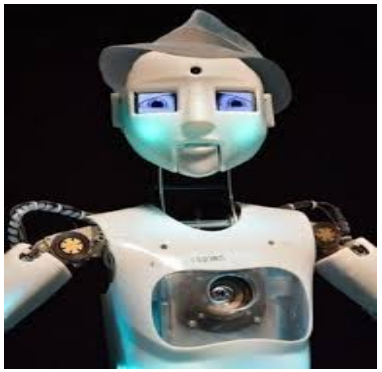
Effects of Artificial Intelligence and Robotics on the Future of Employment"

1. Robots and AI Technology Everywhere
2. Debate Over Employment: Automation Fears Redux or Who Owns Robots Rules the World?
3. Comparative Advantage and Three Laws of Robo-economics
4.Choices: Owning AI Robot Tech, Human Enhancement, or New Feudalism









Richard B. Freeman, Harvard and NBER
Academia Brasileira de Ciencias
Oct 30, 2017

Robot: "Automatic device that performs traditional human functions"

Sensing	Robots employ sensing technology to acquire information about their environm
Intelligence	Robots process information captured through sensor technology and produce outputs for decision making, coordination, and control.
Motion	Robots automatically follow instructions that are pre-programmed or generated in real-time based on sensor input to perform a deliberate, controlled, and often repeated, mechatronic action, including point-to-point mobility.

AI: "capacity of a computer to perform operations analogous to human learning and decision making … visual perception, speech recognition, decision-making, and language translation, and can beat humans at Chess, Go, Poker, Learning Anything"

Why is robot different from any other machine/instrument – physical capital?

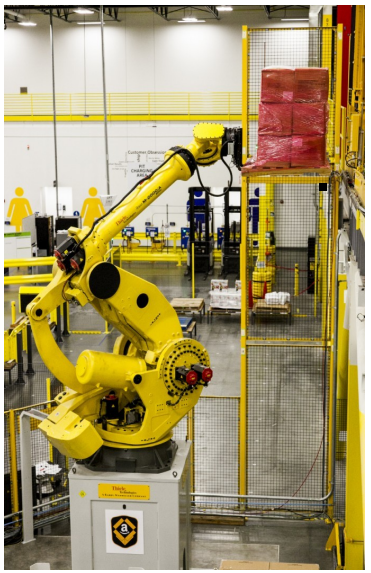
- Robot is substitute for human skills that involve brain power and decision-making, not just muscles or other physical activities.
- Machine/instrument works at human discretion. Robot/AI makes decisions on its own.
- Federation of Robotics provides data on *industrial robot* defined as an "automatically controlled, re-programmable multipurpose manipulator programmable in three or more axes" (ISO) and *service robot* defined as one that performs useful tasks for humans or equipment excluding industrial automation applications"
- Government Census/Statistics gather data on investment in plant & equipment – capital in usual establishment survey. Information, Technology, & Communication survey provides data on spending, including software, at the firm level.

1. Robots – Everywhere!

Robot noodle chef



Amazon Kiva robot



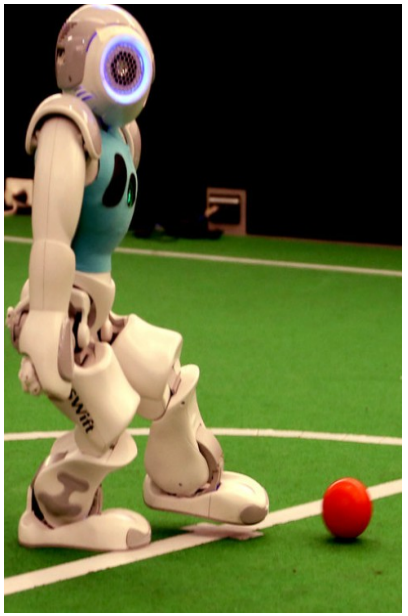
Robot bar-tender,



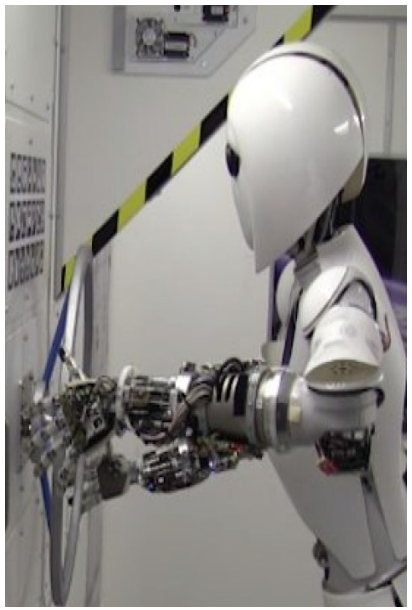
Do's pizzaf-delivery-Au



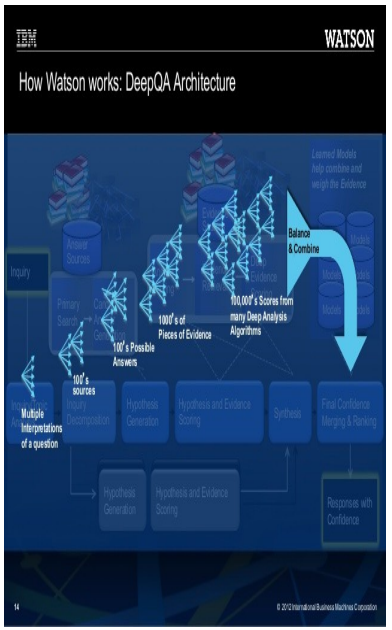
Soccer robot



Space Robot,



IBM Watson



Delivery dog- Boston



Humanoid robot-



Sex robot-Japan



Robot Intensity in Mfg High in Advanced Countries: Number of Multi-purpose Industrial Robots per 10,000 workers

Country	2015	2016	2017*	2018*	2019*	2020*	2017/ 2016	CAGR 2018 - 2020
America	**38,134**	**41,295**	**48,000**	**50,900**	**58,200**	**73,300**	**16%**	**15%**
North America	36,444	39,671	46,000	48,500	55,000	69,000	16%	14%
- United States	27,504	31,404	36,000	38,000	45,000	55,000	15%	15%
- Canada	3,474	2,334	3,500	4,500	3,000	5,000	50%	13%
- Mexico	5,466	5,933	6,500	6,000	7,000	9,000	10%	11%
Brazil	1,407	1,207	1,500	1,800	2,500	3,500	24%	33%
Rest of South America	283	417	500	600	700	800	20%	17%
Asia/Australia	**160,558**	**190,542**	**230,300**	**256,550**	**296,000**	**354,400**	**21%**	**15%**
China	68,556	87,000	115,000	140,000	170,000	210,000	32%	22%
India	2,065	2,627	3,000	3,500	5,000	6,000	14%	26%
Japan	35,023	38,586	42,000	44,000	45,000	48,000	9%	5%
Republic of Korea	38,285	41,373	43,500	42,000	44,000	50,000	5%	5%
Taiwan	7,200	7,569	9,000	9,500	12,000	14,000	19%	16%
Thailand	2,556	2,646	3,000	3,500	4,000	5,000	13%	19%
other Asia/Australia	6,873	10,741	14,800	14,050	16,000	21,400	38%	13%
Europe	**50,073**	**56,043**	**61,200**	**63,950**	**70,750**	**82,600**	**9%**	**11%**
Central/Eastern Europe	6,136	7,758	9,900	11,750	13,900	17,500	28%	21%
France	3,045	4,232	4,700	4,500	5,000	6,000	11%	8%
Germany	19,945	20,039	21,000	21,500	23,500	25,000	5%	6%
Italy	6,657	6,465	7,100	7,000	7,500	8,500	10%	6%
Spain	3,766	3,919	4,300	4,600	5,100	6,500	10%	15%
United Kingdom	1,645	1,787	1,900	2,000	2,300	2,500	6%	10%
other Europe	8,879	11,843	12,300	12,600	13,450	16,600	4%	11%
Africa	**348**	**879**	**800**	**850**	**950**	**1,200**	**-9%**	**14%**
not specified by countries**	4,635	5,553	6,500	7,000	8,000	9,400	17%	13%
TOTAL	**253,748**	**294,312**	**346,800**	**379,250**	**433,900**	**520,900**	**18%**	**15%**

