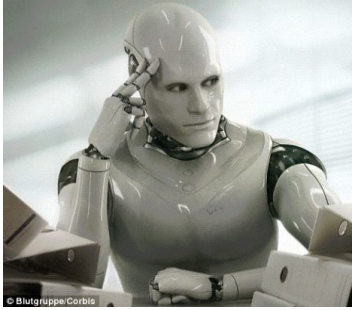# Labor in the Era of Robots and Algorithms

Alpha20? I hear it's smarter than me, works 24 hours a day and is connected to the Cloud and Quantum Computer Supremecy v7. It controls armies of robots tiny as molecules and bigger than dinosaurs. And it never cries or makes dirty diapers. What am I going to do?
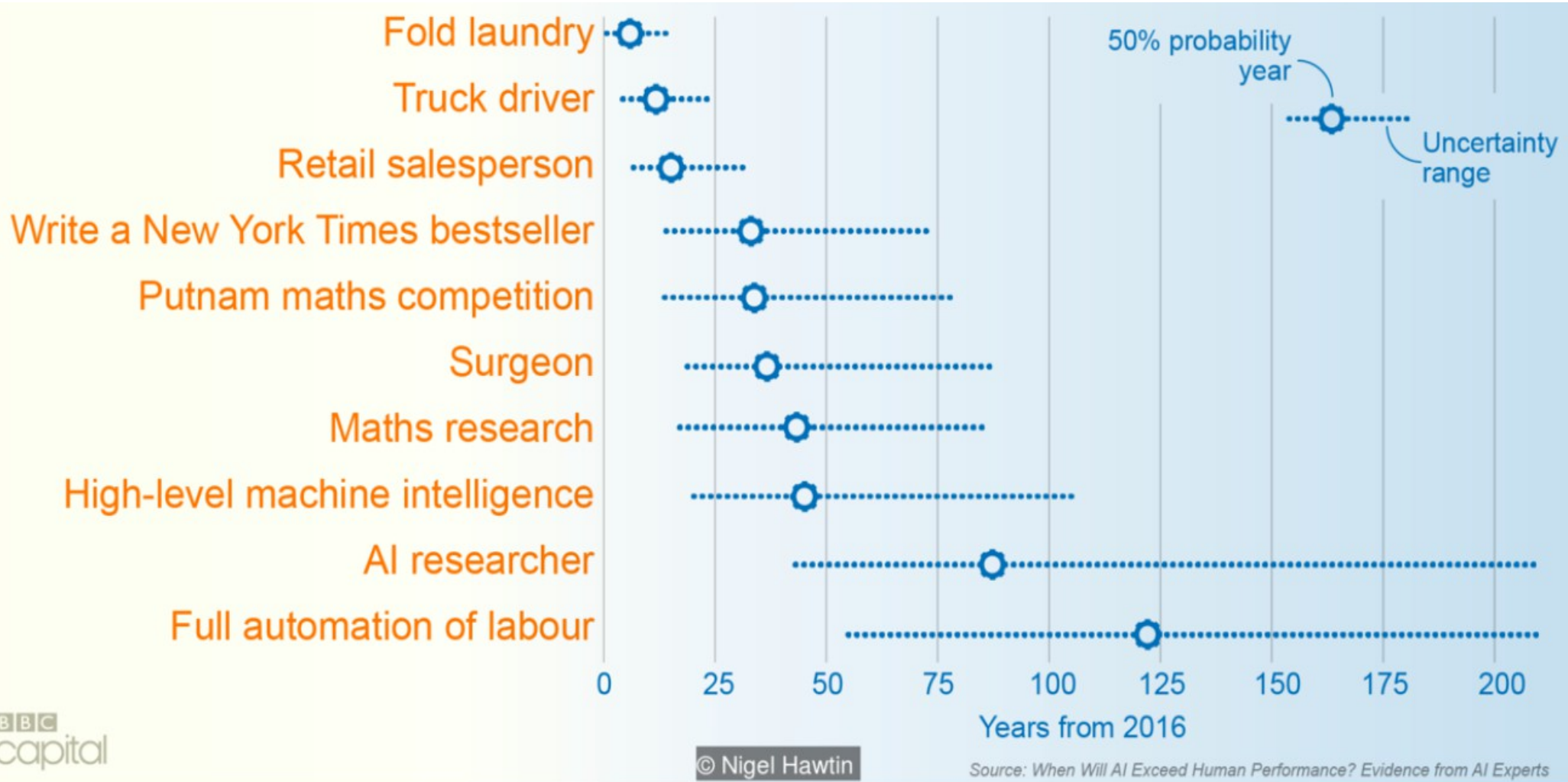

Richard B. Freeman, Harvard and NBER
Morley Gunderson Lecture in Labour Economics and Labour Relations, Toronto, Dec 2, 2019 430-630

When will **AI** outperform **humans** at work?

How many years until a machine can do our jobs better than us?

Survey of 352 AI Experts Who Published at 2015 NIPS, ICML
Conferences (Journal of Artificial Intelligence Research, forthcoming)

Automation Scare Redux: Is this Time different?

1) Past fears that automation destroys jobs fizzled. FDR blamed Great Depression unemp on failure to "employ the surplus of our labor which the efficiency of our industrial processes has created". Early 1960s fears --> US Commission on Automation, followed by rise in E/Pop.

2) Past automation produced rapid increase in productivity and job loss but today productivity growth is modest with low unemployment.

3) Expansionary macro-policies can in any case save the day. Cost-saving technologies that reduce inflation widen scope for expansion policies that build infrastructure, lower taxes.

4) Workforce shifted to better jobs in past technological revolutions – from agric to mfg to retail and service sector and white collar work.

What, if anything, is different about today's technologies to make this time different?

Claim and Counterclaim

Claim : This time is different because in addition to traditional robot/automation that shifts physical or repetitive work to machines, AI TC will shift comparative advantage in high skill creative tasks to machines.

Counterclaim: Despite hullaballoo, labor productivity, economic growth and productivity of investment in science show stagnation in technological change rather than revolutionary advances.

It is too early in "AI robolution" to resolve debate. Magnitude of robolution is too small relative to other economic shocks to show up in aggregate data. We are in period before potential tech storm and societal upheaval, just as fifty years ago it was too early to be sure climate change was real and due to our activities.

Economics says long run impact of technological change will be on wages rather than on job loss.

