

Artificial Intelligence and Technological Unemployment

Moshe Y. Vardi

Rice University

Houston, TX, USA

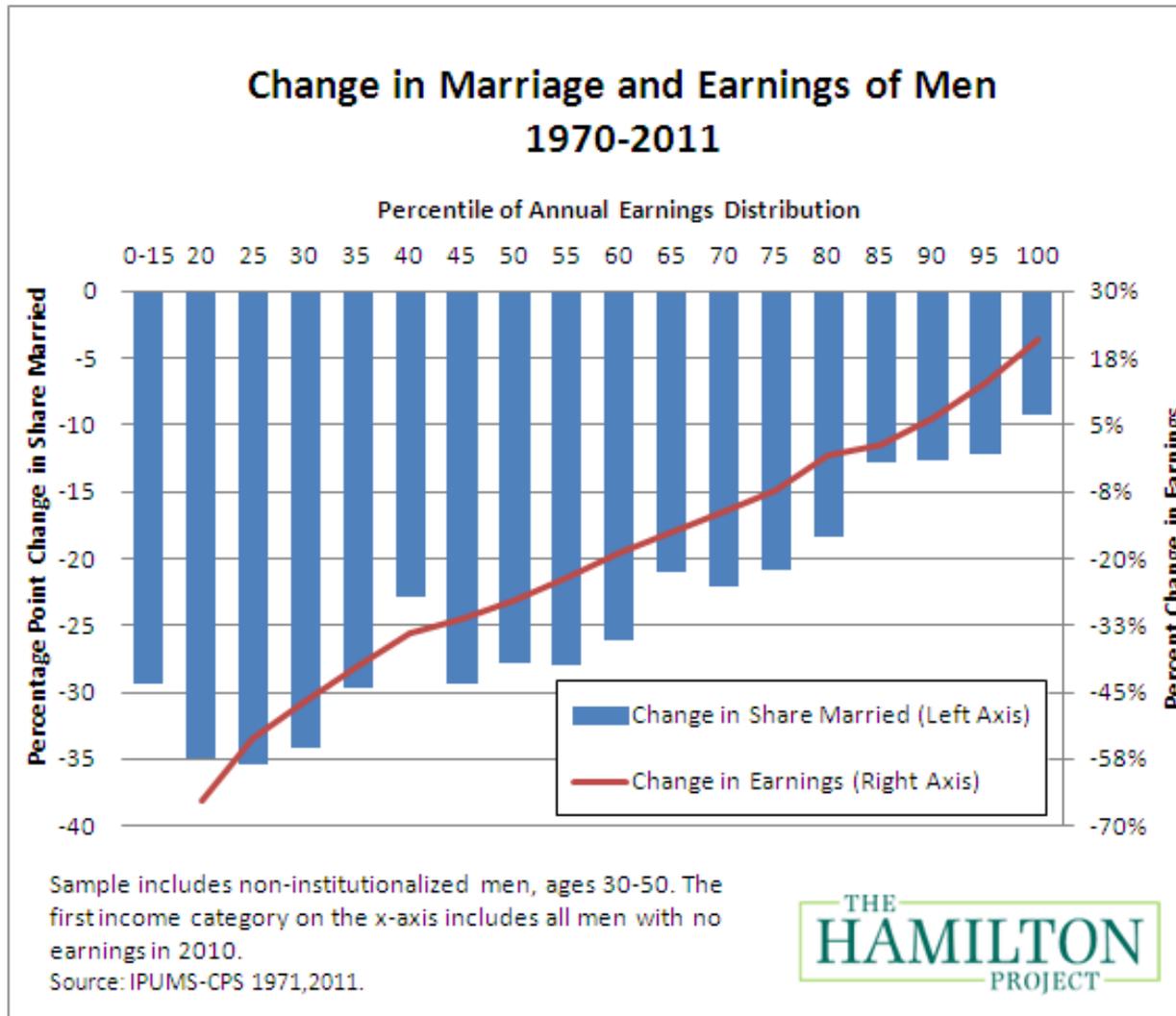
vardi@cs.rice.edu

Follow me on social media!

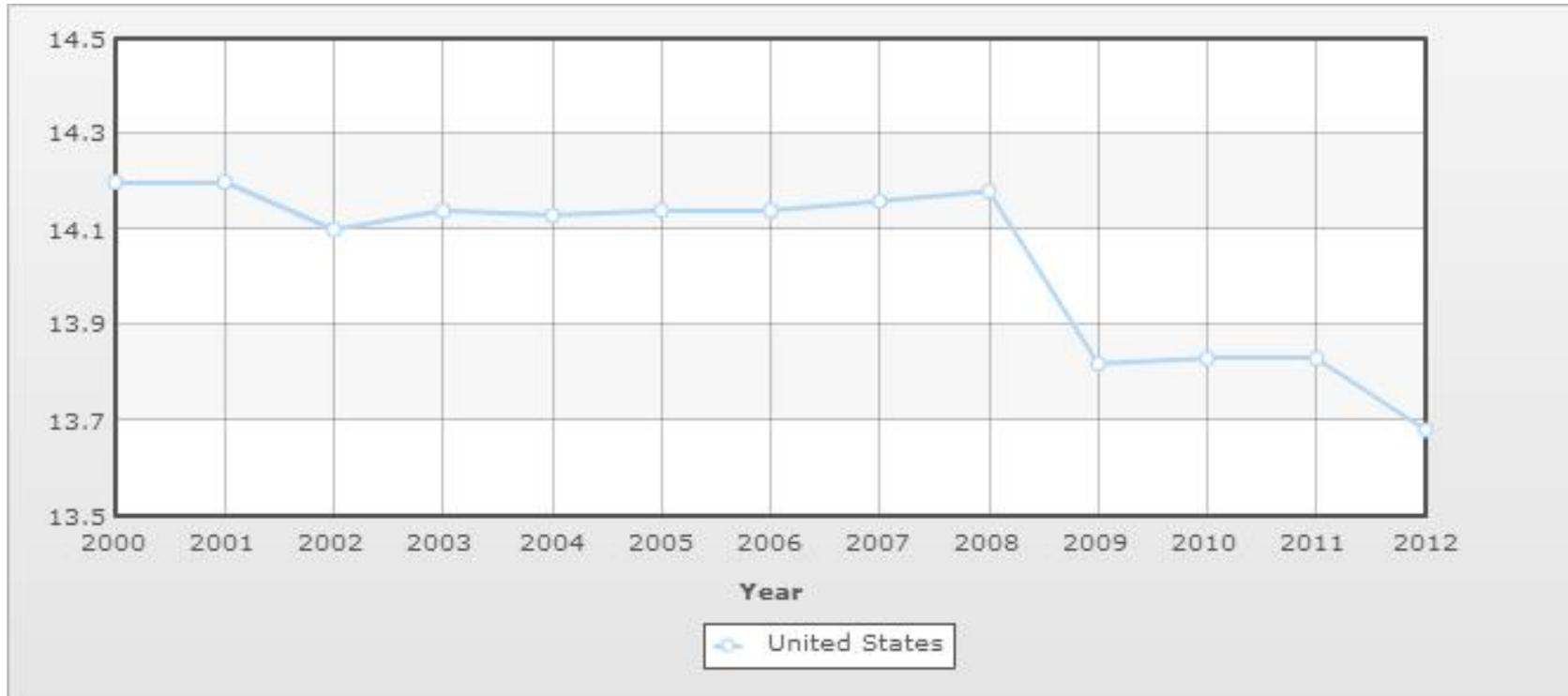
How a New Jobless Era Will Transform America

Don Peck: "The Great Recession may be over, but this era of high joblessness is probably just beginning. Before it ends, it will likely change the life course and character of a generation of young adults. It will leave an indelible imprint on many blue-collar men. It could cripple marriage as an institution in many communities. It may already be plunging many inner cities into a despair not seen for decades. Ultimately, it is likely to warp our politics, our culture, and the character of our society for years to come."

Earning and Marriage

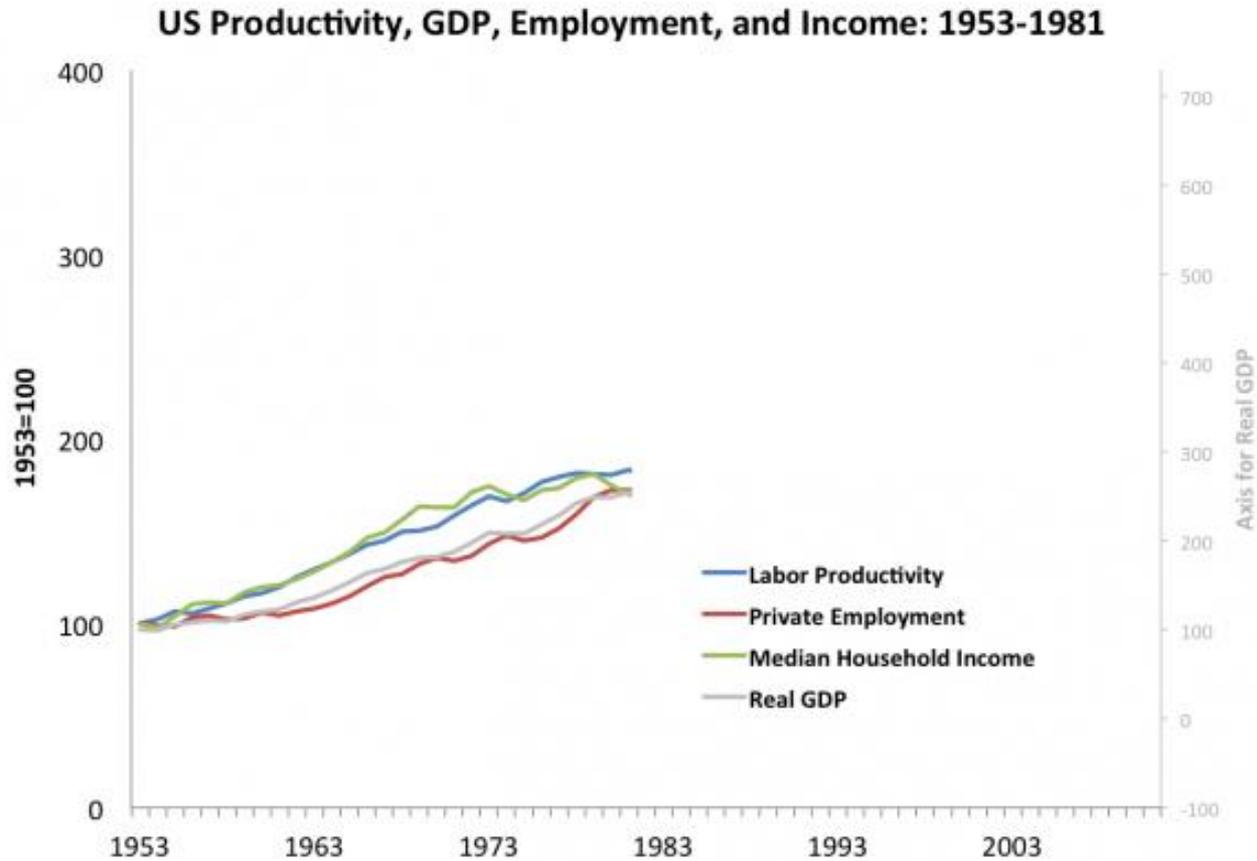


US Birthrate (Births/1000)

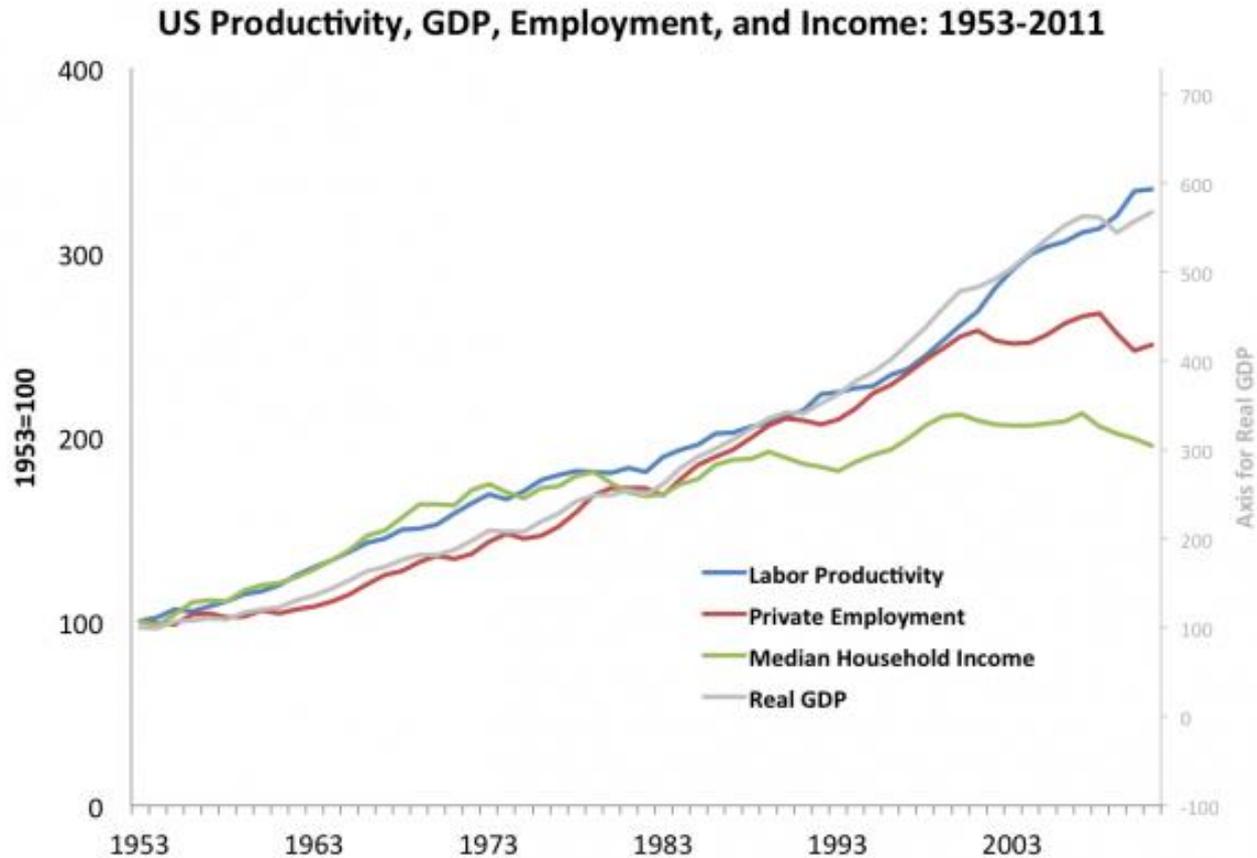


2.3M fewer births!