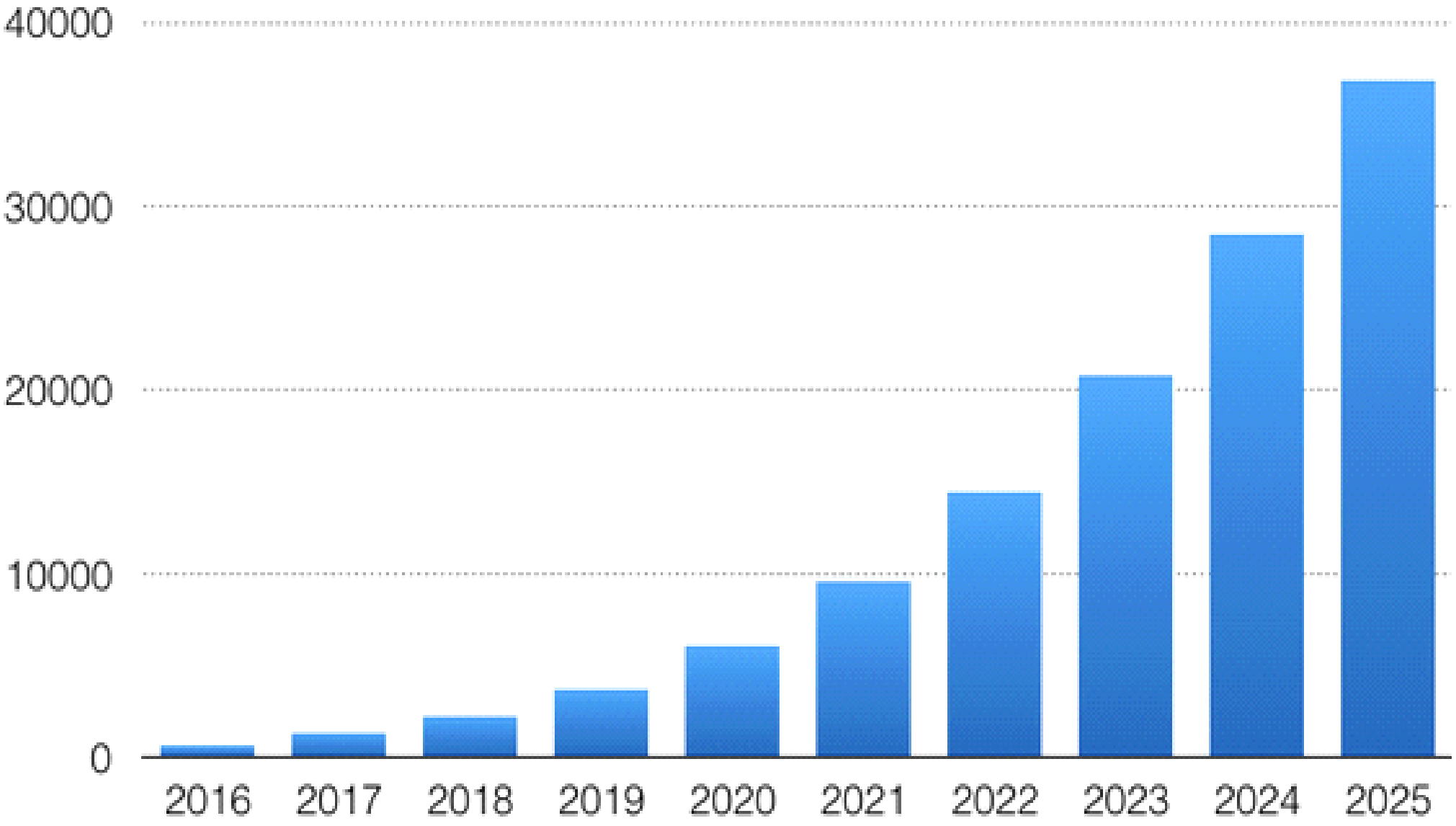
Source: Federation of Robotics 2017, table 4.1

But China is largest purchaser and Mexico, Brazil, India, and Thailand are introducing many multipurpose industrial robots

Country	2015	2016	2017*	2018*	2019*	2020*	2017/ 2016	CAGR 2018 - 2020
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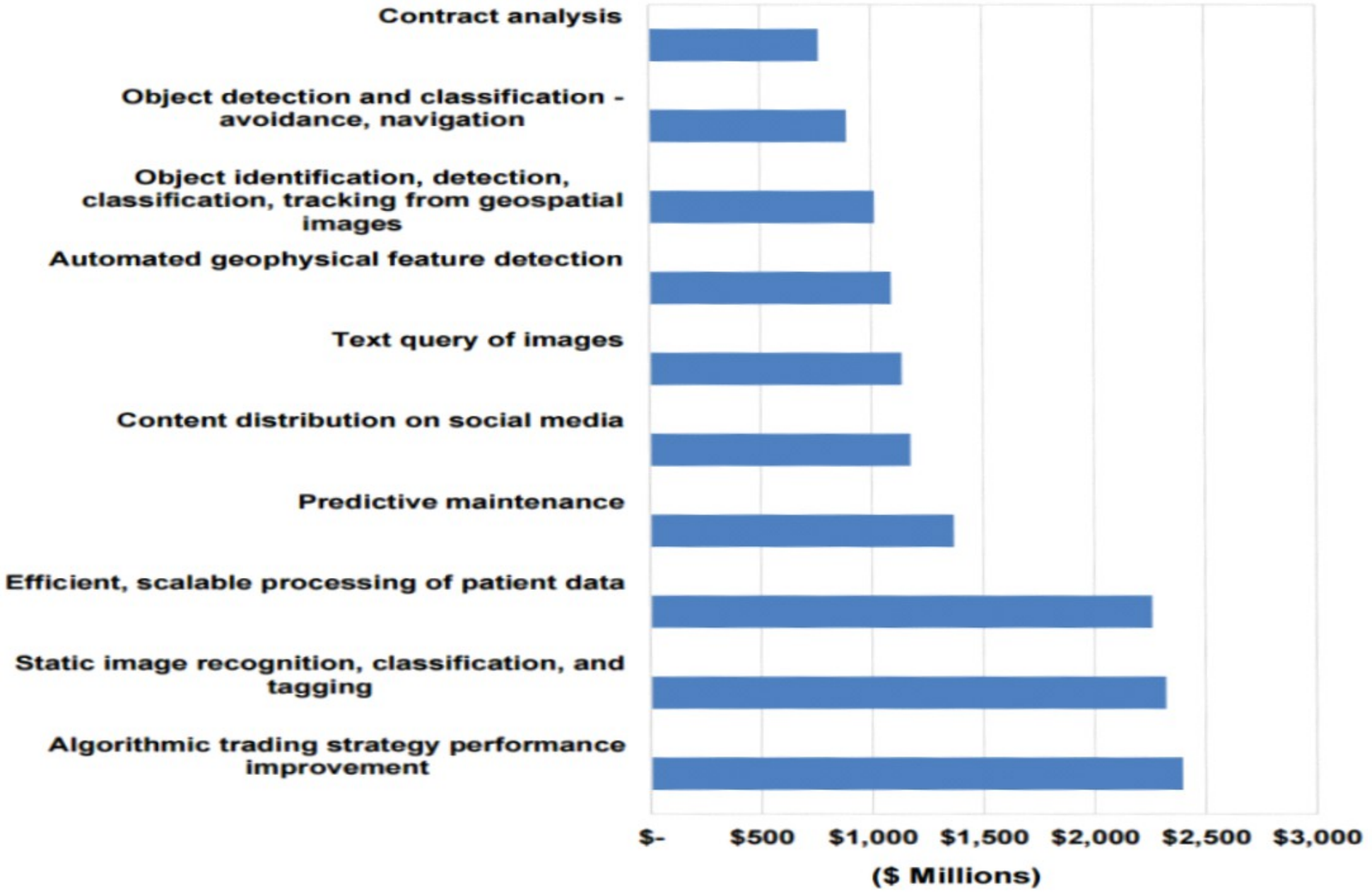
Sources: IFR, national associations