Consider two types of technological change

1-- *Product* Innovation creates new/improved product that reduces cost/per unit value, shifting sales to new product from older products, with uncertain impact on employment, depending on demand, production, income elasticities.

2- *Process* Innovation reduces cost and prices of existing product (say by displacing labor) with uncertain job effects, as increased purchased can dominate substitution effects.

Creation of new jobs from technological change and/or by macro-policies to expand investment/stimulate demand can overcome any technologically-induced joblessness.

Herb Simon long run "reverse Malthus" theorem: Workers benefit from any TC as long as supply of capital is elastic relative to supply of labor. But analysis does not distinguish owners from workers.

Key effect on wages/incomes via comparative advantage

Employers will hire workers for tasks which humans perform at lower costs than machines and will hire robots/machines/software for tasks they perform at lower costs than humans.

Past technologies have given machines comparative advantage in repetitious physical work, as John Henry learned in 1870s

John Henry told his captain,
"A man ain't nothin' but a man,
But before I let your steam drill beat me down,
I'd die with a hammer in my hand. Lord, Lord.
I'd die with a hammer in my hand."

Software (with little AI) has gained comparative advantage in routine brain work. **Can AI give it advantage in creative work?**

Human Comparative Advantage in Brainpower or in "everyday tasks"?

Eleni Vasilaki, professor of computational neuroscience at Sheffield University, said it was an impressive feat. "This may very well imply that by not involving a human expert in its training, AlphaGo discovers better moves that surpass human intelligence on this specific game," she said But she pointed out that, while computers are beating humans at games that involve complex calculations and precision, they are far from even matching humans at other tasks. "AI fails in tasks that are surprisingly easy for humans," she said. "Just look at the performance of a humanoid robot in everyday tasks such as walking, running and kicking a ball."

The issue is whether human comparative advantage is in high or low value added/pay tasks. As long as complex calculations, creative thinking, and precision earn more than "everyday tasks such as walking, running and kicking a ball" and the cost of the robots/AI programs that do cognitive work keeps falling, **comparative advantage for neural activity** will shift to the robots/AI and income will flow to their owners.

The Comparative Advantage Frontier Is Shifting Rapidly

1997 Deep Blue beat Chess champion Kasparov
2011 Watson defeated human Jeopardy champions
2016 Google's Alpha Go defeated Korean Go master Lee Sedol

2016 Carnegie Mellon's Libratus beat top poker pros
2016 University of Alberta's Deep Stack wins No Limit
Texas Hold'em Poker Tournament

2017 AlphaZero learns Chess and beats chess programs in weekend;
Also triumphs over Go, Chess, Shogi, …
2018 Google's DeepMind generated AI agents to play
Quake III Arena's on-line game Capture the Flag.
2019 Facebook and CM's Pluribas trains for 8 days and beats
 five human poker experts
2019 DeepMind's Starcraft II AI beats 99.8% of uhman players

Key – **reinforcement learning (faster than Darwinian survival of fittest) as** machines play huge # of games against themselves
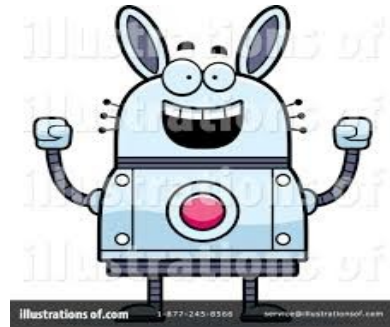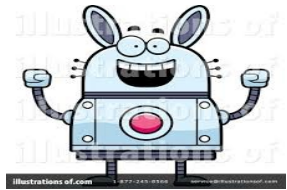
Robot debates humans about the dangers of artificial intelligence

"An artical intelligence has debated with humans about the the dangers of AI – narrowly convincing audience members that AI will do more good than harm. Project Debater, a robot developed by IBM, debated on both sides of the argument, with two human team mates for each side helping it out"
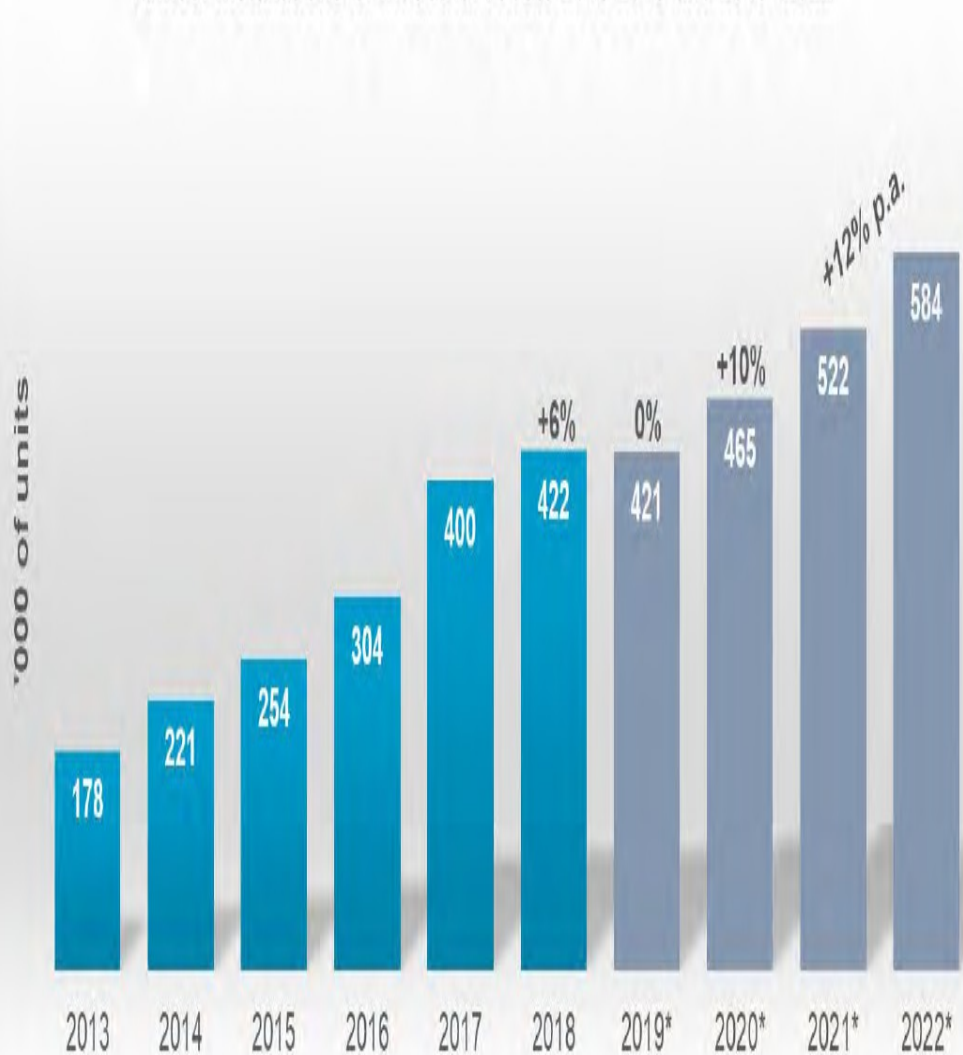
University of Cambridge Union November 24, 2019
NEW SCIENTIST