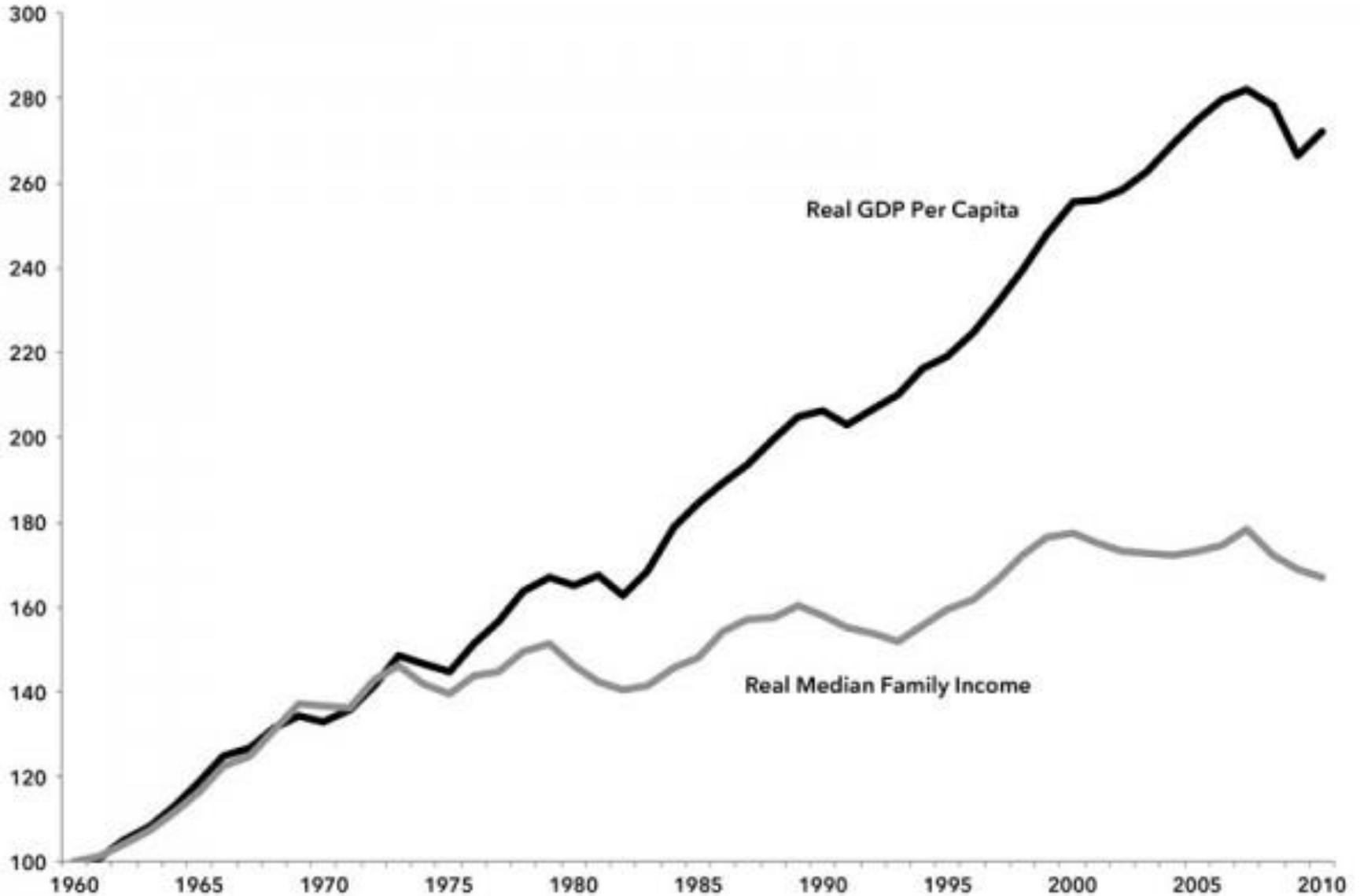
The Great Coupling



The Great Decoupling



US GDP per Capita and House Income



A rising tide lifts all boats?

- ◆ Harold Meyerson: "Tide and boats have parted company!"

The Neoluddites

- ◆ E. Brynjolfsson and A. McAfee: "Productivity growth and employment growth started to become decoupled from each other. We are creating jobs, but not enough of them."
- ◆ J. Sachs and L. Kotlikoff: "What if machines are getting so smart, thanks to their microprocessor brains, that they no longer need unskilled labor to operate?"
- ◆ P. Krugman: "Can innovation and progress really hurt large numbers of workers, maybe even workers in general? The truth is that it can, and serious economists have been aware of this possibility for almost two centuries."

The Neoclassicals

- ◆ K. Rogoff: "Since the dawn of the industrial age, a recurrent fear has been that technological change will spawn mass unemployment. Neoclassical economists predicted that this would not happen, because people would find other jobs, albeit possibly after a long period of painful adjustment. By and large, that prediction has proven to be correct."

The Debate in A Nutshell

- ◆ Neoluddites: "This time it is different."
- ◆ Neoclassicals: "This time it is not different."

Who is right?

Let's go back to basics!

Birth of Intelligent Machines

- ◆ "Logic Piano", built by William S. Jeavons, 1869



Birth of Artificial Intelligence, I

- ◆ William S. Jeavons: "The machine represents a mind endowed with powers of thought, but wholly devoid of knowledge. ... It cannot be asserted indeed that the machine entirely supersedes the agency of conscious thought."



Birth of Artificial Intelligence, II

- ◆ Charles S. Peirce, 1887: "Precisely how much the business of thinking a machine could possibly be made to perform, and what part of it must be left to the living mind is a question not without conceivable practical importance."



Birth of Artificial Intelligence, III

- ◆ Alan M. Turing, 1902-1954



“Computing Machinery and Intelligence”

◆ Turing, 1950:

“ I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted.”

Crux of paper. A compelling philosophical analysis for the feasibility of intelligent machines.

Objections to Machine Intelligence

1. Theological objection
2. Consequentialist objection
3. Mathematical objection
4. Consciousness objection
5. Inability objection
6. Originality objection
7. Continuity objection
8. Informality objection
9. ESP objection

AI: Early Optimism

- ◆ 1958, H. A. Simon and A. Newell: "within ten years a digital computer will be the world's chess champion"
- ◆ 1967, M. Minsky: "Within a generation ... the problem of creating 'artificial intelligence' will substantially be solved."

“AI Winters”

- ◆ The first AI winter 1974–1980: slow progress and dearth of funding
- ◆ The second AI winter 1987–1993: the “Fifth-Generation bust” and dearth of funding

AI Breakthroughs, I

- ◆ 1997: IBM's Deep Blue beats Kasparov.



AI Breakthroughs, II

- ◆ 2005: DARPA Grand Challenge - Stanford autonomous vehicle drives 131 miles along an unrehearsed desert trail.



AI Breakthroughs, III

- ◆ 2007: DARPA Urban Challenge - CMU autonomous vehicle drives 55 miles in an urban environment while adhering to traffic hazards and traffic laws.



AI Breakthroughs, IV

- ◆ 2011: IBM's Watson defeats the two greatest Jeopardy! champions, Brad Rutter and Ken Jennings, by a significant margin.



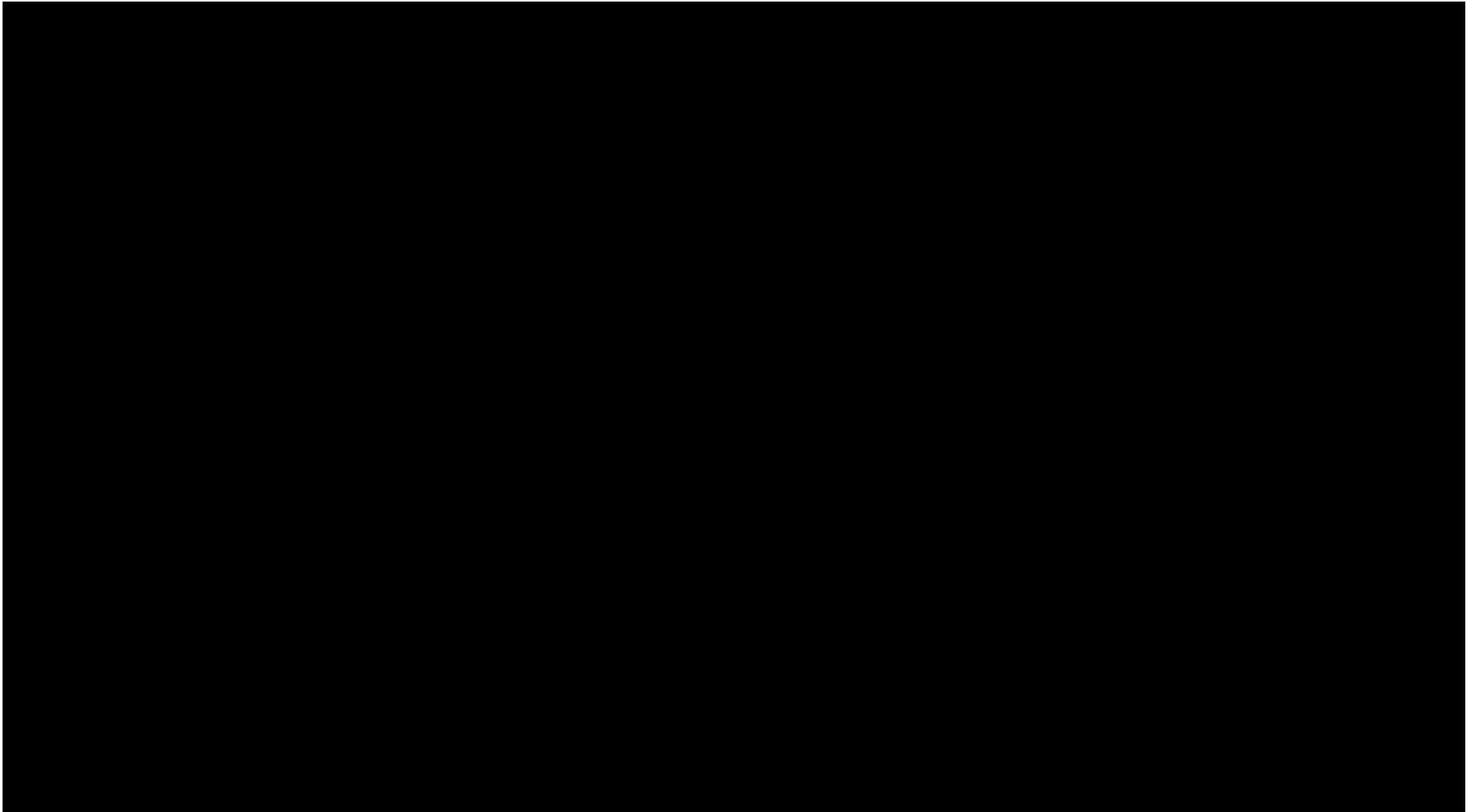
AI Breakthroughs, V

BigDog is a dynamically stable quadruped robot created in 2005 by Boston Dynamics.



AI Breakthroughs, VI

- ◆ Google driverless car



AI Breakthroughs, VII

- ◆ Warehouse robots



The Prospects of Intelligent Machines

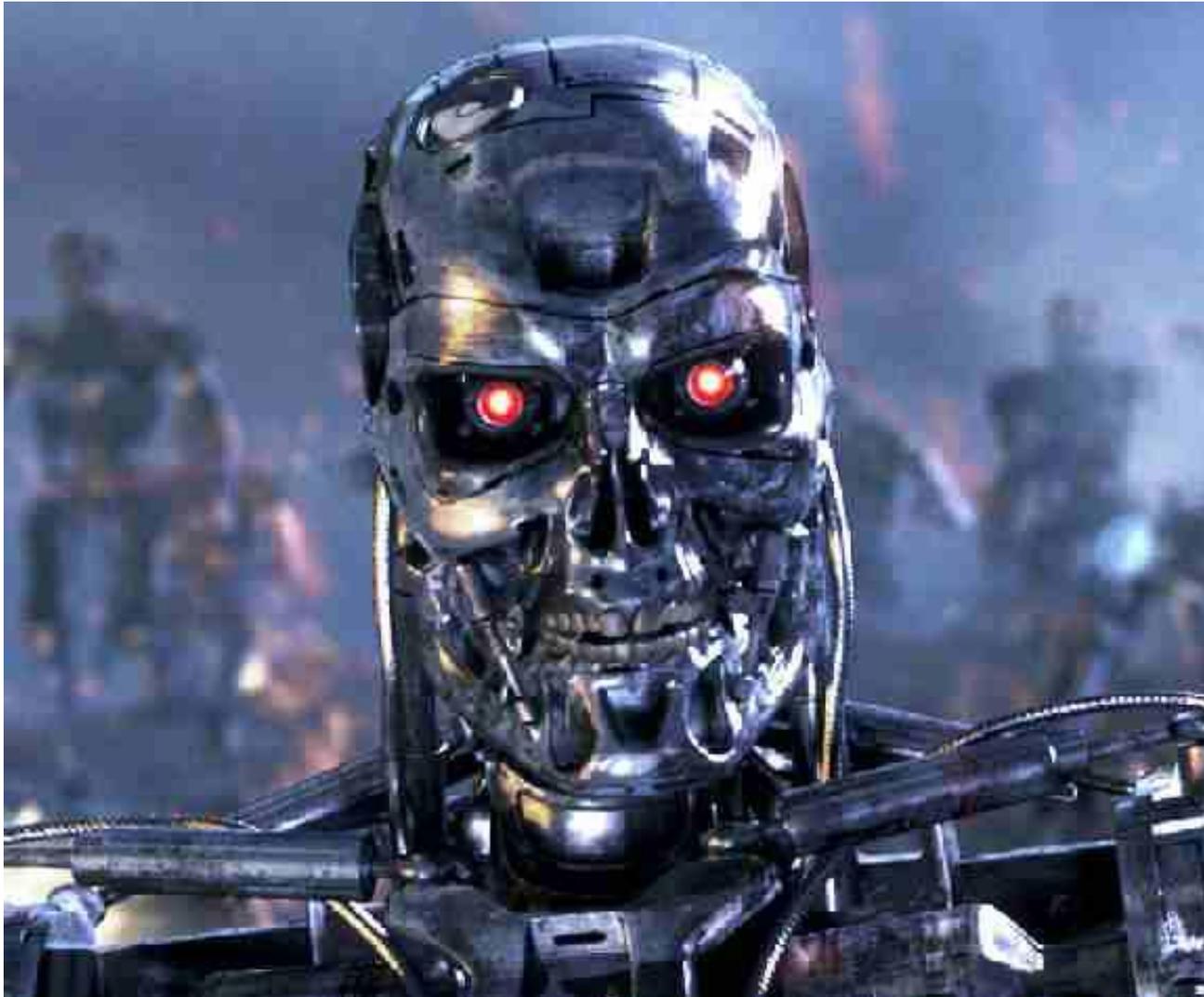
Prospects seem quite very good!