Artificial Intelligence Market Expected to Grow Rapidly as Well: Revenues in 2016 and forecasts through 2025 (in millions $)



Expectations of Tasks Where AI Will Grow

1.2 *Artificial Intelligence Revenue, Top 10 Use Cases, World Markets: 2025*



(Source: Tractica)

Exhibit 1: The global robots & artificial intelligence market

US$152.7bn robot & AI market by 2020E[1,3]

US$67bn robot market by 2025E[2]

Artificial Intelligence



(Softbank/Aldebaran-Pepper)

Artificial Intelligence analytics
US$70bn market by 2020[3]

Agricultural



(Amazone-Bosch – BoniRob)

Agricultural Robots
$16.3bn market by 2020[4]

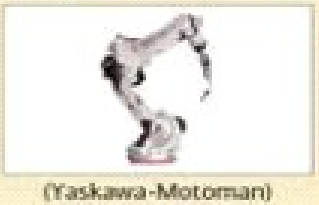
Autos



(Google–Self driving car)

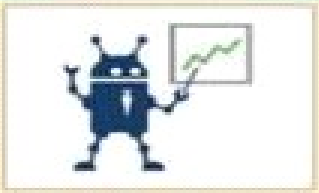
Autonomous Car
$87bn marketby 2030E[5]

Industrials



(Yaskawa-Motoman)
Industrial Robots
US$24bn market by 2025E[6]
Logistics, packaging & materials
US$31bn market by 2020E[7]

Financials



Robo-advisor
$255bn-2.2tn AuMby 2020E[8]

Medical



(Intuitive Surgical-da Vinci)

Surgical
US$18bn market by 2022[9]

Bionics



(Indego-exoskeleton)

Exoskeletons
$2.1bn market by 2021E[10]

Healthcare



(Fraunhofer-Care-O-bot 4)
Rehabilitation
$1.1bn market by 2021E[11]
Personal & Care-bots
US$17.4bn market by 2020E[12]

Home



(iRobot -gutter cleaner)

Domestic Robots
$12.2bn market by 2018E[13]

Entertainment



(Lego -Mindstorm)

Entertainment & Leisure
US$7.6bn market by 2018E[14]

Military



(QinetiQ - MAARS)

Military
$7.5bn market by 2018E[15]

UAV/UGV/UUV (Drones)



(Northrop –Global Hawk)

Drones
US$14bn market by 2025E[16]

[1]Allied market research, [2]BCG, [3]IDC, [4]Radiant Insights, [5]Lux, [6]BCG, [7]Deloitte, WireeGreen Research, [8]MyPrivateBankingResearch, AT Kearney, [9]Grand View Research, [10]ResearchandMarkets, [11]Wintergreen, [12]Frost & Sullivan, [13]IFR, [14]IFR, [15]Teal Group, [16]Teal Group

Source: BofA Merrill Lynch Global Research

Job Fears – Everywhere



Robots And Computers Could Take Half Our Jobs Within the Next 20 Years

Robots 'could take 4m UK private sector jobs within 10 years'

Royal Society of Arts survey suggests technology could phase out mundane roles, raise productivity and bolster wages

What Jobs Will the Robots Take?

Thinking machines: the skilled jobs that could be taken over by robots

Will Robots Steal Your Job? Why the highest-paid doctors are the most vulnerable to automation

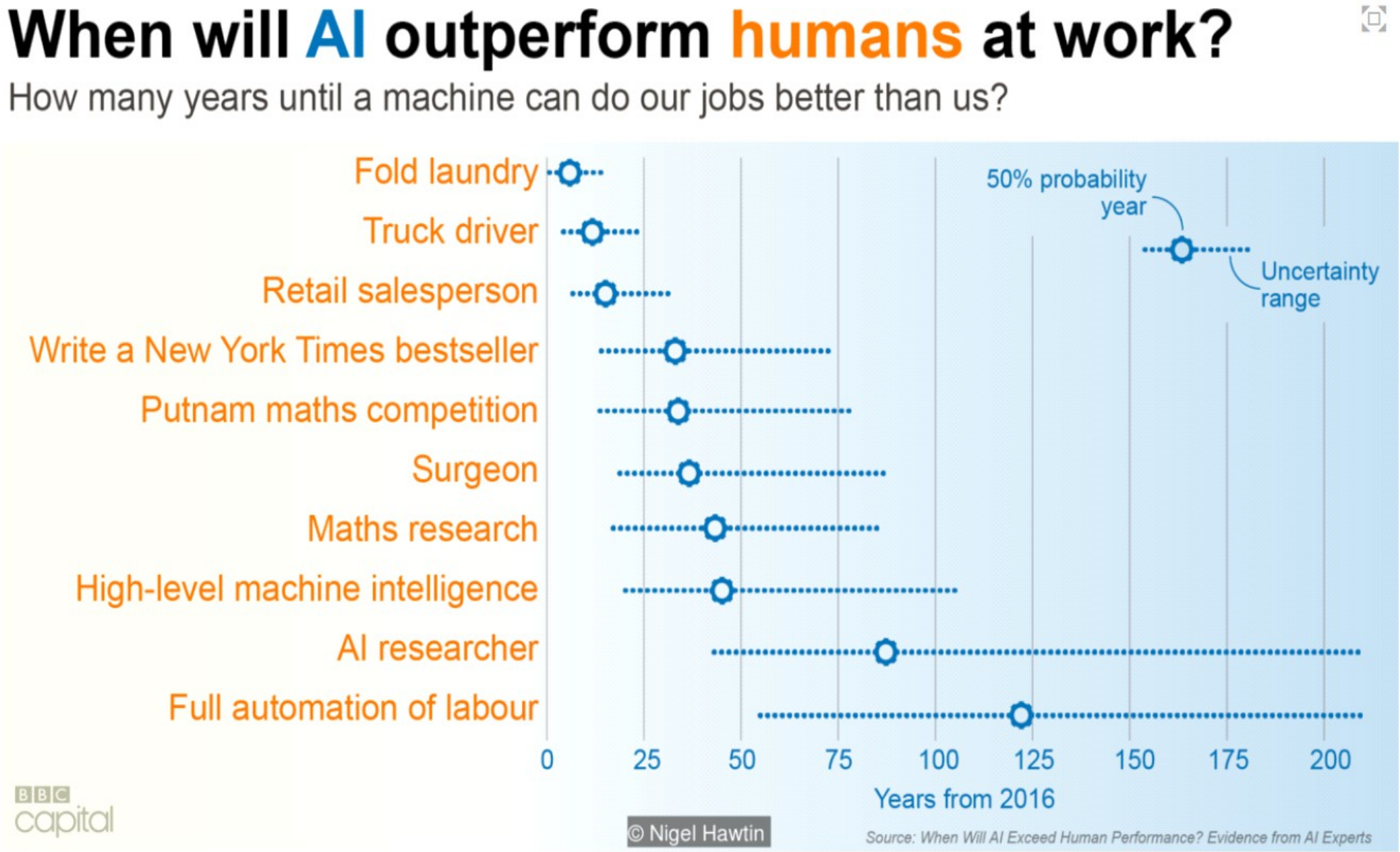
Artificial intelligence commission needed to predict impact, says CBI