I can do anything better than you
Yes I can, Yes I can, YES I CAN
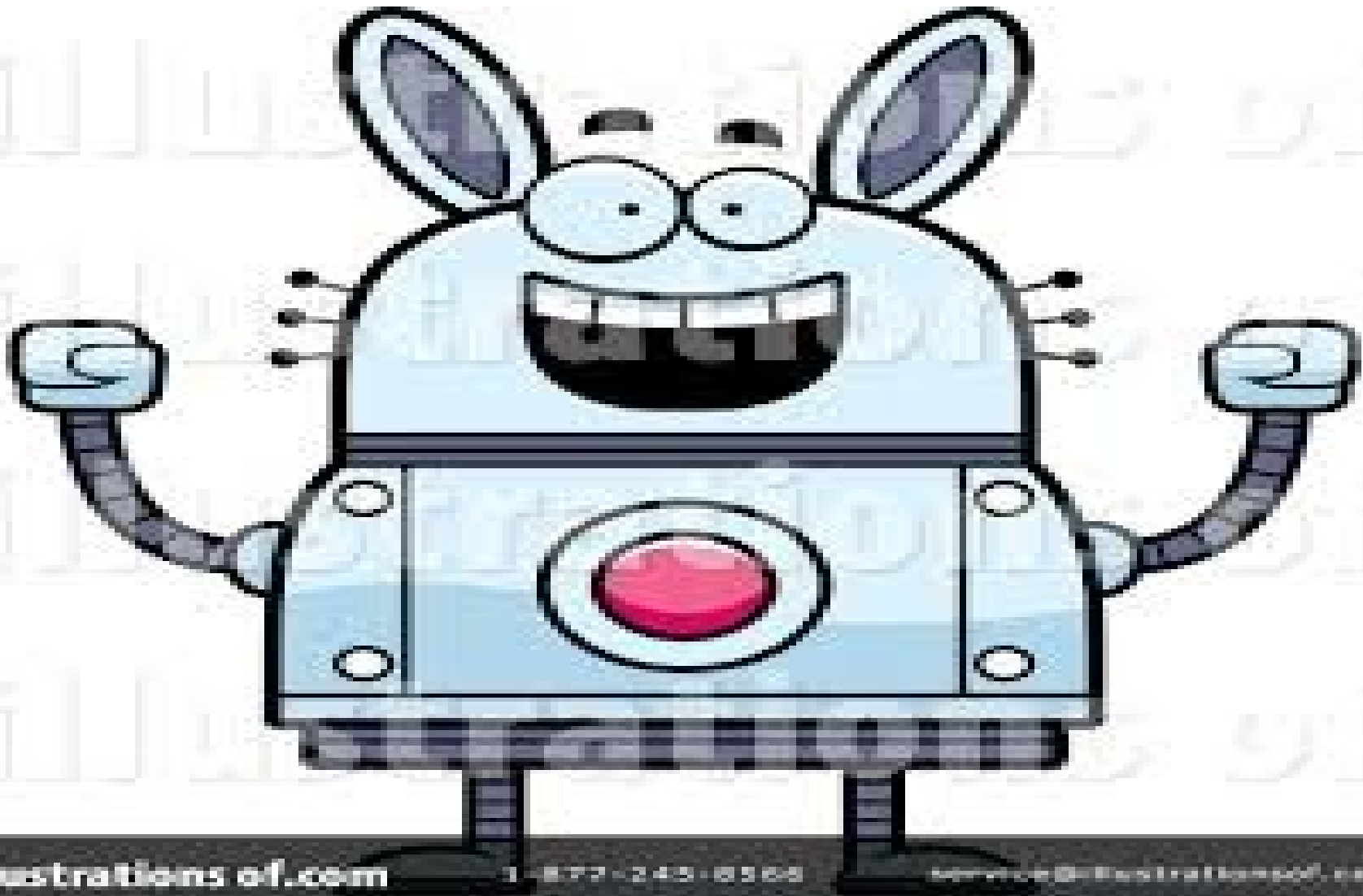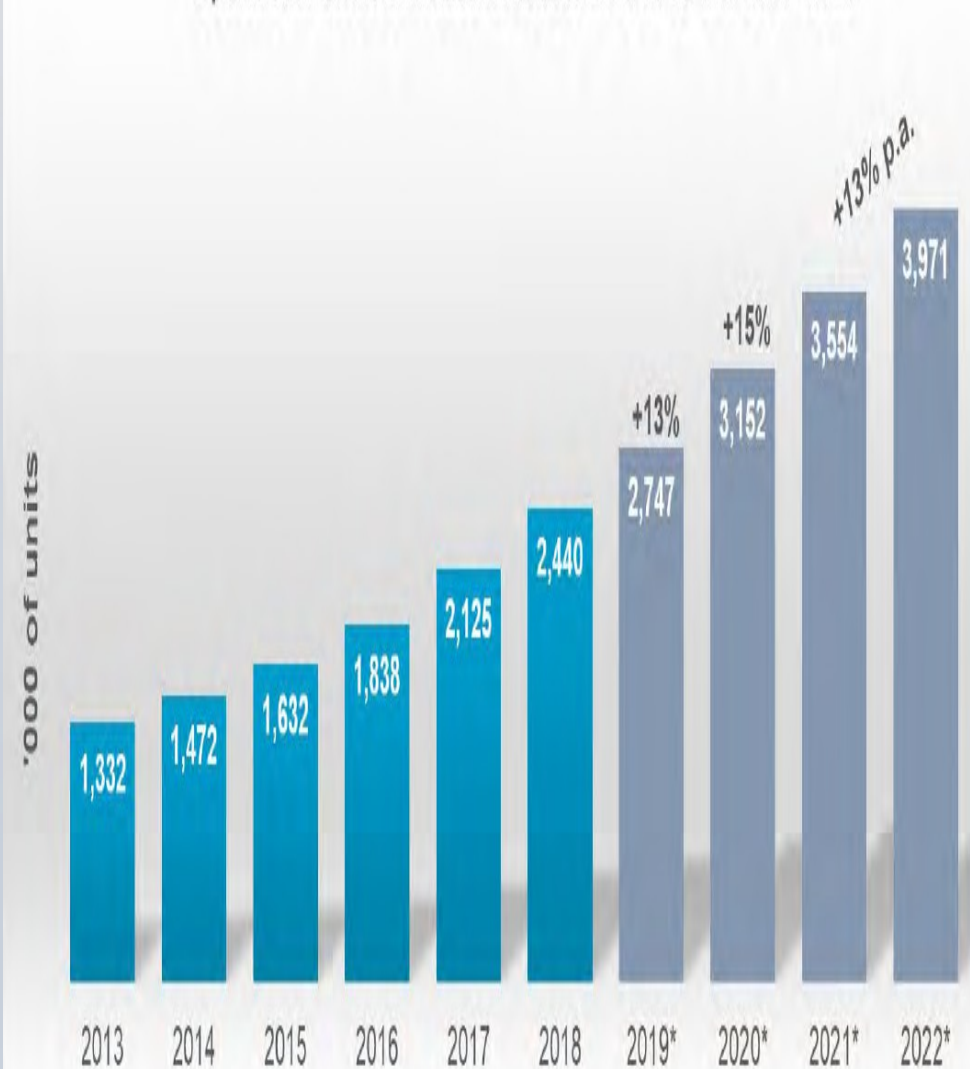
Robot Investment and Stock Increasing Rapidly