- ◆ AI has been making inexorable progress
- ◆ Turing's analysis is still compelling
- ◆ We have an existence proof - us!

The Robots Are Coming

- ◆ 2011: "New UCSF Robotic Pharmacy Aims to Improve Patient Safety"
- ◆ 2011: "Japanese Robot Debones 1,500 Chickens Per Hour"
- ◆ 2012: "Meet South Korea's New Robotics Prison Guards"
- ◆ 2013: "New Sedation Machine Promises Cheaper Colonoscopies; Doctors Fight Back"
- ◆ 2014: "Royal Caribbean's Quantum of the Seas Features a Bionic Bar with Robot Bartenders"

Fear of “Thinking Machines”



Impact on Jobs

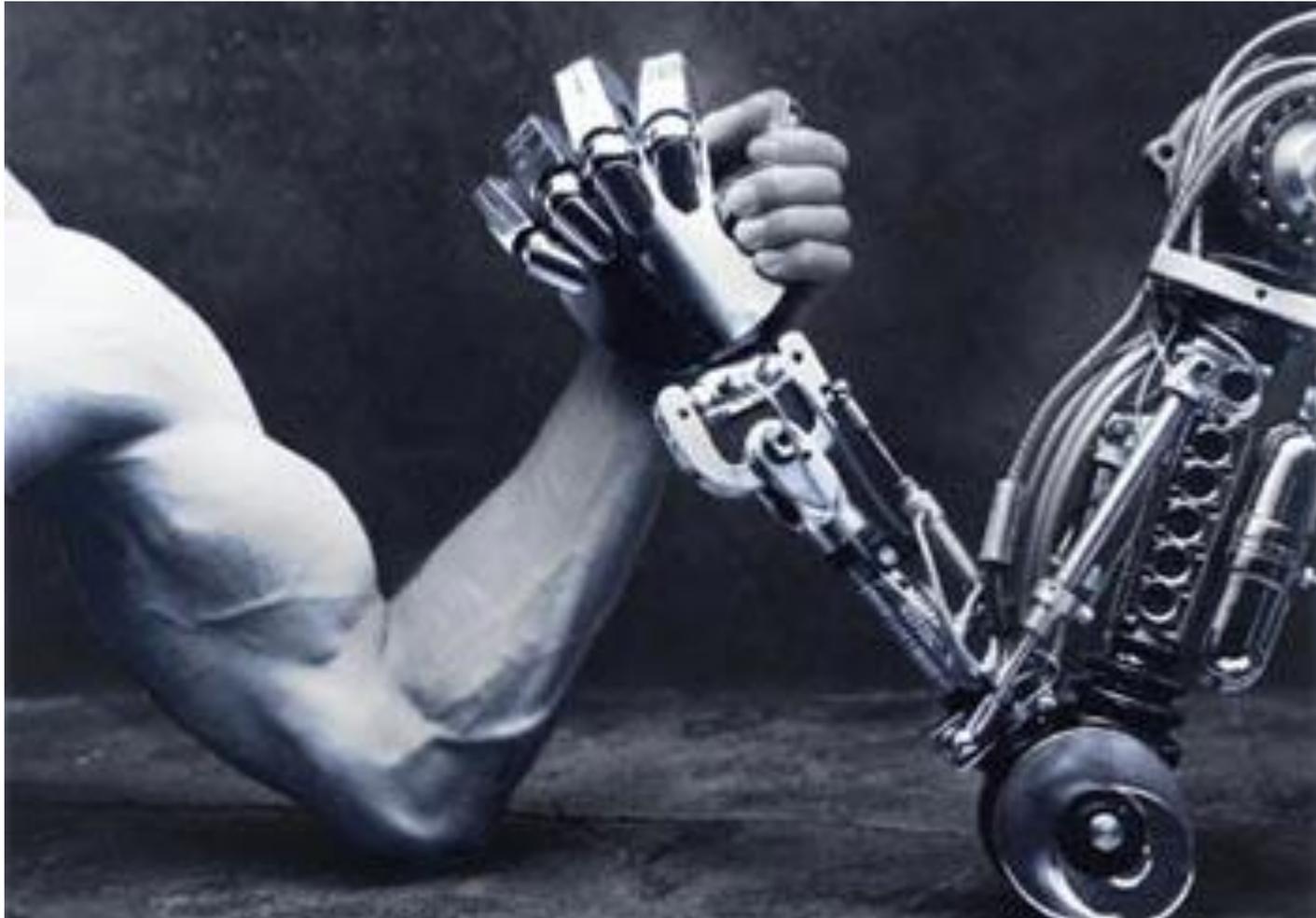
- ◆ 2009, M. Ford, *Lights in The Tunnel*:

"Is it possible that accelerating computer technology was a primary cause of the current global economic crisis—and that even more disruptive impacts lie ahead?"

- ◆ 2012, E. Brynjolfsson and A. McAfee, *Race Against The Machine*: "

Technological progress is accelerating innovation even as it leaves many types of workers behind"

Man vs Machine



Technological Unemployment

- ◆ J.M. Keynes, 1930: *Economic Possibilities for our Grandchildren*
 - "We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come - namely, **technological unemployment**. This means unemployment due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor."

Productivity and Unemployment

- ◆ A. Tabbarok, 2013: "I am growing increasingly annoyed with people who argue that the dark side of productivity growth is unemployment.
 - The "dark side" of productivity is merely another form of the *Luddite Fallacy* - the idea that new technology destroys jobs. If the Luddite fallacy were true we would all be out of work because productivity has been increasing for two centuries.

The Luddites, I

- ◆ The original Luddites were hosiery and lace workers in Nottingham, England in 1811. They smashed knitting machines that embodied new labor-saving technology as a protest against unemployment, publicizing their actions in circulars mysteriously signed, "King Ludd".*

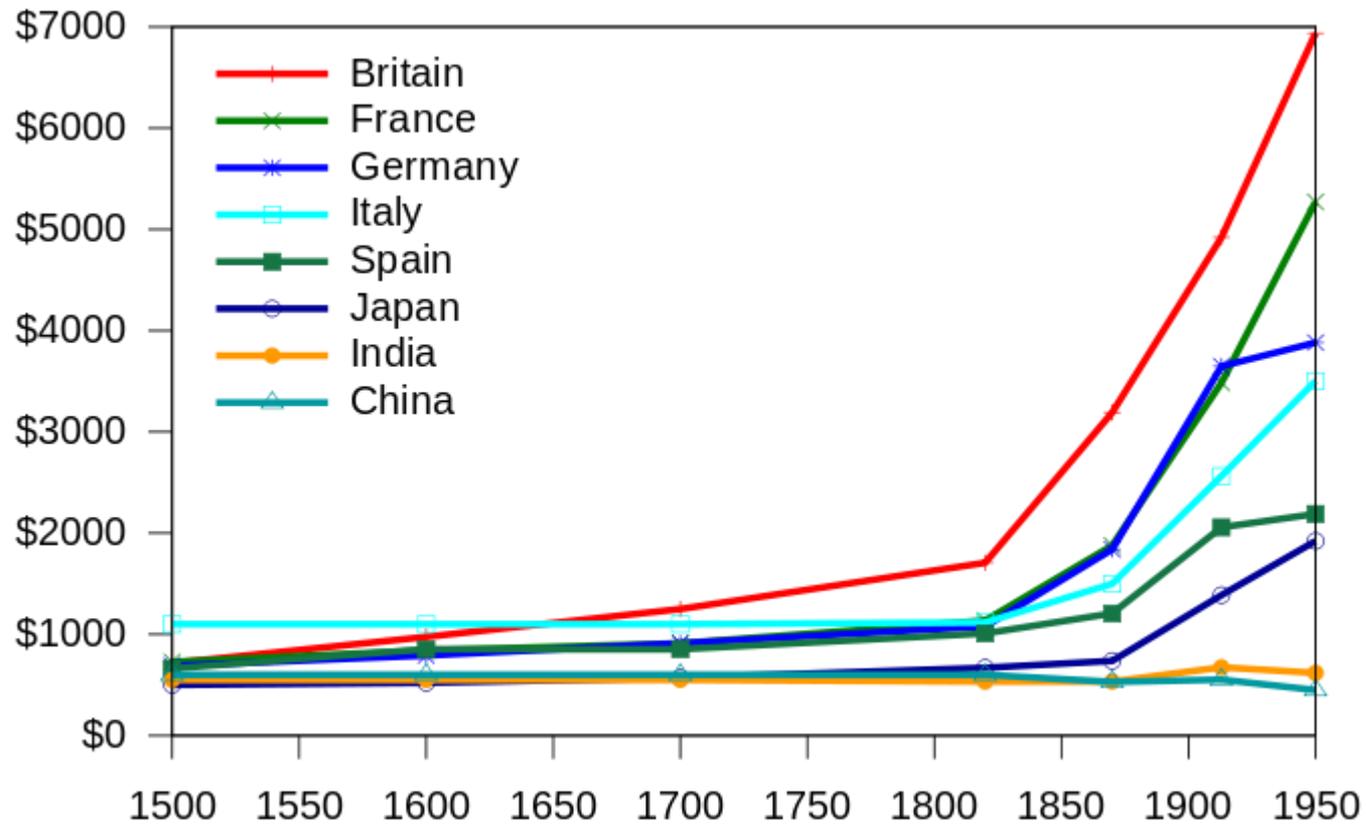
*In 1779, Ned Ludd is supposed to have broken two stocking frames in a fit of rage.

The Luddites, II

John Kay fleeing a mob intent on destroying his mechanical loom



Historical GDP Growth



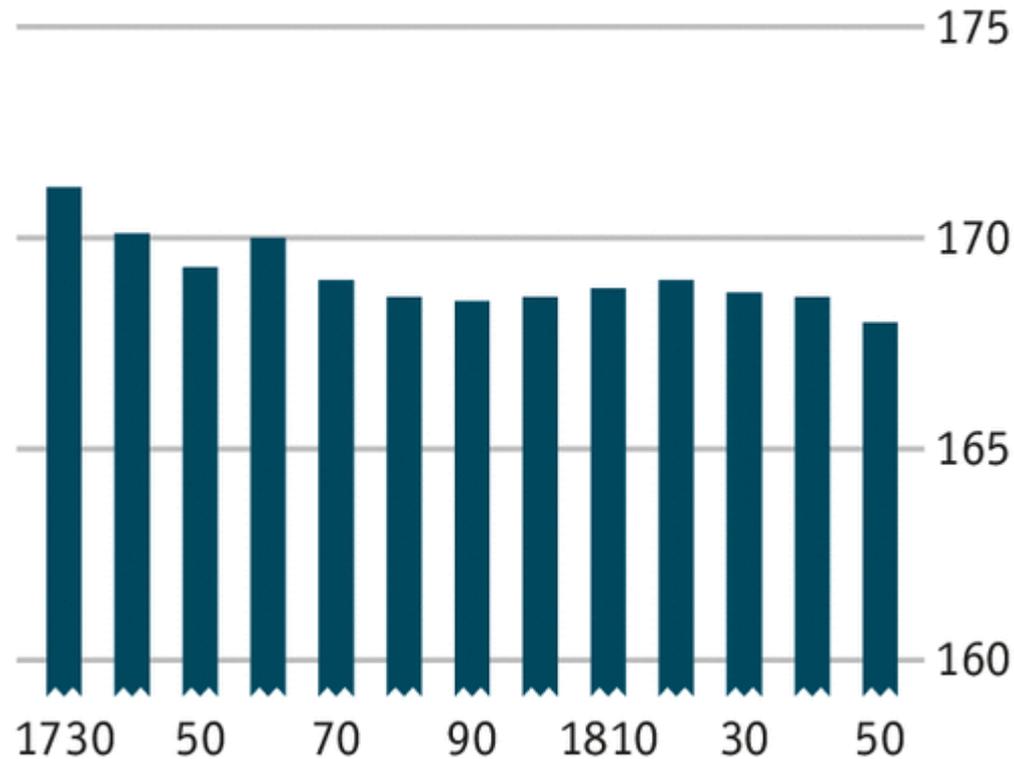
The Luddites, III

- ◆ R. Bray: Luddite Spring — The Huddersfield Luddite Uprising
 - “All available Luddite literature, usually in the form of popular songs, protest songs, and broadsheets, shows that unemployment, poverty, and starvation were their major concerns.”