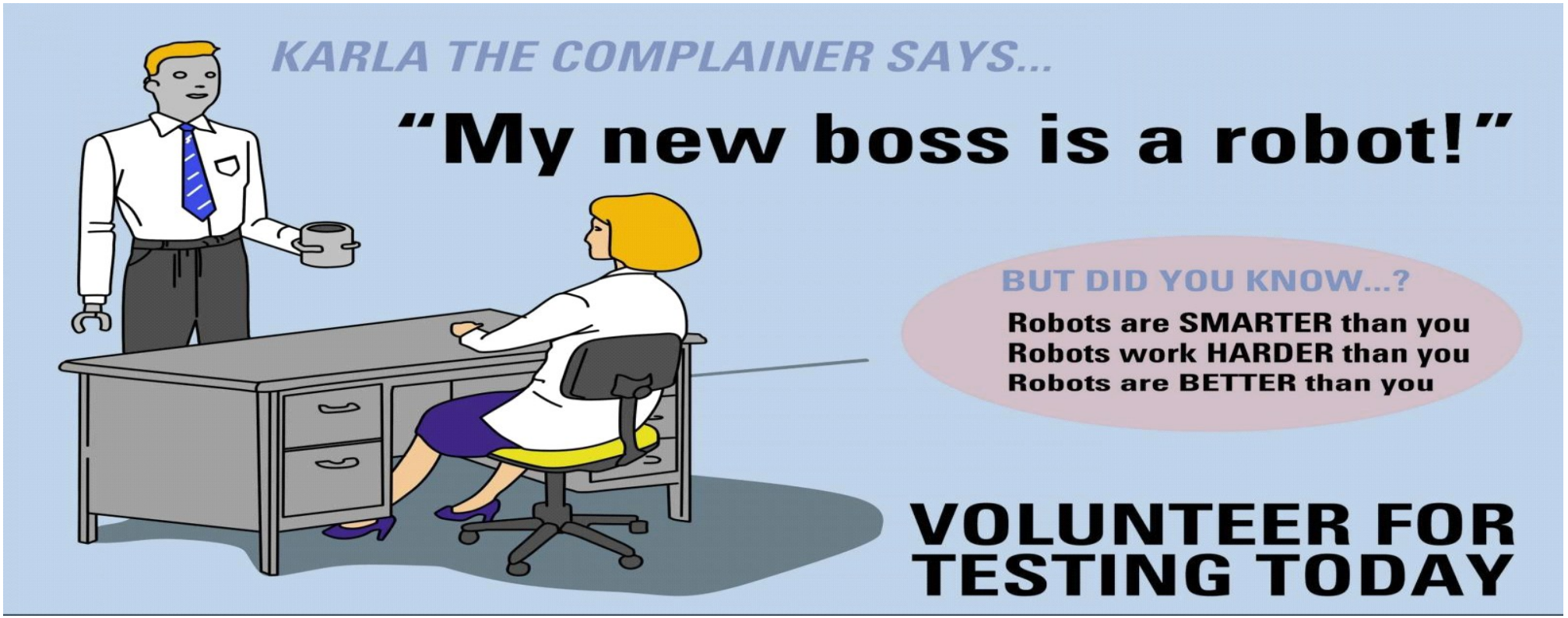
Business group urges government to launch commission to assess consequences of AI on jobs and increasing productivity

Robots could destabilise world through war and unemployment, says UN

United Nations opens new centre in Netherlands to monitor artificial intelligence and predict possible threats

Survey of 352 AI Experts Who Published at 2015 NIPS and ICML Conferences https://arxiv.org/abs/1705.08807, May 30, 2017





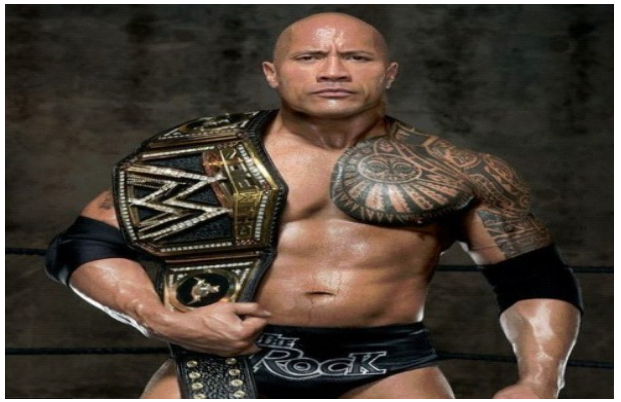
Robots Are Coming for These Wall Street Jobs



Wall Street is entering a new era. The fraternity of bond jockeys, derivatives mavens and stock pickers who've long personified the industry are giving way to algorithms, and soon, artificial intelligence.

2. Comparative Advantage and Three Laws of Robotics

Comparative Advantage says "The Rock" is better at everything than you, but is relatively better as wrestler/movie star. Even though he is better at your job than you, it is better for him to stick to car chases/beating villains and for you to do your work.



DEPT. OF THE FUTURE

Could a Robot Be President?

Yes, it sounds nuts. But some techno-optimists really believe a computer could make better decisions for the country—without the drama and shortsightedness we accept from our human leaders.

Could a Robot Be Professor?

I don't know any facts. I don't try to remember. I look it up on Google Search … until the Robot Professor replaces me... or my brain has direct link to Google Search.



Machines have comparative advantage in physical repetitious 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."

https://www.youtube.com/watch?v=ydTRk1l0ZqI

https://www.youtube.com/watch?v=U3eutnpTr3E

At present, our comparative advantage is in brain-power. For how long will we have that advantage?