Annual installations of industrial robots 2013-2018 and 2019*-2022*

'000 of units

2013	2014	2015	2016	2017	2018	2019*	2020*	2021*	2022*
178	221	254	304	400	422	421	465	522	584

+6%   0%   +10%   +12% p.a.

*forecast

Source: World Robotics 2019

Operational stock of industrial robots 2013-2018 and 2019*-2022*

'000 of units

2013	2014	2015	2016	2017	2018	2019*	2020*	2021*	2022*
1,332	1,472	1,632	1,838	2,125	2,440	2,747	3,152	3,554	3,971

+13%   +15%   +13% p.a.

*forecast

Source: World Robotics 2019

Investment in Software Shifts White Collar Work from "Real World" to Digital World
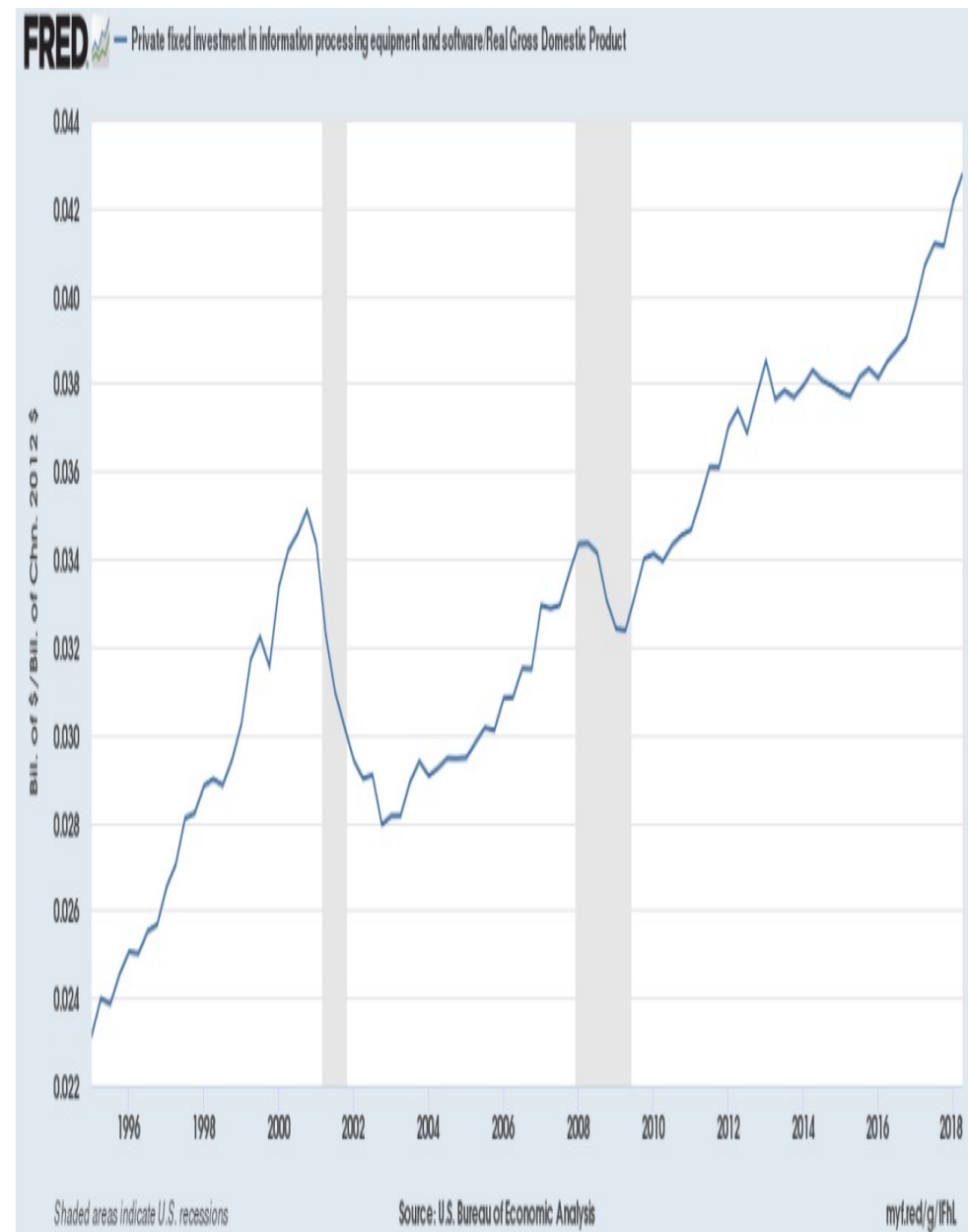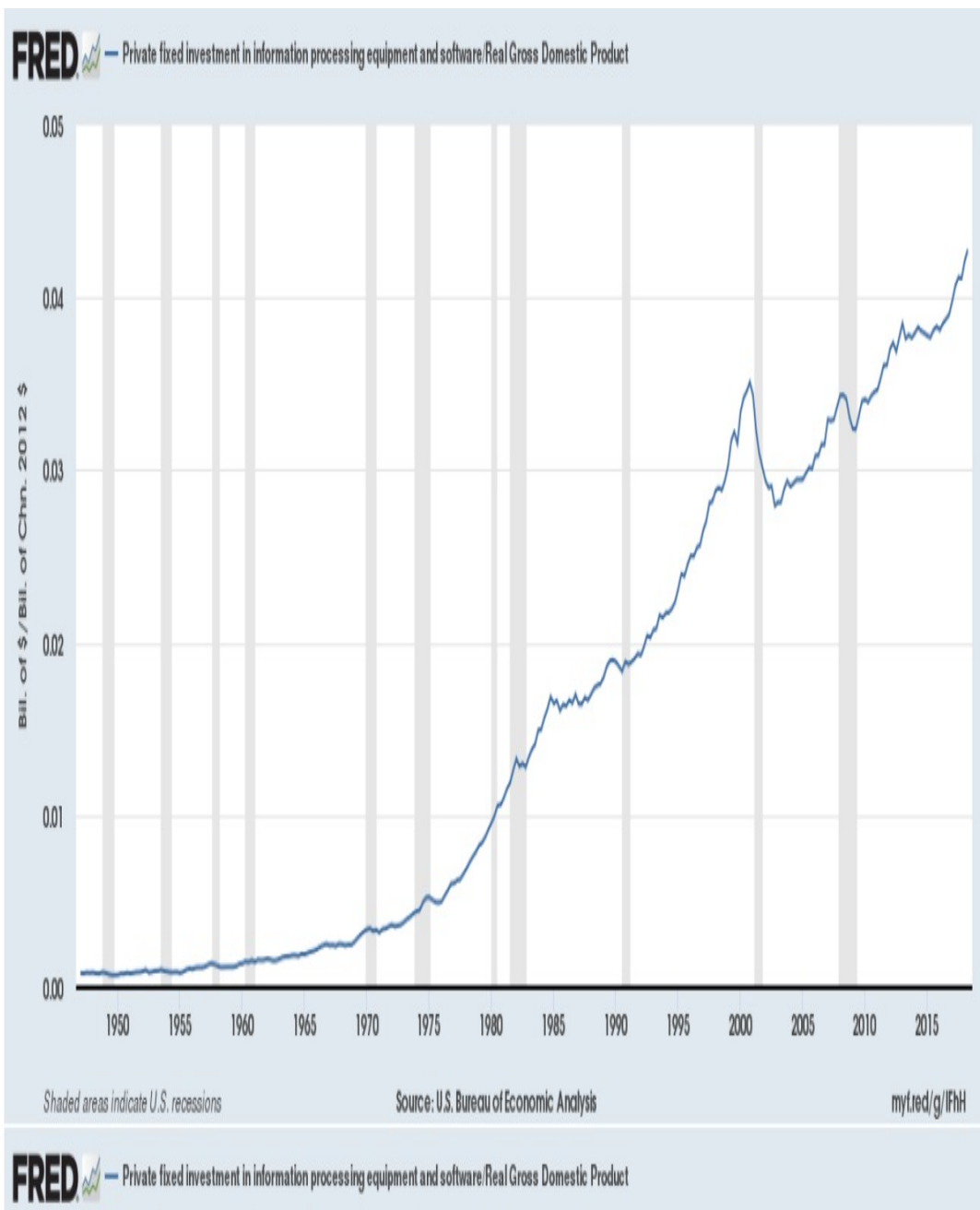
Industries, by Software Spending Per Worker, 2013

ICTS_Code	Industry	PerCapitaSoftwareExpenditure	Employment
52	Finance and insurance	2891.6014	7747956
22	Utilities	886.0610	1738029
54	Professional, scientific, and technical services	727.0209	13028511
51	Information	717.0795	13415529
42	Wholesale trade	628.0546	3768780
31, 322-326	Nondurable goods industries	602.4467	6520079
21	Mining	588.1049	1994542
31-33	Manufacturing	573.9490	18186284
321, 327, 33	Durable goods industries	572.9310	11362624
44-45	Retail trade	266.5946	19730334
56	Administrative and support and waste management	171.2747	11653792
71	Arts, entertainment, and recreation	156.3555	3402502
48-49	Transportation and warehousing	152.6748	10872785
62	Health care and social assistance	148.6542	37974044
81	Other services (except public administration)	101.1071	9771814
53	Real estate and rental and leasing	91.3794	7693199
23	Construction	59.5969	10218660