Historical Income-Proxy Data, I

Mean height of English soldiers

Aged 20-23 years old, cm

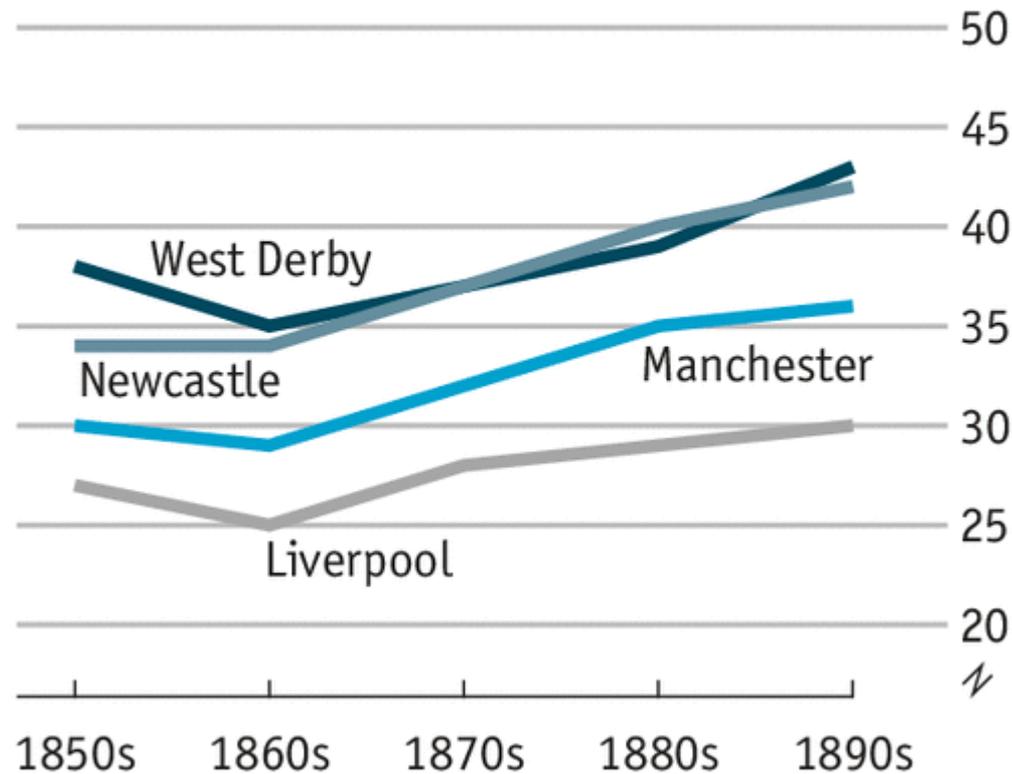


Source: Komlos, 1998

Historical Income-Proxy Data, II

Life expectancy at birth

Cities in England, years



Source: Szreter and Mooney, 1998

Communist Manifesto, 1848

- ◆ K. Marx and F. Engels: "Constant revolutionising of production, uninterrupted disturbance of all social conditions, everlasting uncertainty and agitation distinguish the bourgeois epoch from all earlier ones. All fixed, fast-frozen relations are swept away, all new-formed ones become antiquated before they can ossify. All that is solid melts into air, all that is holy is profaned, and man is at last compelled to face with sober senses his real conditions of life, and his relations with his kind."

Communist Revolutions

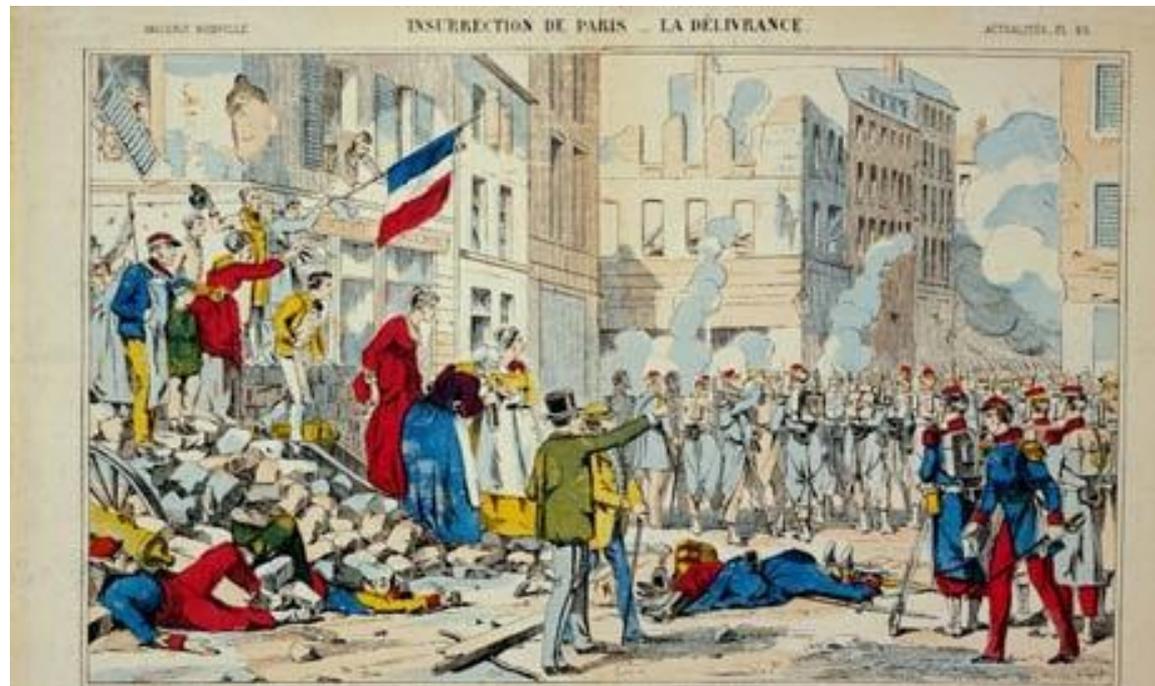
- ◆ Soviet Revolution, 1917
 - Estimate: Stalin killed 25M people

- ◆ Chinese Revolution, 1949
 - Estimate: Mao killed 50M people



The Paris Commune

- ◆ May 1871: Massacres in Paris as army takes control - 10,000 killed (estimate)



Evolution of Labor Laws

- ◆ Eliminate power to order corporal punishment, and hard labor for breach of labor contracts
- ◆ Eliminate right to enforce labor contracts
- ◆ Regulation of child labor
- ◆ Health and safety laws
- ◆ Regulation of working hours
- ◆ Allowing unionization

Bottom Line: Society responded to the new industrial reality.

Neo-Luddism, I

- ◆ The Economist, 2011: Difference Engine--Luddite Legacy
 - An apocryphal tale is told about Henry Ford II showing Walter Reuther, the veteran leader of the United Automobile Workers, around a newly automated car plant. "Walter, how are you going to get those robots to pay your union dues?", giped the boss of Ford Motor Company. Without skipping a beat, Reuther replied, "Henry, how are you going to get them to buy your cars?"

Neo-Luddism, II

◆ N. Wiener, 1949:

To: Walter Reuther, UAW

"I am Professor of Mathematics at the Massachusetts Institute of Technology, and I am the author of the recently published book, *Cybernetics*. I have been interested for a long time in the problem of automatic machinery and its social consequences. These consequences seem to me so great that I have made repeated attempts to get in touch with the Labor Union movement, and to try to acquaint them with what may be expected of automatic machinery in the near future."

“Disastrous Unemployment”

◆ N. Wiener, 1949:

“This apparatus is extremely flexible, and susceptible to mass production, and will undoubtedly lead to the factory without employees; as for example, the automatic automobile assembly line. In the hands of the present industrial set-up, the unemployment produced by such plants can only be disastrous.”

<https://libcom.org/history/father-cybernetics-norbert-wieners-letter-uaw-president-walter-reuther>

Why Socialism?

◆ A. Einstein, 1949:

“Technological progress frequently results in more unemployment rather than in an easing of the burden of work for all. ... The result of these developments is an oligarchy of private capital, the enormous power of which cannot be effectively checked even by a democratically-organized political society.”

<http://monthlyreview.org/2009/05/01/why-socialism/>

“The Triple Revolution”, I

- ◆ “Cybernation, Weaponry, Human Rights”
 - An open memorandum sent to U.S. President Lyndon B. Johnson March 22, 1964.
 - Drafted under the auspices of the Center for the Study of Democratic Institutions,
 - Signed by an array of noted social activists, professors, and technologists who identified themselves as the Ad Hoc Committee on the Triple Revolution.

http://www.educationanddemocracy.org/FSCfiles/C_CC2a_TripleRevolution.htm

“The Triple Revolution”, II

- ◆ The Cybernation Revolution: “A new era of production has begun. Its principles of organization are as different from those of the industrial era as those of the industrial era were different from the agricultural. The cybernation revolution has been brought about by the combination of the computer and the automated self-regulating machine. This results in a system of almost unlimited productive capacity which requires progressively less human labor.”

“The Triple Revolution”, III

- “The fundamental problem posed by the cybernation revolution in the U.S. is that it invalidates the general mechanism so far employed to undergird people’s rights as consumers. Up to this time economic resources have been distributed on the basis of contributions to production, with machines and men competing for employment on somewhat equal terms. In the developing cybernated system, potentially unlimited output can be achieved by systems of machines which will require little cooperation from human beings.”

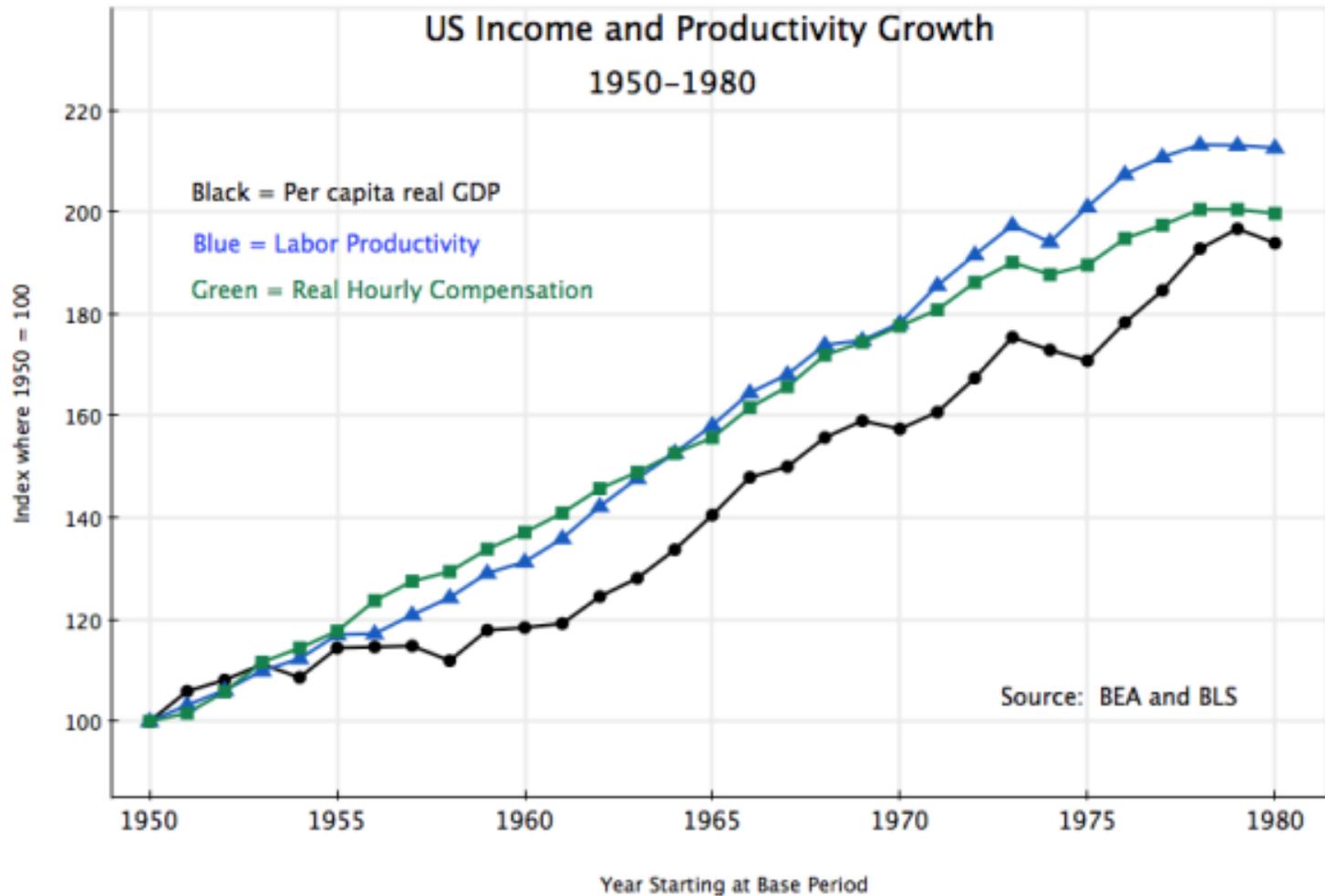
“The Brain Center at Whipples”

- ◆ Episode 153 of the American television series *The Twilight Zone*, aired on May 15, 1964 on CBS.
 - In 1967, Wallace V. Whipple, owner of a vast manufacturing corporation, installs the "X109B14 modified transistorized totally automated machine," which leads to layoffs.
 - Eventually, he is replaced by a robot.
 - "It isn't fair, Hanley! It isn't fair the way they...diminish us."