Advances in AI shift Comp Advantage

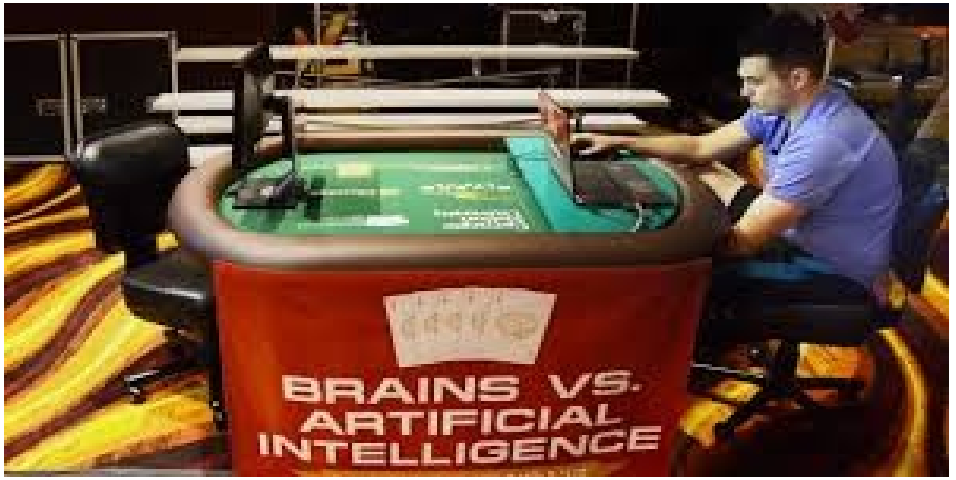
Google AlphaGo beats Humans at Go

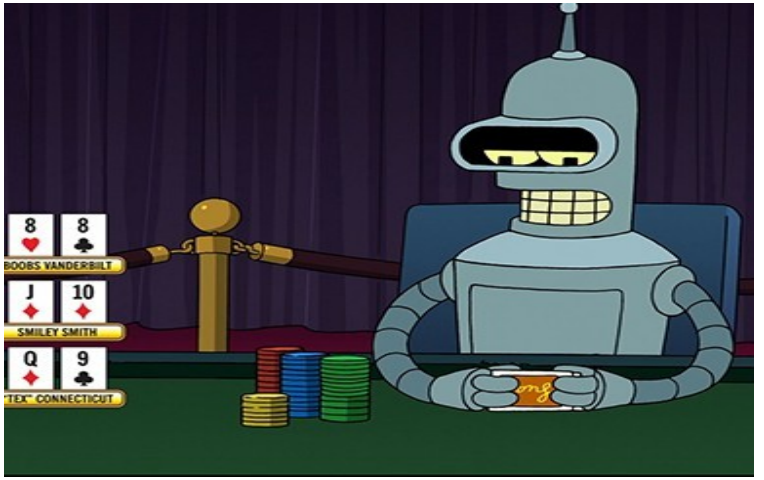
AlphaGo

Google DeepMind



AI beat pro card players at Texas Hold 'em poker ... could lead to AIs that … beef up airline security … simplify business negotiations.... DeepStack … combin(es) new algorithms and deep machine learning ... that … mimics the human brain, allowing machines to teach themselves.





Three Laws of Robo-Economics

1. Artificial intelligence + improved computerization + robotics based on biological analogies→ better machine substitutes for humans: **higher elasticity of substitution**

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

3 Effect on incomes depends on who owns 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!**

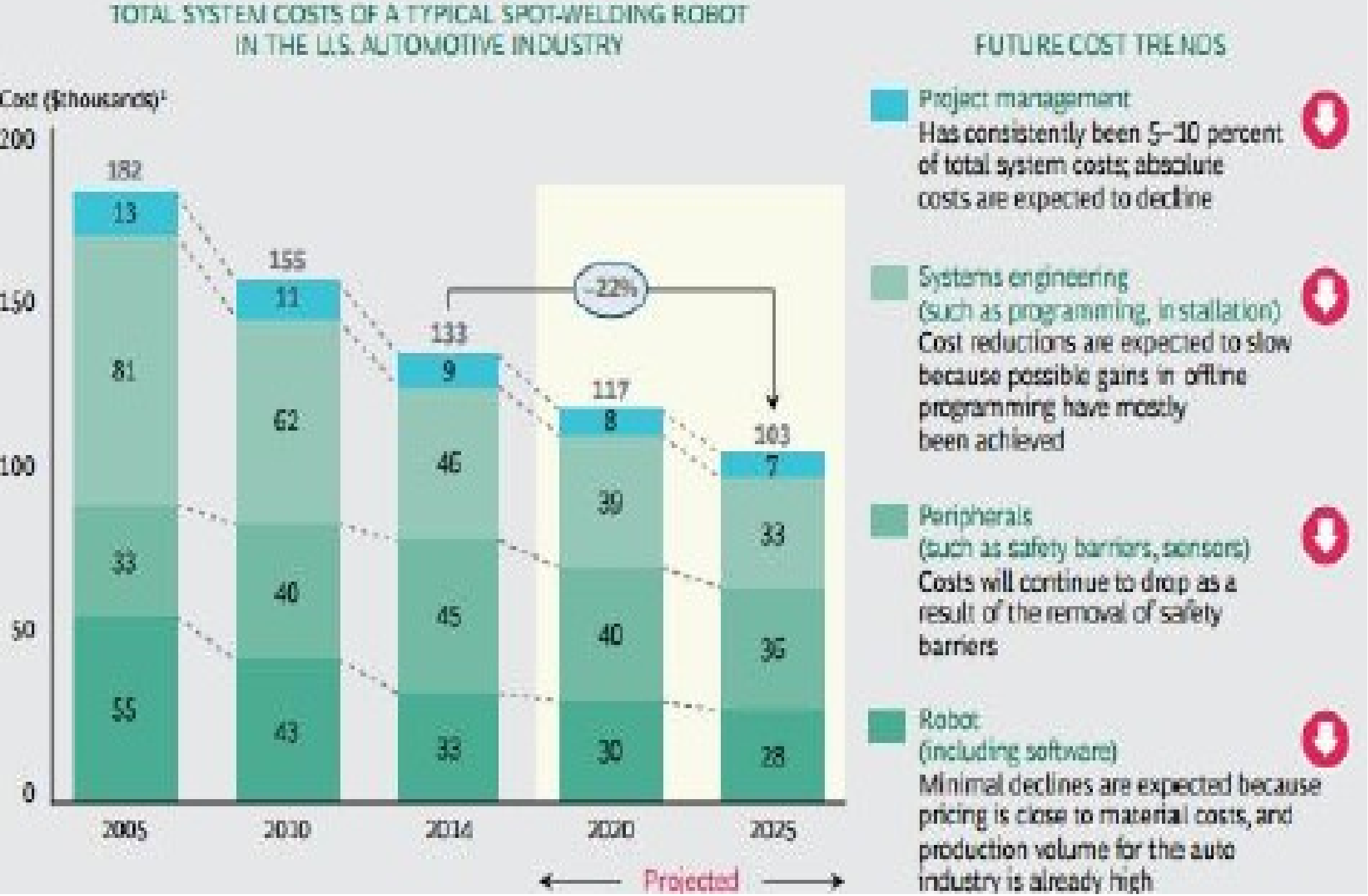
Law 1: The Importance of Substitability

Comparative advantage says don't worry about jobs: even if AI robots beat humans in all jobs, there will still be jobs for us, but if the AI robots are better substitutes for you and me than for existing machines, traditional aggregate analysis that divides factors between capital and labor must be modified.