72	Accommodation and food services	51.8930	20542251
113-115	Forestry, fishing, and agricultural services	30.4991	1344302

Per capita software spending by Industry (using ICTS Industries which are really just groupings of NAICS industries). Data obtained from: https://www.census.gov/programs-surveys/icts/data/tables.html

Three Laws of Robo-Economics
(Asimov reprise)

1. *Robots and Humans become better substitutes.* Advances in artificial intelligence; improved computerization; engineering biomicry; human enhancement implants → machine and humans better able to do what the other does: **higher elasticity of substitution and cyborgs**

2. *Technological change reduces costs of robot substitutes for humans over time, bounding wages:* **W < Production cost of robot substitute.**

3 *The effect on incomes depends on who owns the robots.* If you own robot that does your job it is a tool that improves your work & income. But if I own robot that does your job, tough luck suckah! **Who owns the robots rules the world!**

Law 1: What Drives Substitution?

Technological possibilities and cost of TC? Yes. But TC is driven by R&D, which reflects firm decisions. What directs firms to seek software/robot substitutes in come occs rather than others? Could they develop robot AI boss that many workers claim they would prefer to human? Could a US-made robot defeat the likely candidates in Presidential election – if not in 2020 in the future?

Society can incentivize firms to work on problems with benefits they cannot capture in market and can enact regulations that make it costly to go down some developmental paths.