<https://www.youtube.com/watch?v=7jsQoyfO7U>

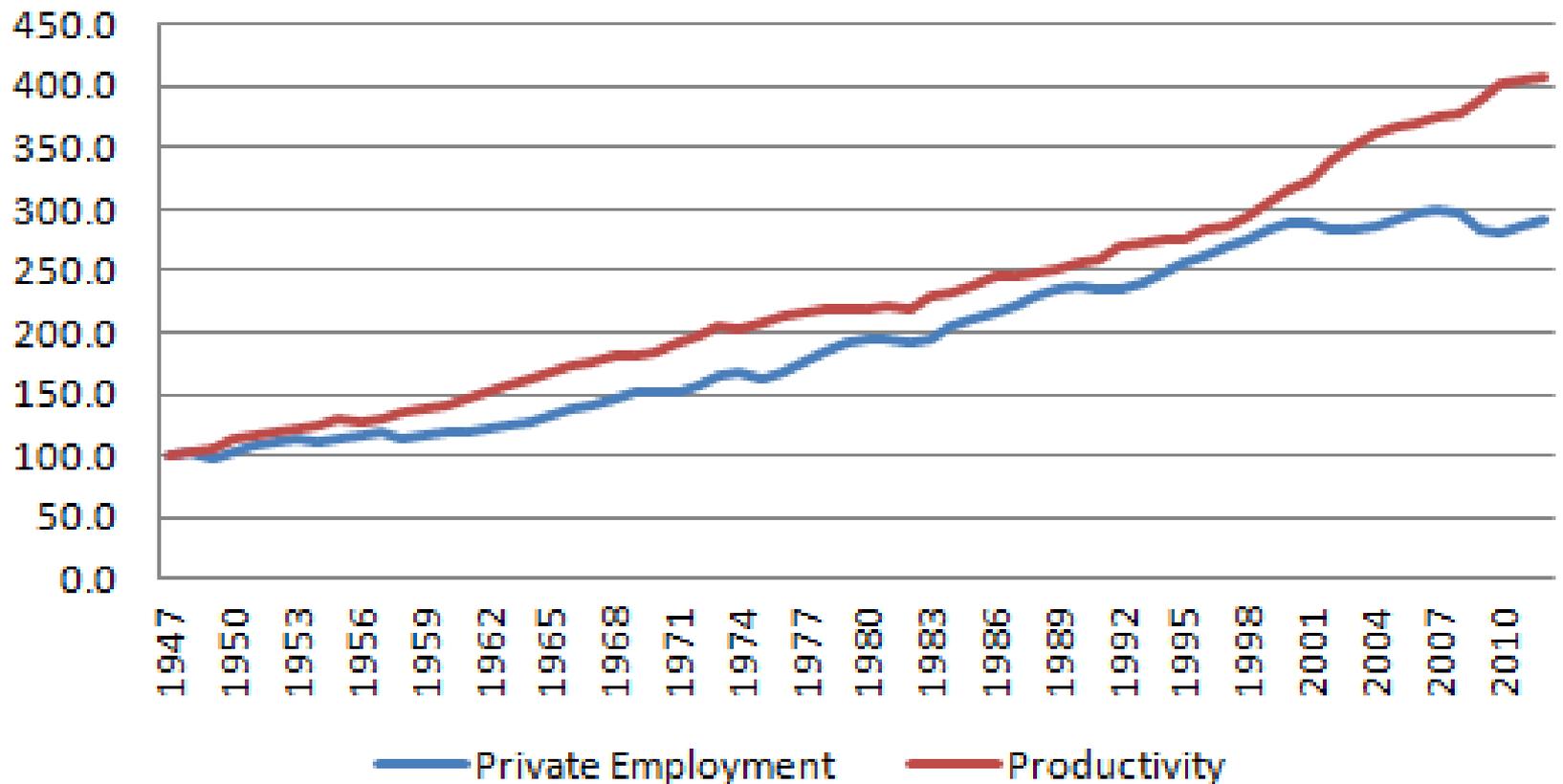
W

Pessimism Refuted, I



Pessimism Refuted, II

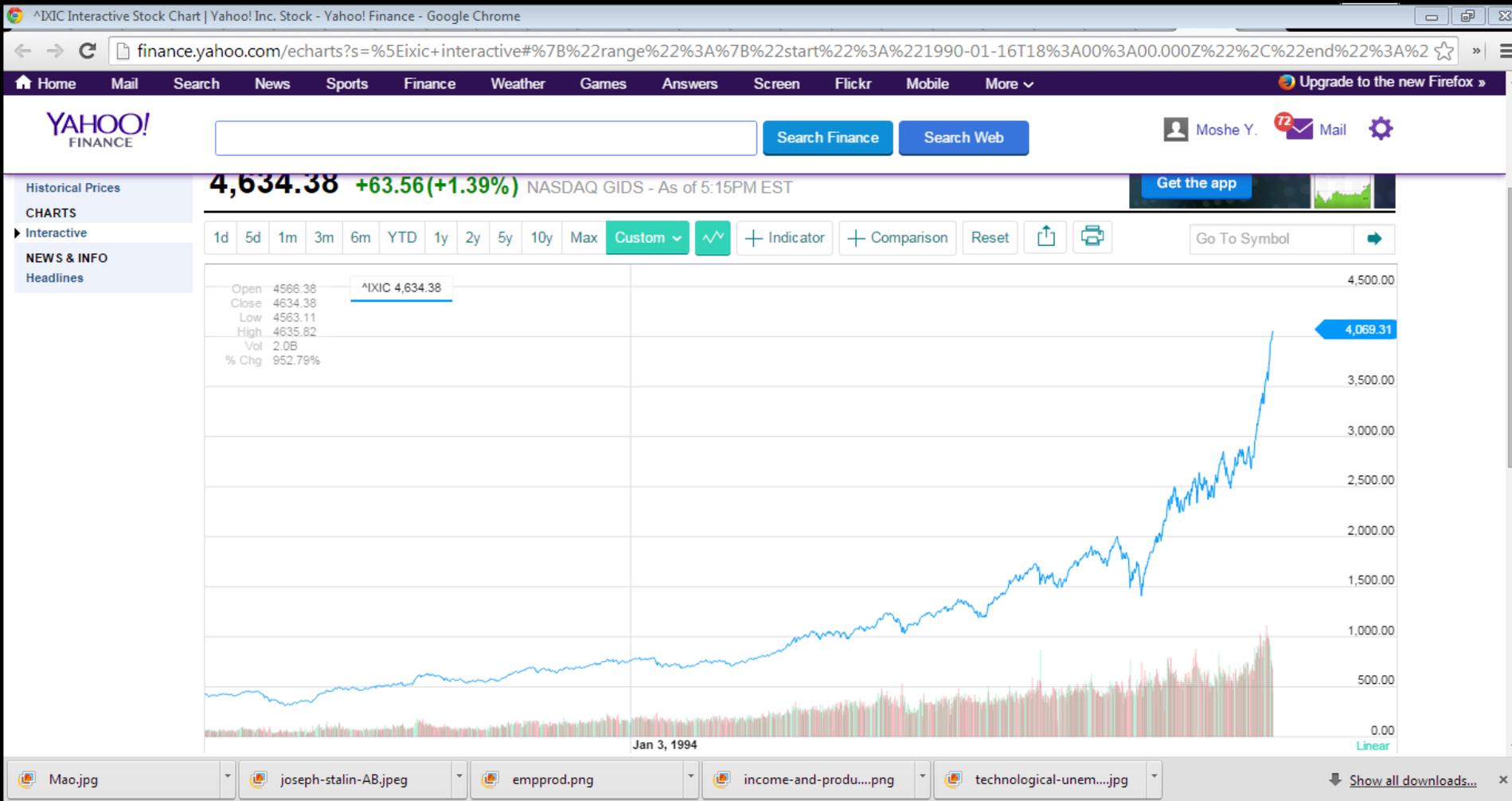
Employment and Productivity Growth, 1947-2012



“The End of Work”

- ◆ J. Rifkin, 1995: Worldwide unemployment would increase as information technology eliminated tens of millions of jobs in the manufacturing, agricultural and service sectors. There will be devastating impact of automation on blue-collar, retail and wholesale employees. While a small elite of corporate managers and knowledge workers would reap the benefits of the high-tech world economy, the American middle class would continue to shrink and the workplace become ever more stressful.

The Dot.Com Boom: NASDAQ



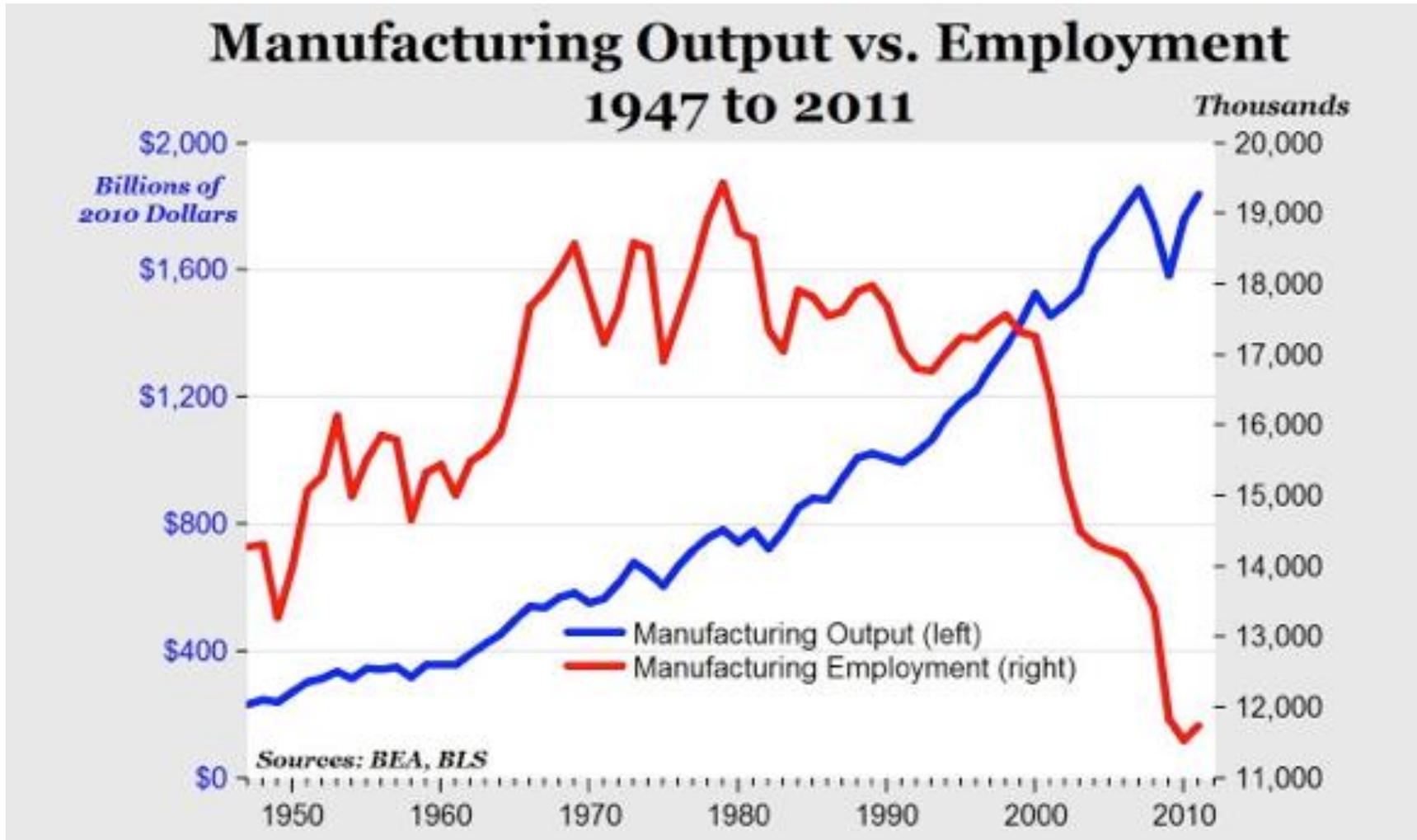
Luddism Redux

- ◆ W.H. Davidow and M.S. Malone, HBR, 2014: What Happens to Society When Robots Replace Workers?
 - “The technologies of the past, by replacing human muscle, increased the value of human effort - and in the process drove rapid economic progress. Those of the future, by substituting for man’s senses and brain, will accelerate that process - but at the risk of creating millions of citizens who are simply unable to contribute economically, and with greater damage to an already declining middle class.”

This Time It May Be Different!

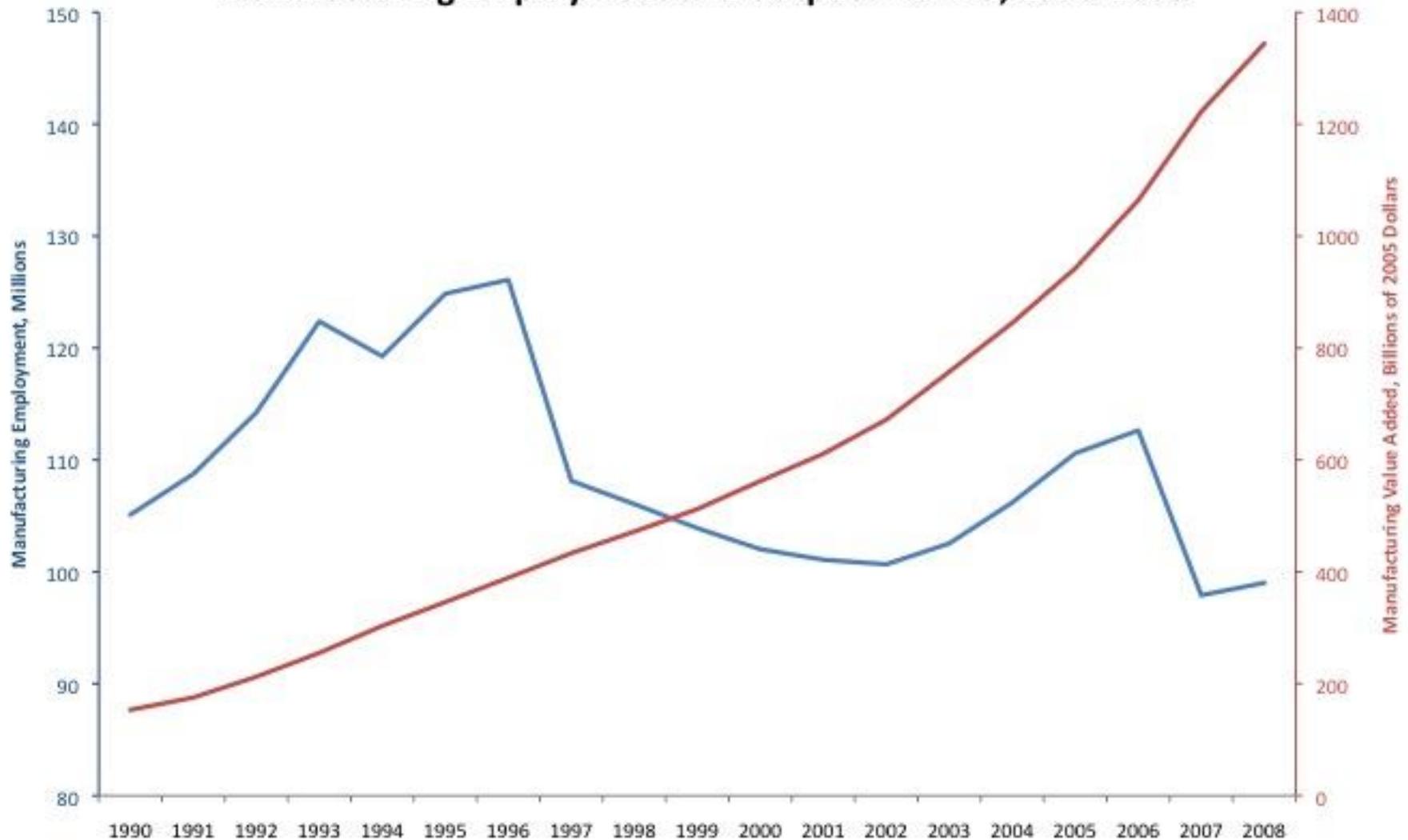
- ◆ Technology has been destroying jobs since the start of the Industrial Revolution, yet new jobs have continually been created.
- ◆ *But we have never faced machines that may be able to outcompete us in almost everything!*
- ◆ Thought experiment: Suppose that machines can do *everything* we can do. What is our comparative advantage?