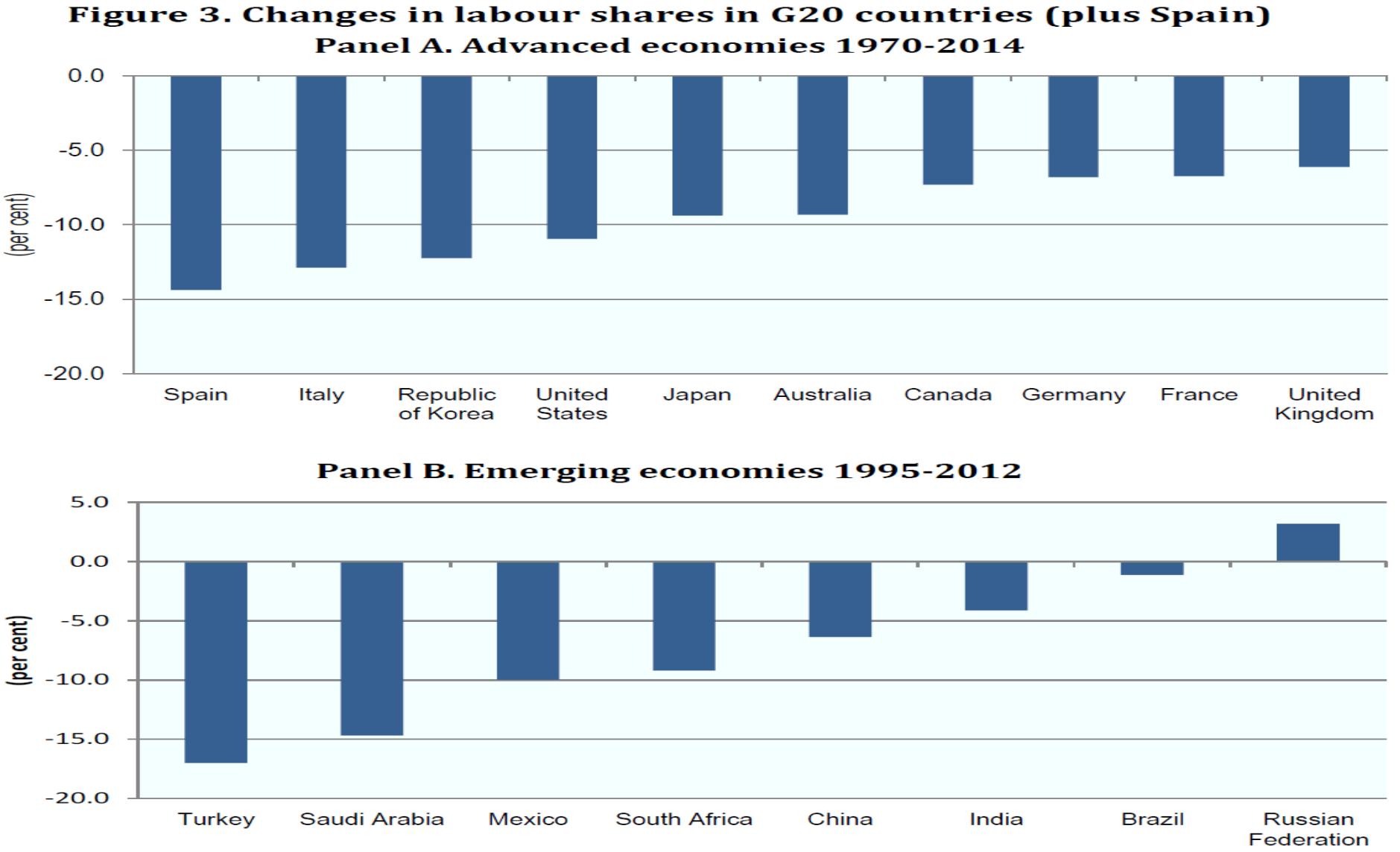
In the past economists treated investment in machines as raising capital stock and thus improving labor productivity and earnings, which are positively related to capital/labor ratio.

But if AI robots are substitutes for humans, then investment in machines raises labor and wages of workers falls. Alternative way to say this is that AI/robots are part of labor-saving technology that will lower wages (and possibly jobs) unless there is some offsetting expansion of aggregate demand.

Law2: TC Improves Robot Capability and Lowers Cost



Law 3: Falling Labor's Share of Incomes: Effect of better substitute robots/machines?



Source: OECD-ILO, "Labour's Share in G20 Economies (Feb 2015)

AI Turns Malthus Upside Down



The power of population is so superior to the power of the Earth to produce subsistence for man that premature death must in some shape or other visit the human race – Thomas Malthus, 1798

The power of AI robots is so superior to the mind of flesh and blood creatures that replacement by robot work must in some shape or other visit the human race" – Labor Economist, 2015.



3. Automation Fears Redux, or AI Robots Running Over You?

Redux Case:

1) Past fears that automation destroys jobs fizzled out. FDR blamed Great Depression joblessness on failure to "employ the surplus of our labor which the efficiency of our industrial processes has created". Early 1960s automation fears led to US Commission on Automation, followed by rise in E/Pop until 1971 recession; 1990s Rifkin's End of Work (1995) preceded dot.com boom. Why should this time be different?

2) Past periods of major change produced rapid productivity which sparked shift of employment to better jobs. Decline of agriculture --> rise of mfg jobs. Decline of mfg → rise of retail and service sector jobs and white collar work . Does modest productivity growth imply that AI robots are just a bunch of headline hype!

3) However technology changes, expansionary macro-policies can save the day. Cost-saving technologies that reduce inflation widen the scope for those policies. Danger is deflation not inflation so build infrastructure, lower taxes, "let the good times roll".

Herb Simon's Shape of Automation (1966) Analysis

1- Labor less elastic supply than machines. Labor market clears. Evidence – low unemployment despite tech change.
2- Technology for producing machines has constant returns to scale so infinitely elastic. Evidence – real price of capital constant.
3. Then real wages of workers benefit rise through reduced prices or higher wages. Evidence – real wages increase with productivity.

Simon's conclusion: "the world's problems *in this generation and the next* are problems of scarcity, not of intolerable abundance. The bogeyman of automation consumes worrying capacity that should be saved for real problems..."

But today labor's share of national income has fallen as real wages stagnate despite rising productivity/increase less than productivity; inequality has risen to levels that threaten democracy and stability.

AI-Robot Technology is Different

- Shift of work on-line gives AI edge in its digital world; while improved sensors give robots abilities to see and change our off-line world
- Deep learning, neural net, reinforcement algorithms with big data and computer power leads to experiential learning beyond us.
- General purpose technology that can be applied widely; Cloud connections link computers/robots to enhance learning.
- Ensemble of programs can mimic general intelligence even though each algorithm is task or occupation limited.
- *"It's more powerful than previous approaches by not using human data, or human expertise in any fashion, we've removed the constraints of knowledge and it is able to create knowledge itself"* (D. Silver, AlphaGo)

'It's able to create knowledge itself': Google unveils AI that learns on its own

In a major breakthrough for artificial intelligence, AlphaGo Zero took just three days to master the ancient Chinese board game of Go ... with no human help

Ian Sample Science editor

Wednesday 18 October 2017 13.00 EDT

Google's artificial intelligence group, DeepMind, has unveiled the latest incarnation of its Go-playing program, AlphaGo - an AI so powerful that it derived thousands of years of human knowledge of the game before inventing better moves of its own, all in the space of three days.

Named AlphaGo Zero, the AI program has been hailed as a major advance because it mastered the ancient Chinese board game from scratch, and with no human help beyond being told the rules. In games against the 2015 version, which famously beat Lee Sedol, the South Korean grandmaster, AlphaGo Zero won 100 to 0.

The feat marks a milestone on the road to general-purpose AIs that can do more than thrash humans at board games. Because AlphaGo Zero learns on its own from a blank slate, its talents can now be turned to a host of real-world problems.

Mastering the Game of Go without human knowledge (Nature, Oct 2017)

A long-standing goal of artificial intelligence is an algorithm that learns, *tabula rasa*, superhuman proficiency in challenging domains. Recently, AlphaGo became the first program to defeat a world champion in the game of Go. The tree search in AlphaGo evaluated positions and selected moves using deep neural networks. These neural networks were trained by supervised learning from human expert moves, and by reinforcement learning from self-play. Here we introduce an algorithm based solely on reinforcement learning, without human data, guidance or domain knowledge beyond game rules. AlphaGo becomes its own teacher: a neural network is trained to predict AlphaGo's own move selections and also the winner of AlphaGo's games. This neural network improves the strength of the tree search, resulting in higher quality move selection and stronger self-play in the next iteration. Starting *tabula rasa*, our new program AlphaGo Zero achieved superhuman performance, winning 100–0 against the previously published, champion-defeating AlphaGo.