Implication of increased substitutability of robots for labor: Traditional view counts robot as part of physical capital K so robots raise K/L → wage up. But if robot is better substitute for worker than machine, it lowers capital/labor → wages down. Robot substitutes at going cost of capital replaces Malthus' infinite supply of labor at subsistence wage → human misery.

# 1': Beyond Substitution: Human or AlgorithmBoss/Expert?

Google "robot boss" and you will find dodgy surveys reporting that many people prefer robot bosses to human bosses.

- Oracle and Future Workplace: 64% of workers worldwide would trust a robot more than human manager. In China and India, figure rises to almost 90%. Workers believe robot managers are better at certain tasks – such as maintaining work schedules and providing unbiased information.

- If your firm offered to replace your manager with a robot boss, would you do it? 20% of survey respondents answered yes. If the "robot boss looked and acted friendly like the C3PO robot from Star Wars," 30% said yes.

- A British survey reports that nearly a third of British workers (31 per cent) would be happy to work for a robot boss.

But generalizing from data sets from biased society raises issues of "algorithmic bias" and fairness in AI.

Who would you trust more to for advice in decision … Professor or Google? Politician or Supercomputer?

2018 Logg, Minson, Moore HBS "Algorithmic Appreciation" study says "People prefer algorithmic to human judgment"
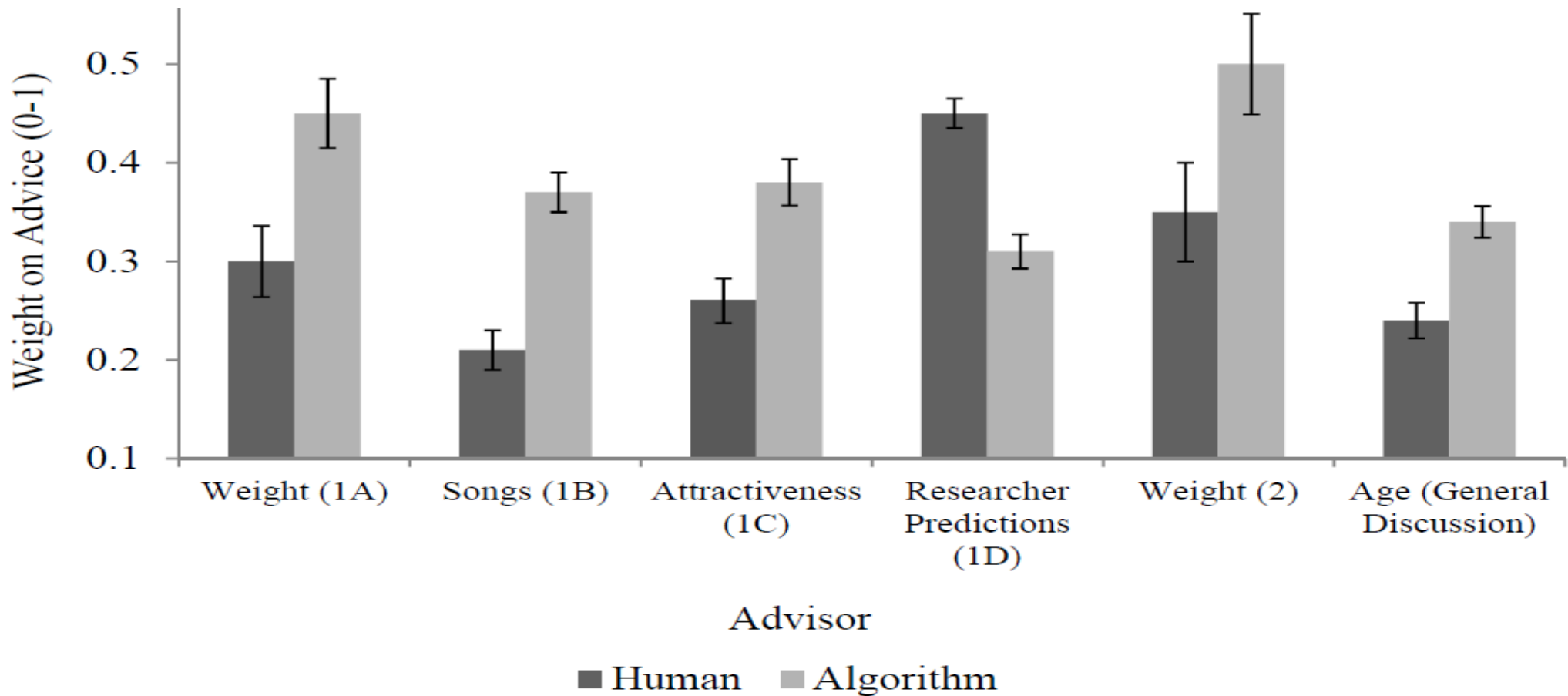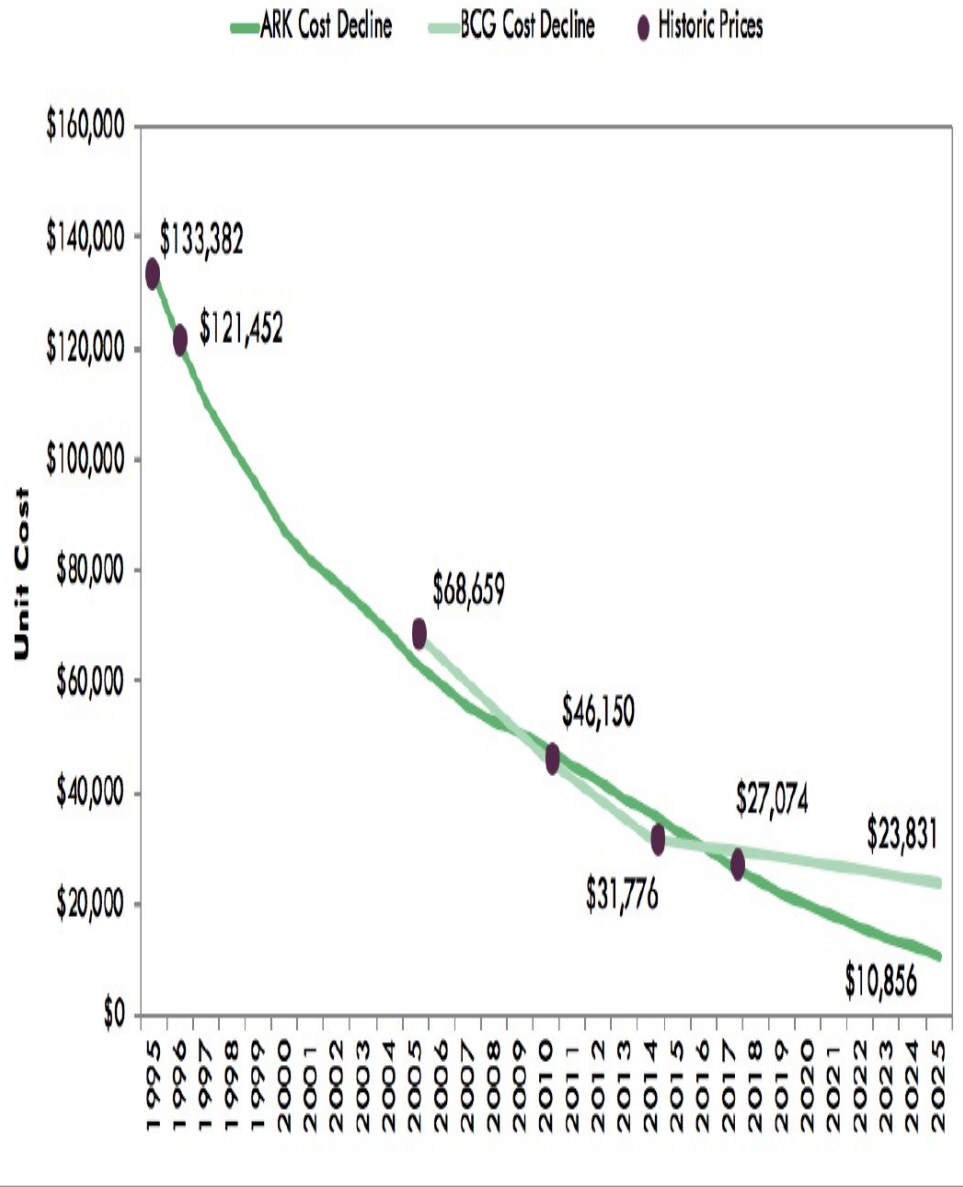