Decoupling in Manufacturing, I



Decoupling in Manufacturing, II

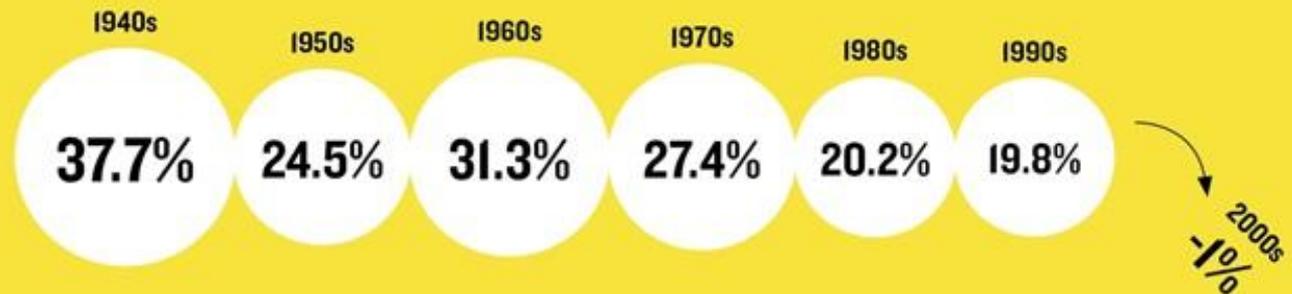
Manufacturing Employment and Output in China, 1990-2008



US Historical Job Growth

⊖ U.S. job growth by decade

The percentage change in nonfarm employment through the last seven decades illustrates just how dismal job prospects have been since 2000.

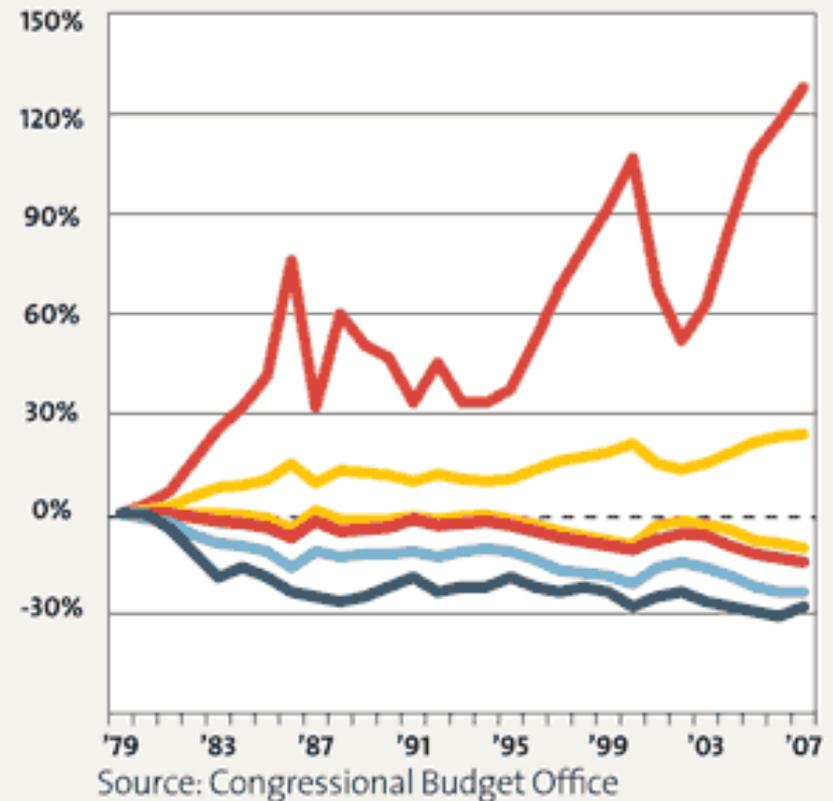


Growing Inequality, I

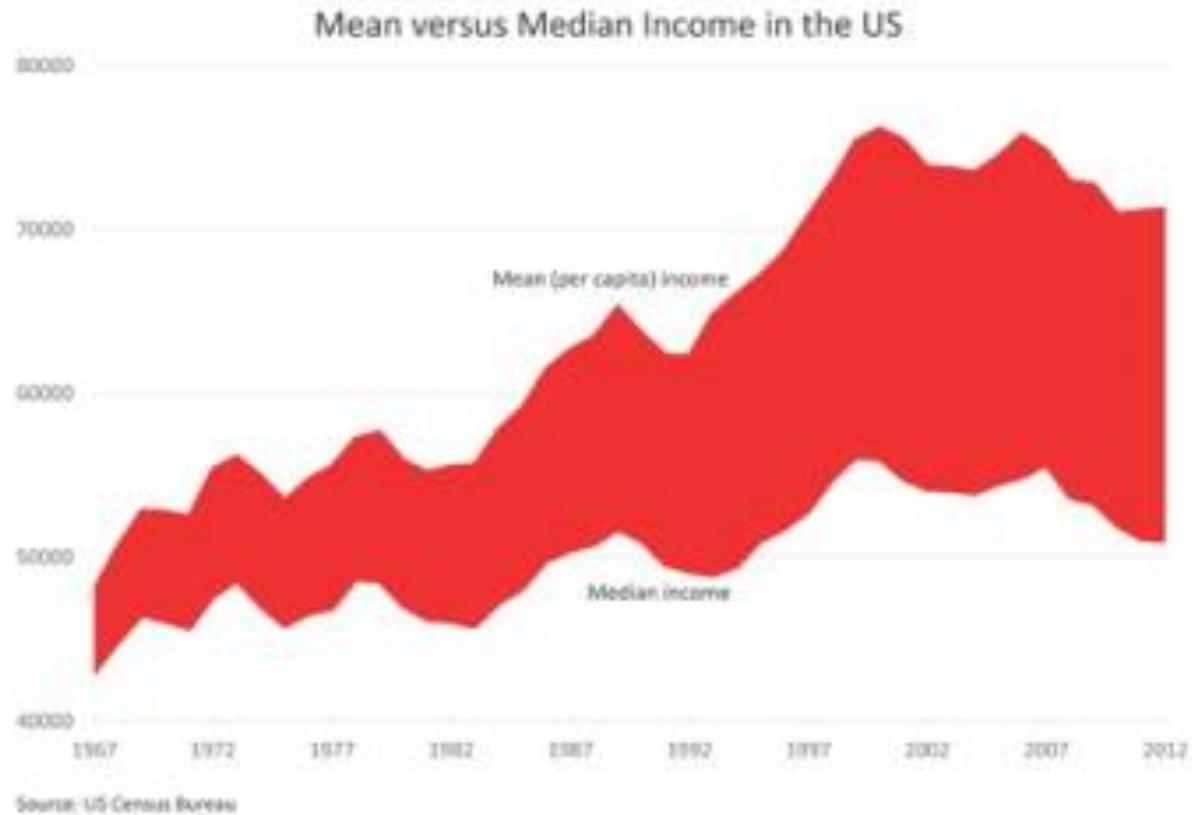
AVERAGE HOUSEHOLD INCOME
before taxes



CHANGE IN SHARE OF INCOME
vs. 1979, after taxes

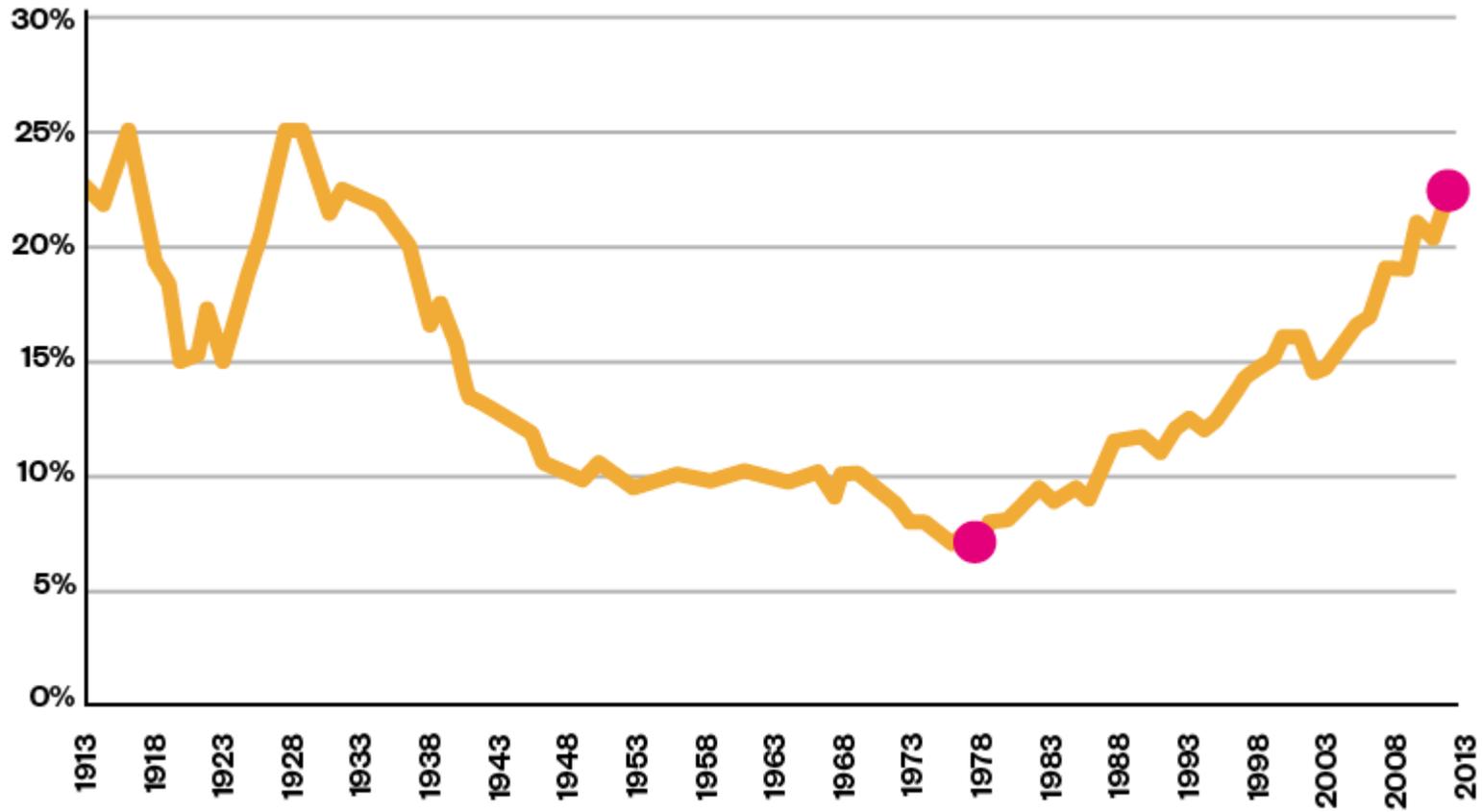


Growing Inequality, II



Growing Inequality, III

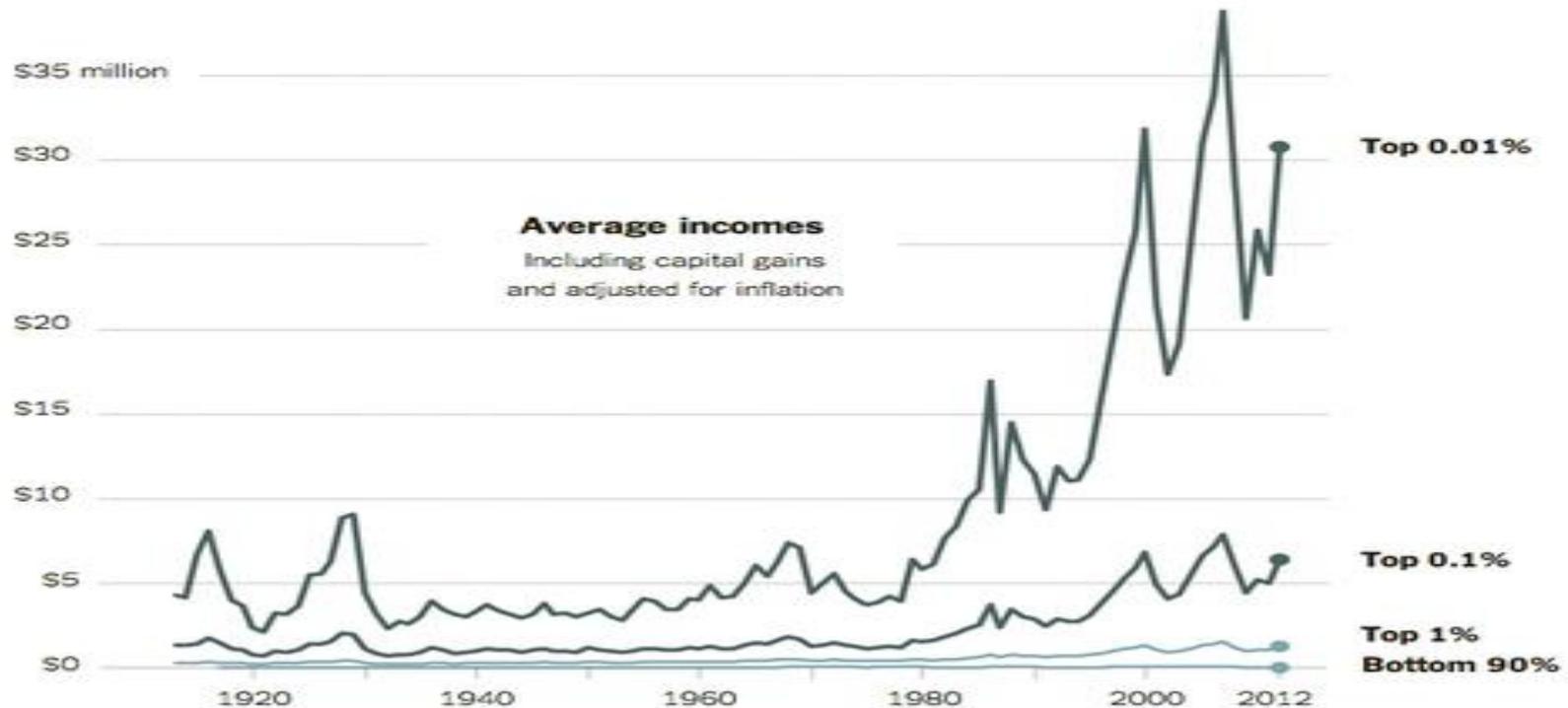
Percentage of wealth owned by top 1%



Growing Inequality, IV

Divergence At the Top

While the incomes of the top 1 percent of American households have pulled away significantly from those of the bottom 90 percent, an even larger gap has emerged at the very top of the scale.