Extended Data Table 3 | Learning rate schedule

Thousands of steps	Reinforcement learning	Supervised learning
0–200	10^{-2}	10^{-1}
200–400	10^{-2}	10^{-2}
400–600	10^{-3}	10^{-3}
600–700	10^{-4}	10^{-4}
700–800	10^{-4}	10^{-5}
>800	10^{-4}	-

Extended Data Table 1 | Move prediction accuracy

	KGS train	*KGS* test	*GoKifu* validation
Supervised learning (20 block)	62.0	60.4	54.3
Supervised learning (12 layer [12])	59.1	55.9	-
Reinforcement learning (20 block)	-	-	49.0
Reinforcement learning (40 block)	-	-	51.3



Human Comparative Advantage?



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."

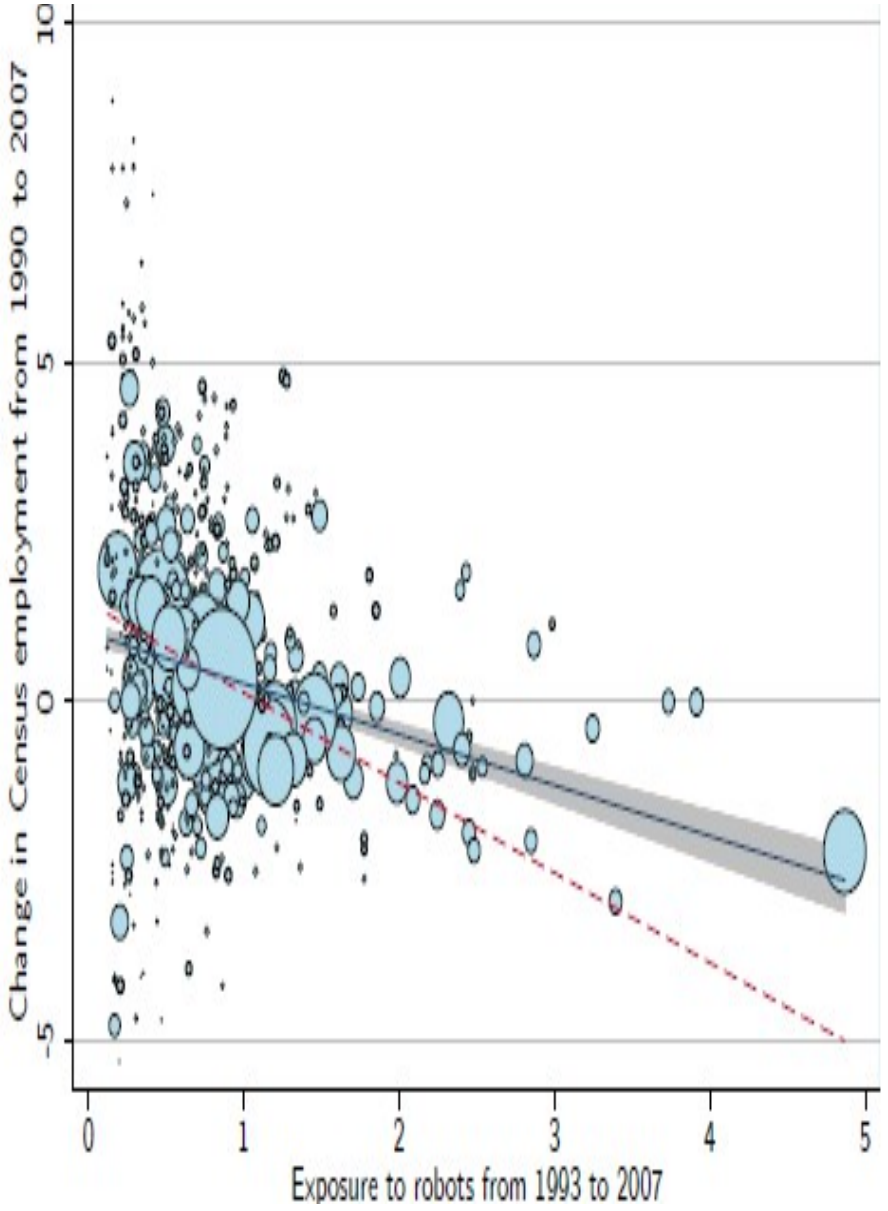
The economics issue for comparative advantage is whether our advantage is in high value added/pay tasks or low value added/pay tasks. As long as value of complex calculations and precision exceed the value of "everyday tasks such as walking" and it is easy to replicate robots/AI programs that do the valuable work, earnings will shift to the owners of the robots/AI away from workers good at outwalking humanoid robots and in other everyday tasks.

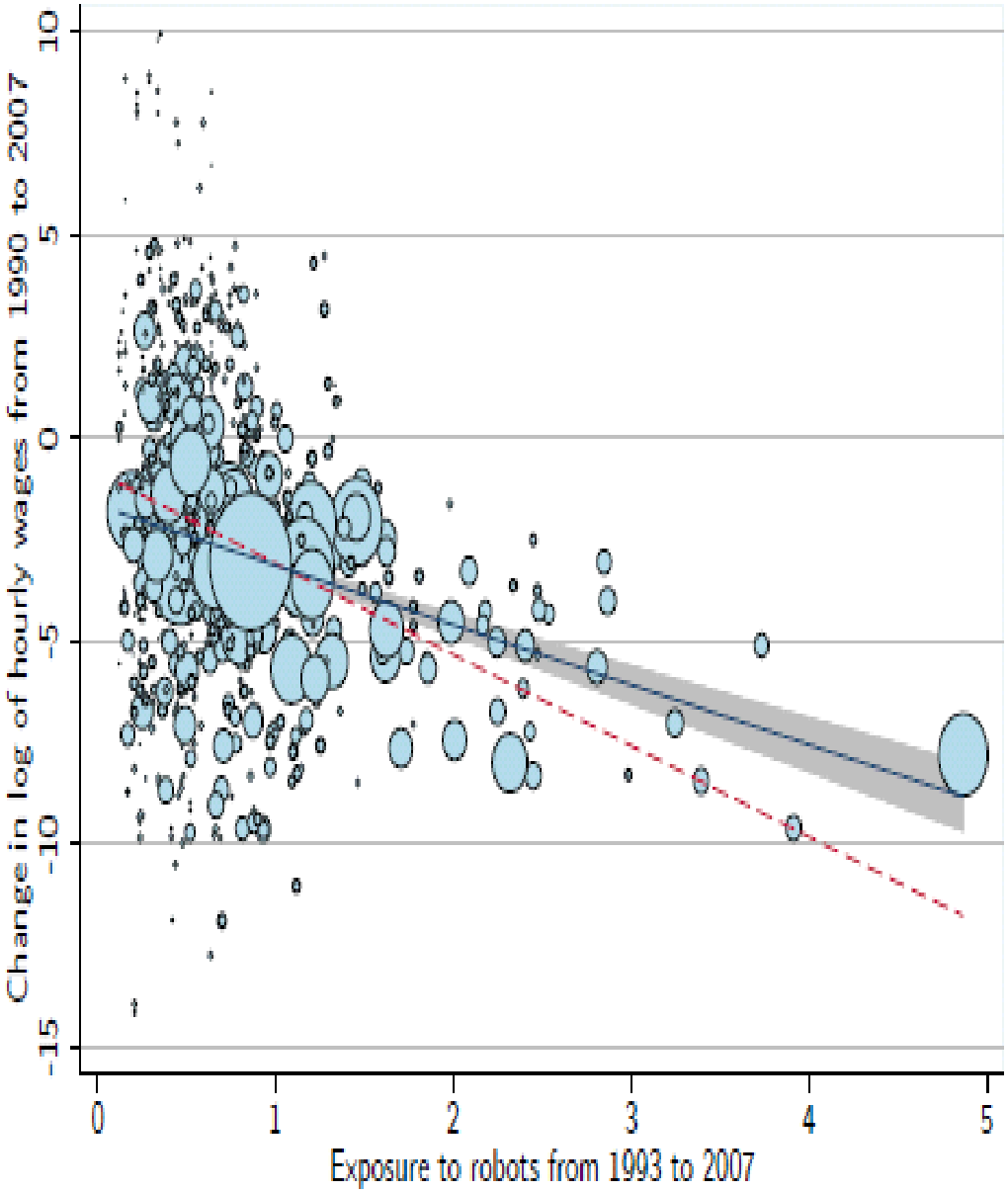
Why Substitute Robots for Workers in Low Wage Countries?