Weight on Advice measures how much participants revised their estimate toward the advice given by human or algorithm.
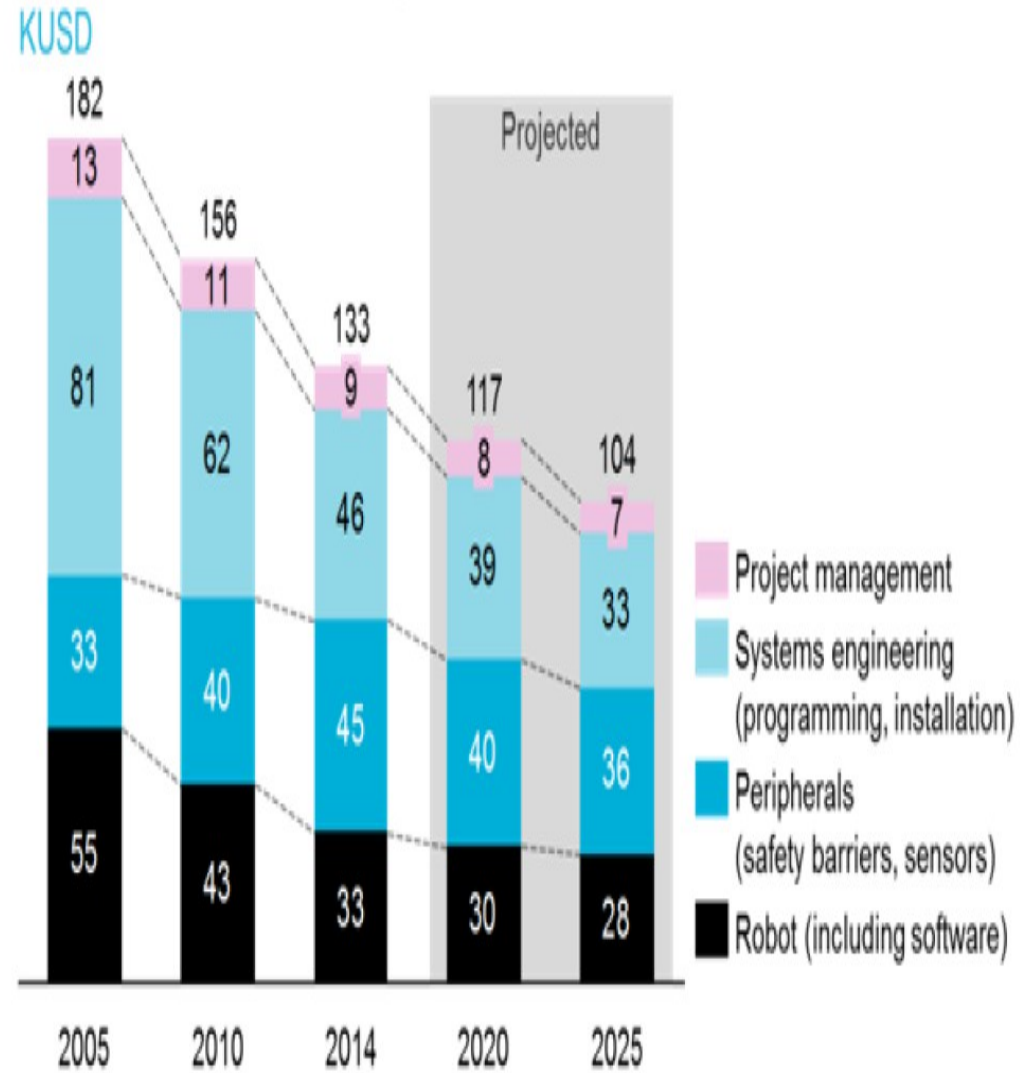
They know I am better so they believe me more

Law 2: The Falling Cost of Robots

ARK Cost Decline   BCG Cost Decline   ● Historic Prices

Historic prices (Unit Cost):
- $133,382
- $121,452
- $68,659
- $46,150
- $31,776
- $27,074
- $23,831
- $10,856

Source: ARK Investment Management LLC, 2019 | ark-invest.com; Data from: United Nations Economic Commission for Europe; International Federation of Robotics; Sirkin, Hal, et al. "How Robots Will Redefine Competitiveness." BCG, 23 Sept. 2015, https://arkinv.st/2VLoOJt.