By ALICIA PARLAPIANO

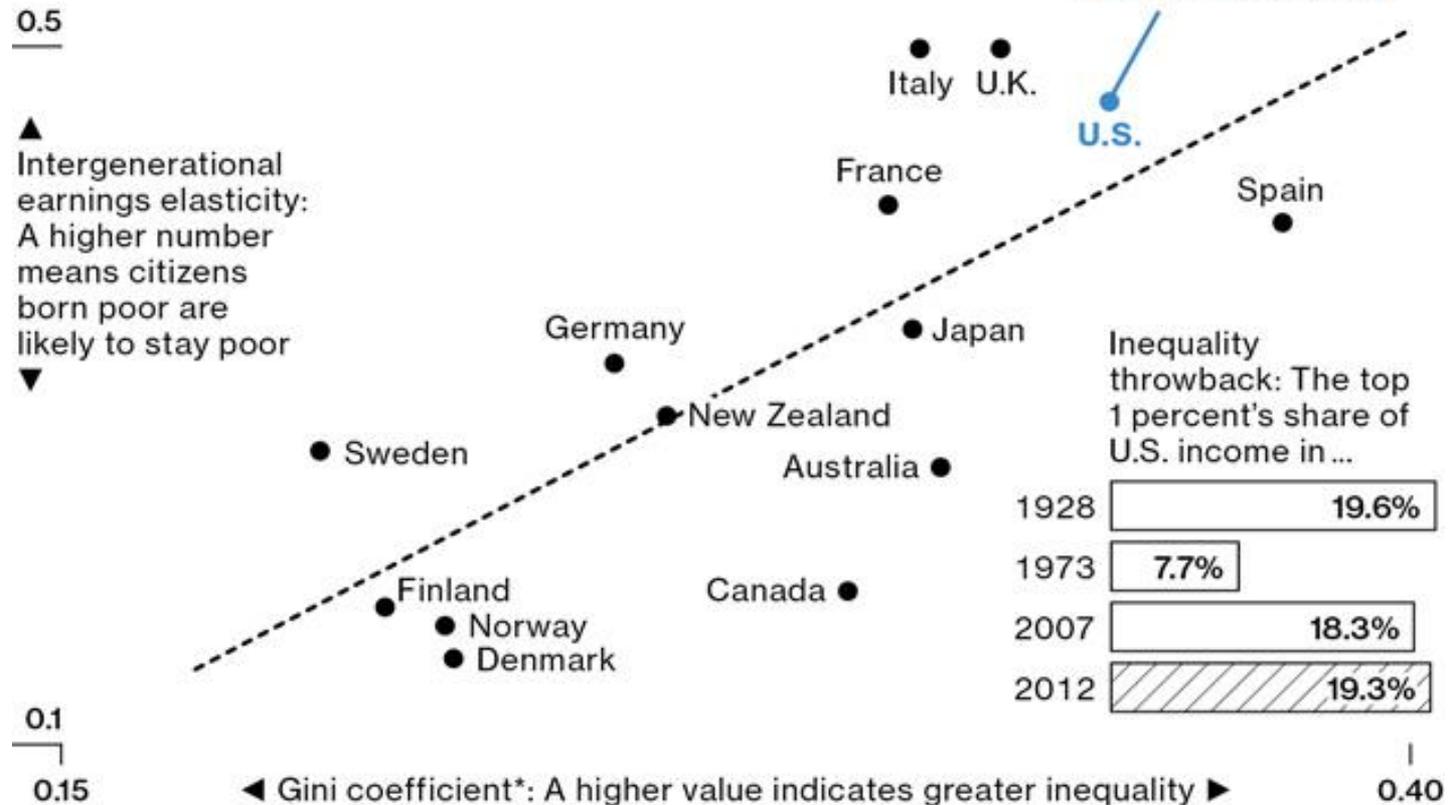
Source: The World Top Incomes Database

Inequality vs Social Mobility

The Great Gatsby Curve

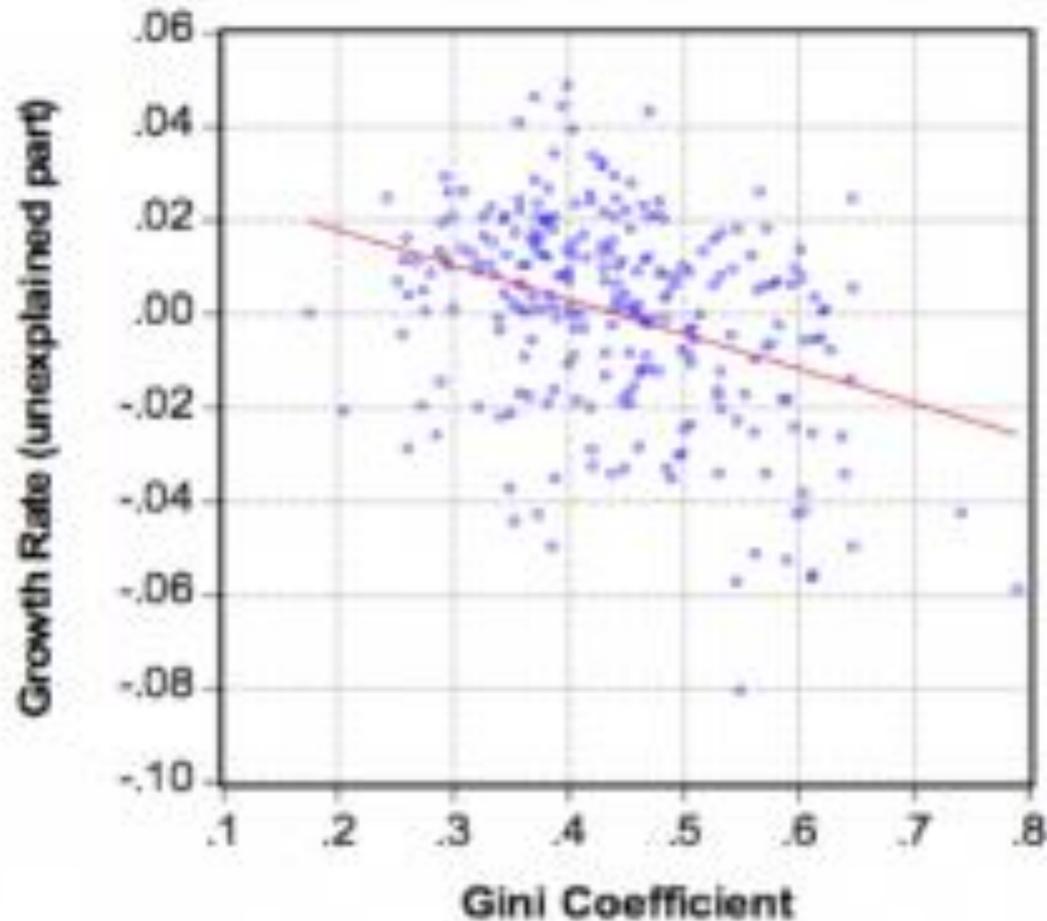
This graph, named after Fitzgerald's novel, traces the connection between income inequality and social mobility

The U.S. has the worst of both worlds: low social mobility and rapidly increasing inequality



Inequality vs Growth

Figure 2: Effect of Income Inequality on Economic Growth



This graph corresponds to the regression system in Table 4, column 2. The curve shows the partial relation between the growth rate of per capita GDP and the Gini coefficient, holding fixed the estimated effects of the explanatory variables other

Labor Share of National Economies

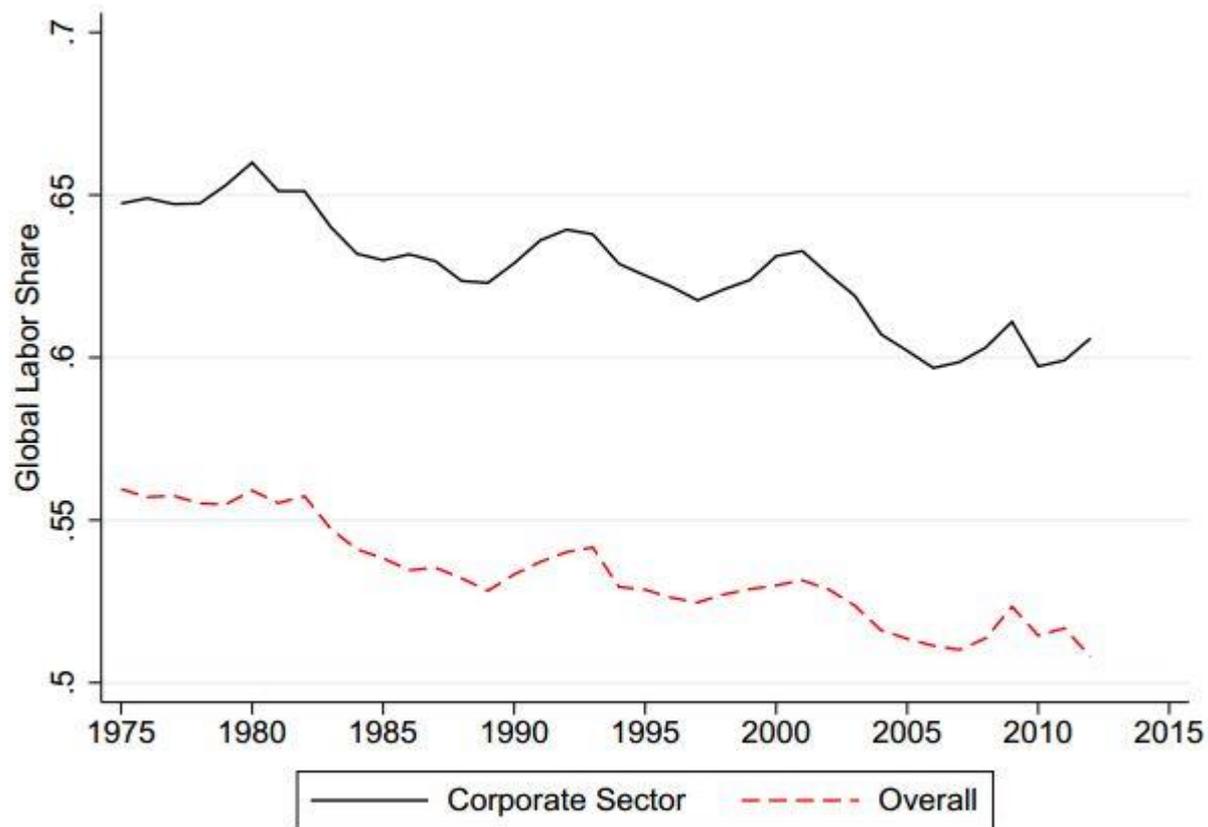
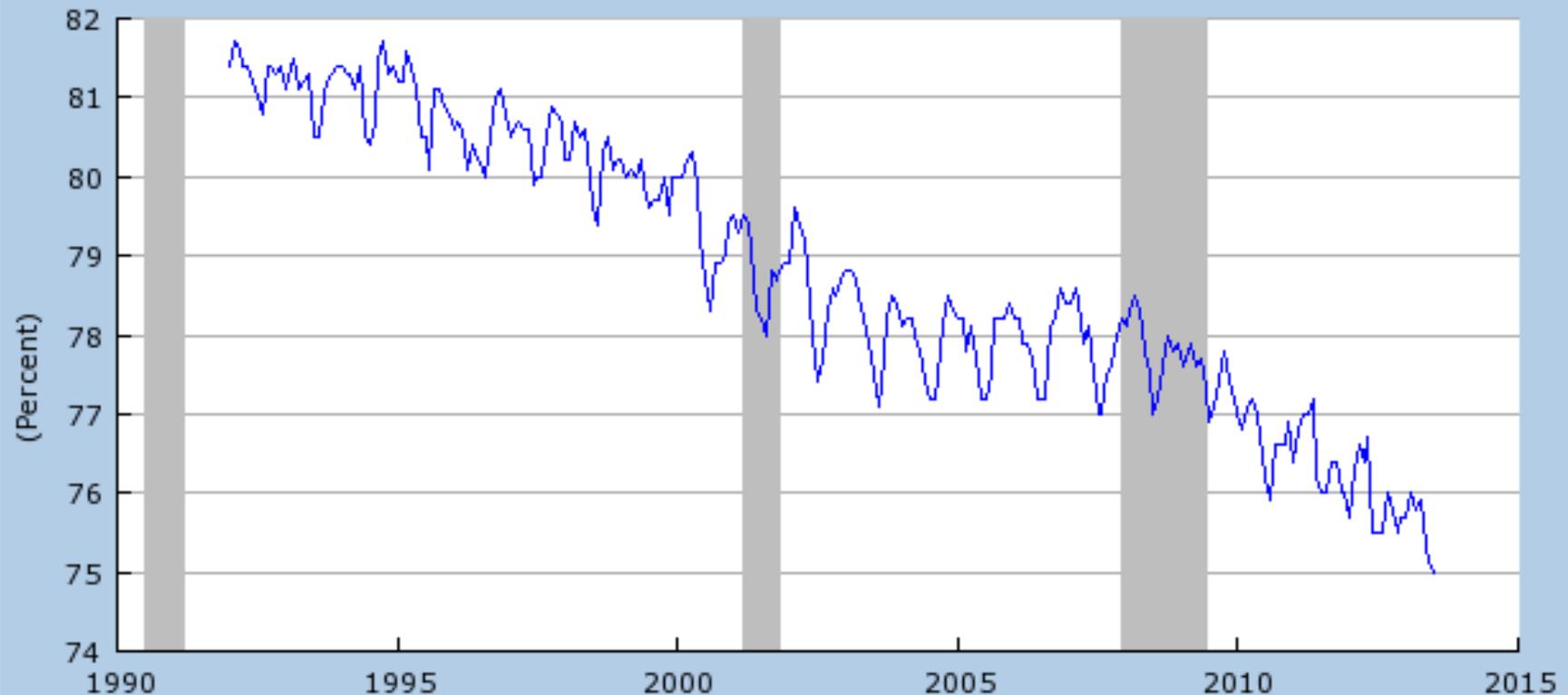


Figure 1: Declining Global Labor Share

Labor Force Participation

Civilian Labor Force Participation Rate - Bachelor's degree and higher, 25 years and over (LNU01327662)