- If you are paying workers $35 per hour to produce some good or service it surely pays off to buy a robot substitute that does the same work at $20 an hour. But what if the wage is $3.50 per hour? Keep the worker employed and forego robotization? Not necessarily.
- The economics requires that one compares the cost of the robot and workers in cost per unit produced. If the $35 per hour worker is 10 times as efficient as the $3.50 worker, the incentive for buying the robot is the same in both countries. In the high wage country, the firm would displace one worker and gain $15 per hour in profit. In the low wage country the firm would displace10 workers and also gain $15 per hour.
- If Output (O)/Employment (E) is the productivity of labor and W is the wage, a firm will have an incentive to replace workers with robots when W/(O/E) = WE/O > Cost of robot substitute. Assuming the same cost of robot substitute in low and high wage countries, a low wage country with low labor productivity could have greater incentive to robotize than a high wage country with high labor productivity. *If wages reflect productivity similarly,the incentive to robotize would be the same*.

Evidence on Effects of Industrial Robots on Jobs and Wages by US Areas with High Robot Exposure 1993-2007

Acemoglu-Restropo (NBER, WP23285)





4. Choices

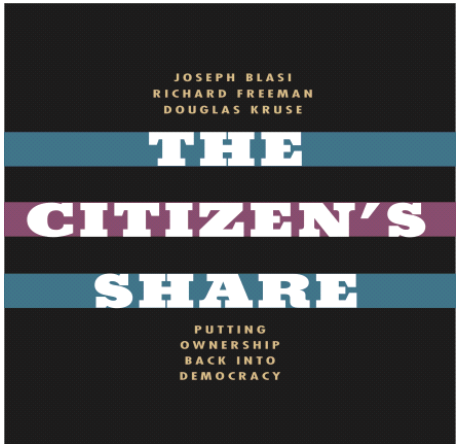
- Stipulate comparative advantage argument that the danger is less joblessness per se than falling wage incomes and increased inequality as the owners of the robots, capital, gain while the rest of us lose. That eventually AI robots will improve productivity and raise total output.

- Any plausible solution involves some redistribution of income so that benefits of higher productivity are shared by all.
  - Picketty Capital Tax?
  - Gates Robot Tax?
  - More progressive taxes to expand welfare state?
  - Strengthen unions and CB?
  - Attack robots?
  - Attack trade, immigrants?

- Lots of attention to Universal Basic Income, with more public free goods, access to health care, food, leisure, etc?

A better way?: Ownership solutions

- Paths to ownership for workers, that harness incentives
  - Employee Ownership through ESOPs (US),
  - Stock Purchase Plans (UK),
  - Mandated profit-sharing (France)
  - Stock Options.



- Paths to ownership for citizens,
  - Pension funds, private (US, Australia)
  - Mandated public for private investment (Sweden)
  - Sovereign Funds (Norway, Alaska)



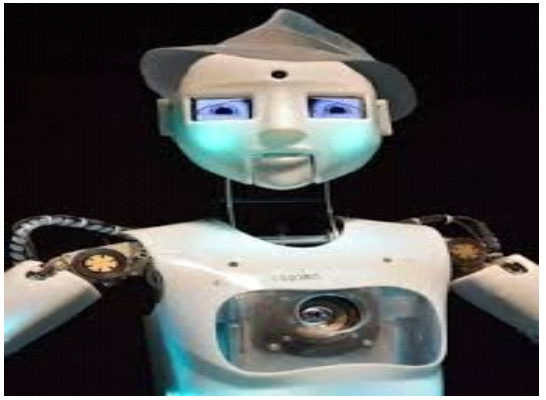
CITIZENS, OWNERSHIP MEANS YOUR AI ROBOT WORKS FOR YOU

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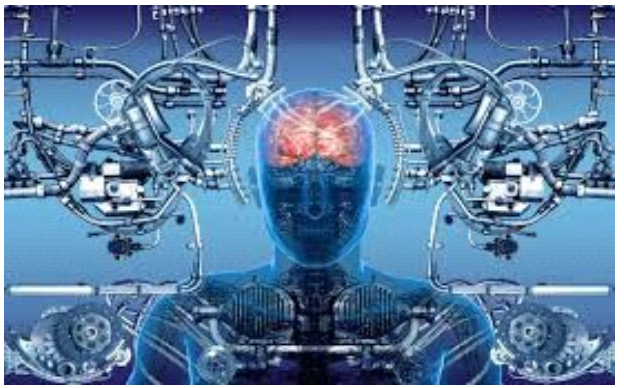
YOU DON'T WORK FOR THE ROBOT.

MAKE HUMANS GREAT AGAIN!

Human Enhancement Technology (HET) → Cyborg



Robots: If you can't beat 'em, join 'em



HET: application of IT, nano-tech, bio-tech,cognitive science to improve human performance. Used in neuroprosthetics--artificial limbs BUT ...

- Seeker Aug 28,2017 “Elon Musk’s Neuralink Gets $27 Million to Merge Humans and Machines” the only way to keep pace with artificial intelligence is to upgrade human intelligence
- Science June 30,2017 “Ethical dimensions of neuroprosthetics”
- Nature July 7, 2017 “Giant Health Studies try to tap wearable electronics”
- Guardian, Nov 2016 “US military successfully tests electrical brain stimulation to enhance staff skills”

What do we do if we own the robots who do the work?



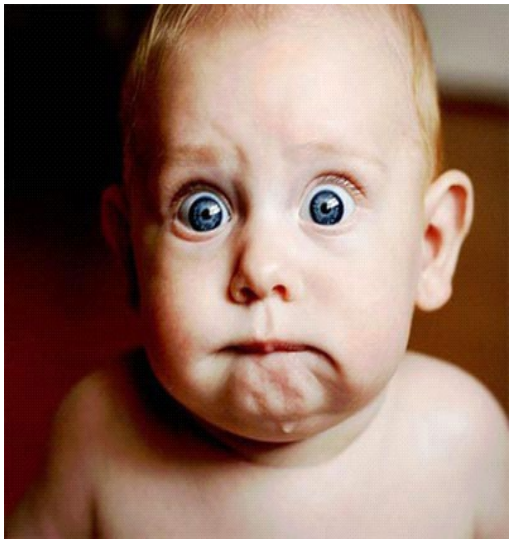








What, me worry about work? You are MAD. I have better things to do than to worry. Anyhow, it's not my problem. It's the baby's problem. Good luck, kid! I hear Version N+1 is cuter than you and don't cry.



It is our problem

AI robotic technology will diffuse gradually around the world, so we have time to adjust policies and practices to assure that the vast majority of humans benefit from AI robots rather than becoming new serfs to a small elite of owners.

Updating Simon's 1966 advice that we should worry about real problems of scarcity instead of the possible future “bogeyman of automation”, we should focus on policies that make AI robotics technology broadly inclusive both in terms of consumption and ownership so that billions of people can benefit from higher productivity and get on the path to the coming age of intolerable abundance.