Total system costs of a typical spot-welding robot in the U.S. automotive industry
KUSD

	2005	2010	2014	2020	2025
Total	182	156	133	117	104
Project management	13	11	9	8	7
Systems engineering (programming, installation)	81	62	46	39	33
Peripherals (safety barriers, sensors)	33	40	45	40	36
Robot (including software)	55	43	33	30	28

(2020 and 2025: Projected)

(http://www.lgcnsblog.com/wp-content/uploads/2016/07/1-1.png)

Law 3: Earning the Money for the Owners of the Technology "Who Owns the Robots Rules the World"

"We do the work and make the money"

"We own the robots that do the work and make the money"

the upper 1%   er-- the 0.1%   er – the 0.001%

Robots Reduce Wages and Employment in US

1. **Industrial robots concentrated in mfg autos**; Borjas-Freeman (2019) estimates across industries and time that robots reduce employment and wages more than immigrants, suggesting robot is equivalent to 2-3 workers, with bigger effect on less educated and in automatable occupations. Acemoglu and Restropo (2017) show drop in wages and employment in local areas subject to biggest robot shocks based on composition of employment

2. **But robot shock is small relative to Immigrant shock**

   30,000 industrial robots purchased in 2017 compared to 900,000 new immigrant employees; 28 million immigrant workers (17% of US workforce) vs 350,000 stock of robots.

3. **Missing is evidence on non-industrial robots**. Wide variation in reports of non-industrial robots, dependng on definitions, but large increases. Smallest estimates for ISO definition of robots. Larger estimates includes other machines (ATM, digital tools, etc)

Changes on within occupation activities dominates shift away from routine automatable occupations in what workers do, eight attributes, ~2005 to ~2015
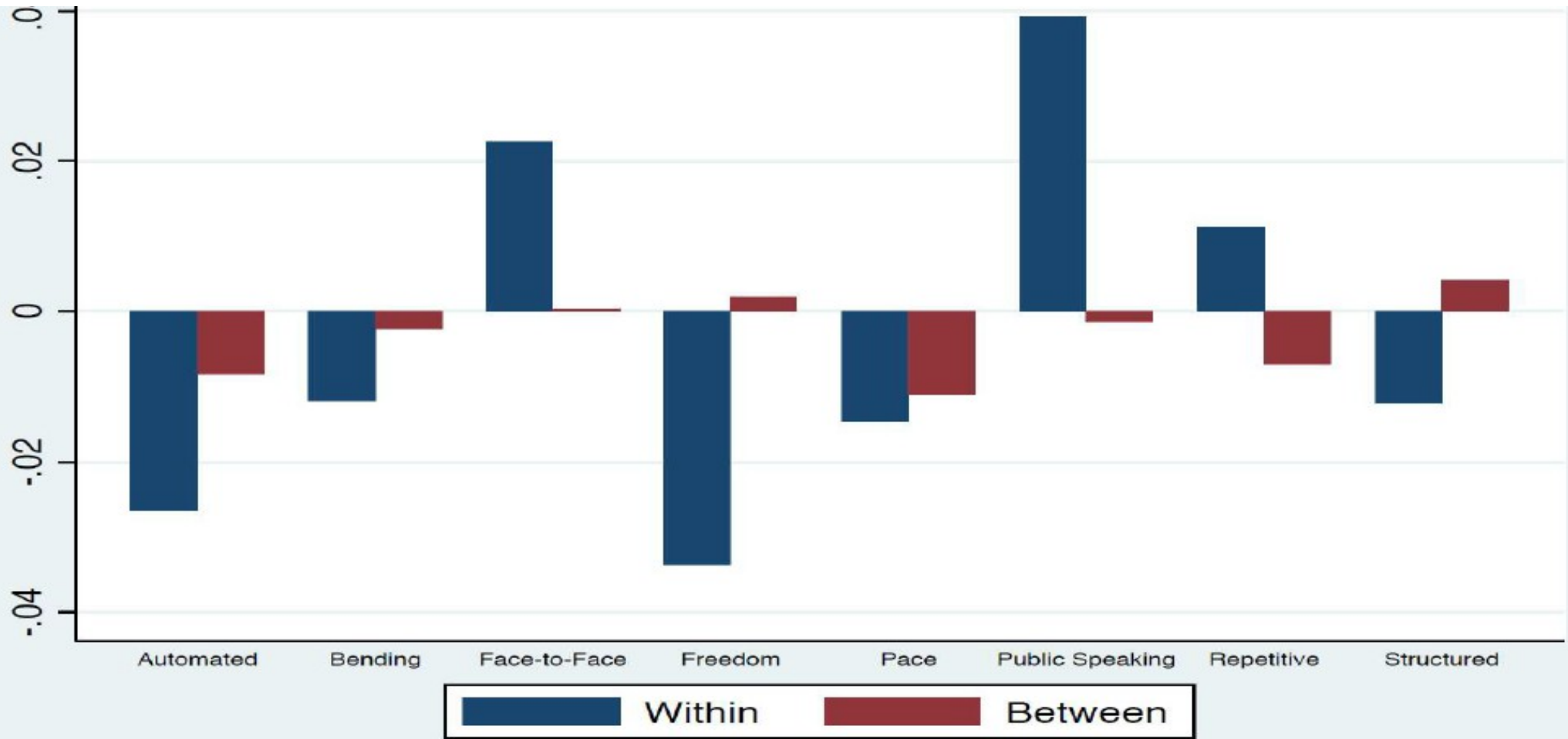
The eight attributes: Degree of Automation, Spend Time Bending or Twisting the Body, Face-to-Face Discussions, Freedom to Make Decisions without Supervision. Pace Determined by Speed of Equipment, Public Speaking, Spend Time Making Repetitive Motions, Structured--Freedom to to determine the tasks, priorities, or goals.

Conclusion: Policy Solutions

Stipulate that AI robotics/software productivity will keep improving relative to human productivity, raising the share of income going to the machines and their owners. Then to assure that most people benefit from the new technologies, socieiy must distribute income from technological progress more widely.

Three possible ways to do this:

1) Tax and redistribute income, through greater public services or possibly UBI

2) Rebuild strong trade union and collective bargaining to give workers greater ability to raise pay and benefits.

3) Expand ownership of capital so all citizens have capital income via *employee ownership* (ESOP; share purchase plan;etc) or *profit/gain-sharing;* and *Sovereign Fund ownership* of capital with some current dividend (per Alaska Provident Fund).