- **MIT Tech Review wrote:**
  - With the pace of hardware improvement faltering and deep learning applications maturing, the future of AI is clouded by uncertainty. MIT Tech Review (2017) speculates “maybe we’re not actually at the beginning of a revolution, … (but) at the end of one.”
- **AI will cost mid-level jobs while creating high-skill jobs, exacerbating inequality**
- **AVs illustrate limitations of AI**
- **The main lesson about robots: how unimportant they are, esp. outside of manufacturing**