Source: U.S. Department of Labor: Bureau of Labor Statistics

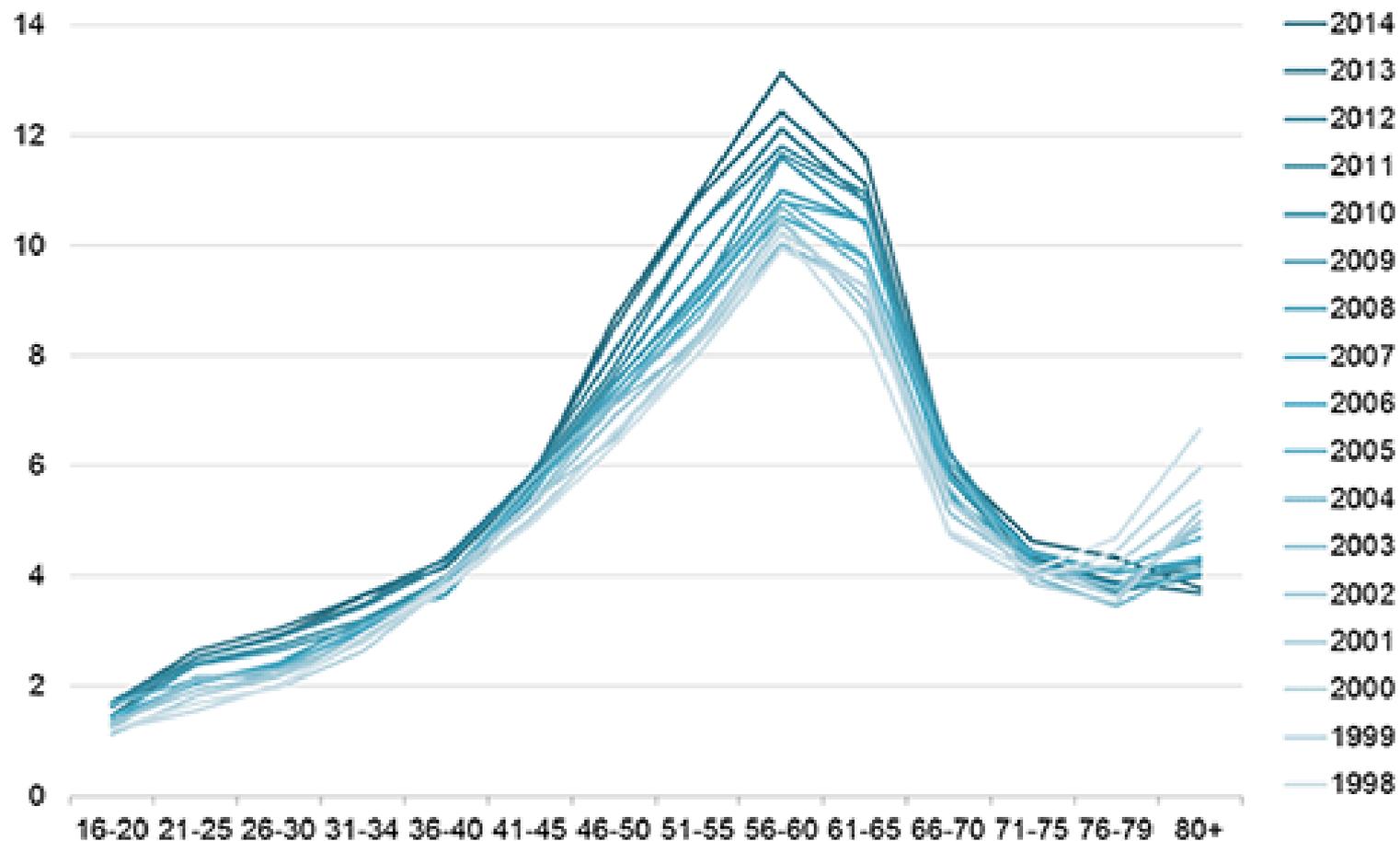


Shaded areas indicate US recessions.
2013 research.stlouisfed.org



Labor Force Participation

Percent of Age Group Reporting Disability or Illness as the Reason for Not Participating in the Labor Market



Sources: Current Population Survey/Author's calculations

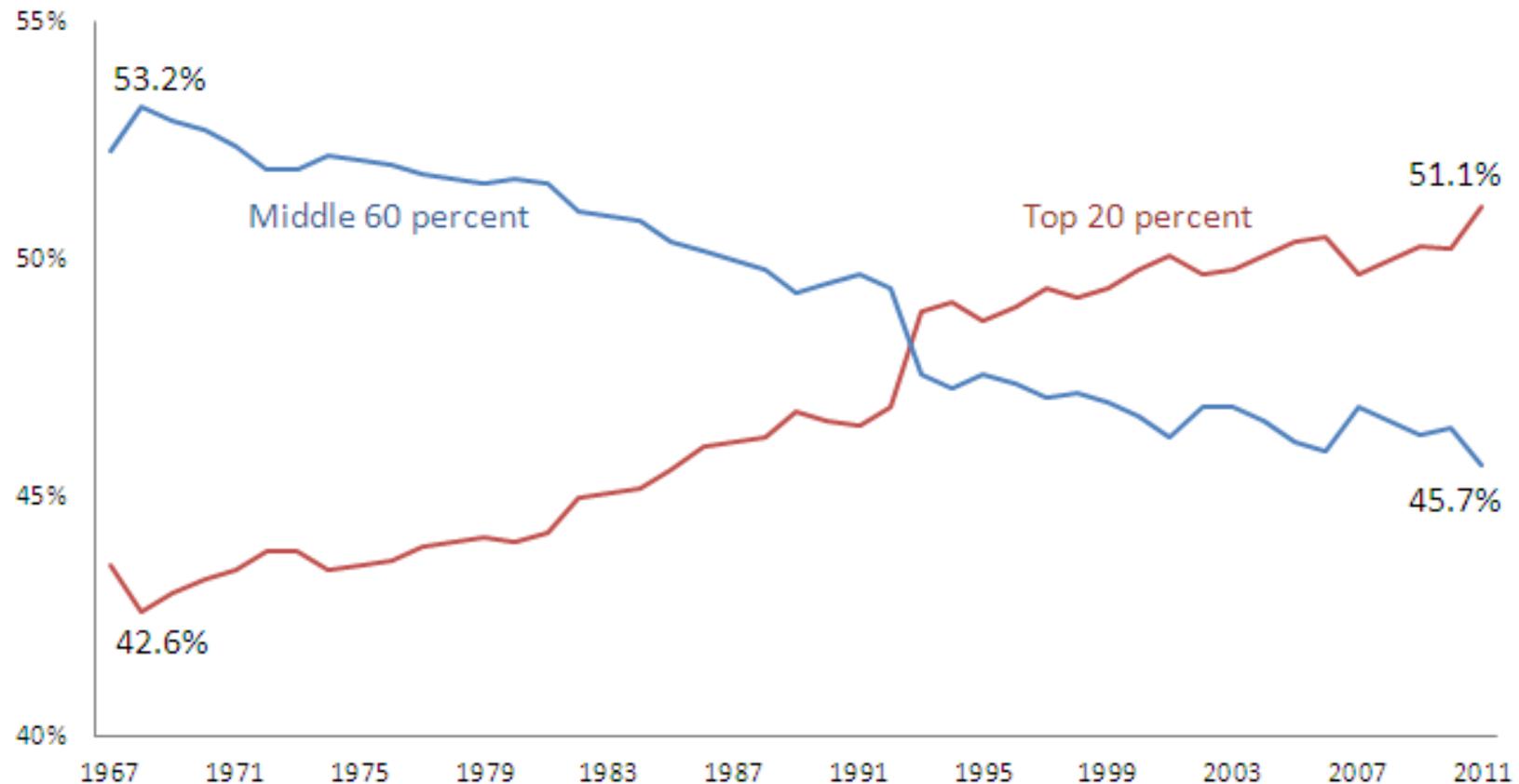
Wages vs. GDP



Decline of Middle Class, I

The decline of the American middle class

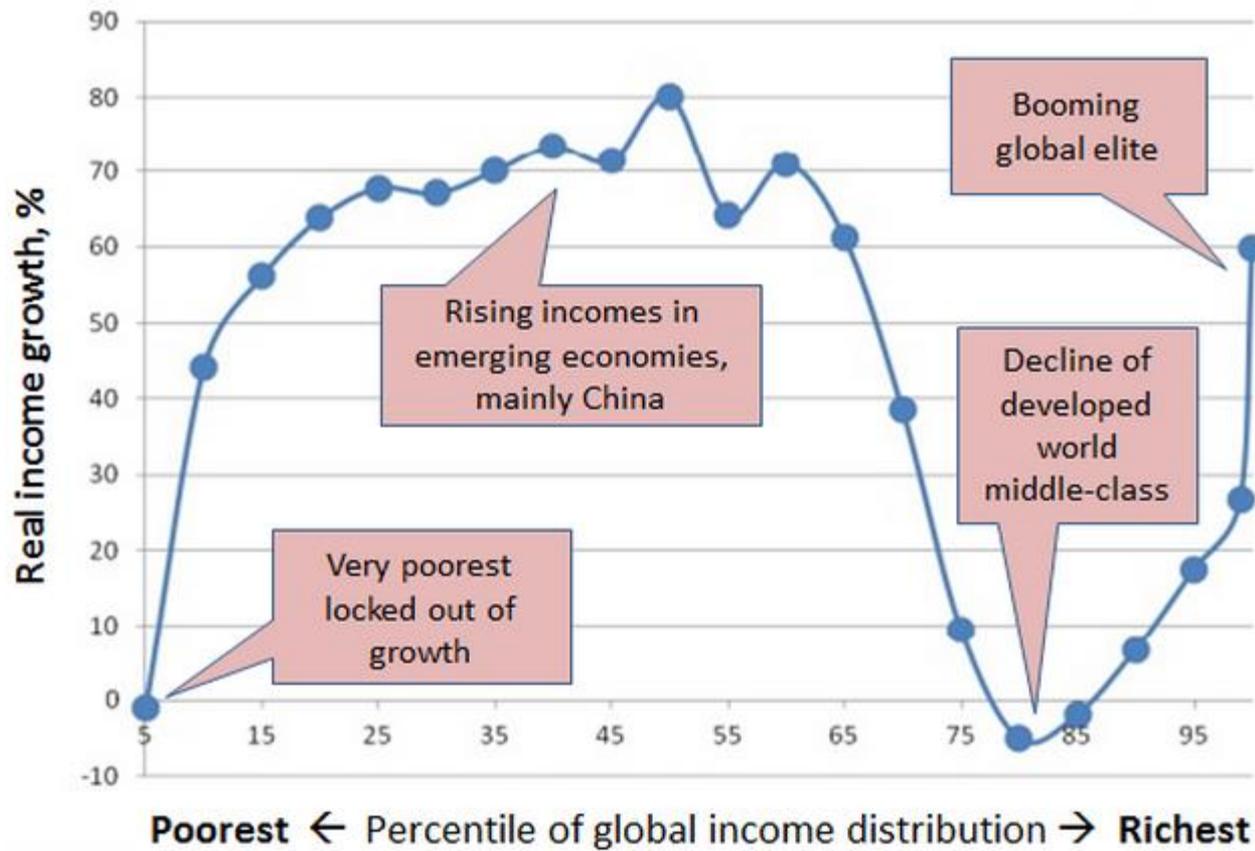
Share of aggregate income per household income group



Source: U.S. Census Bureau

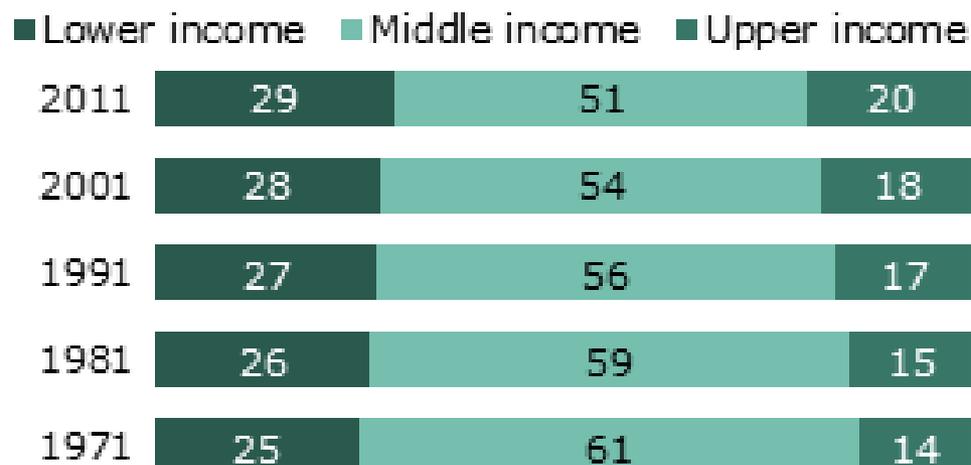
Decline of Middle Class, II

Global income growth from 1988 to 2008



Decline of Middle Class, III

Percentage Distribution of Adults by Income Category, 1971-2011



Note: Adults are assigned to income categories based on their size-adjusted household income in the calendar year prior to the survey year (e.g., 2010 income is from the 2011 survey).

Source: Pew Research Center tabulations of the Current Population Survey, Annual Social and Economic Supplements, 1971-2011

PEW RESEARCH CENTER

Automation and Labor – Complex Dynamics

- ◆ *Factor-Biased Technological Change*
 - Technology makes capital and high-skill workers more productive, encourages financialization
- ◆ *Class-Biased Technological Change*
 - Technology makes capital and high-skill workers more powerful politically

Outcome: Decline of labor and rise of inequality

“Widespread and Deep Business Impact”

Gartner, Oct. 2013: “Smart Machines Will Have Widespread and Deep Business Impact Through 2020”

“Most business and thought leaders underestimate the potential of smart machines to take over millions of middle-class jobs in the coming decades. Job destruction will happen at a faster pace, with machine-driven job elimination overwhelming the market's ability to create valuable new ones.

AI, Robotics, and the Future of Jobs

- ◆ **Pew Center, 2014:** "The vast majority of respondents anticipate that robotics and artificial intelligence will permeate wide segments of daily life by 2025, with huge implications for a range of industries such as health care, transport and logistics, customer service, and home maintenance. But even as they are largely consistent in their predictions for the evolution of technology itself, they are deeply divided on how advances in AI and robotics will impact the economic and employment picture over the next decade."

<http://www.pewinternet.org/2014/08/06/future-of-jobs/>

Oxford Study

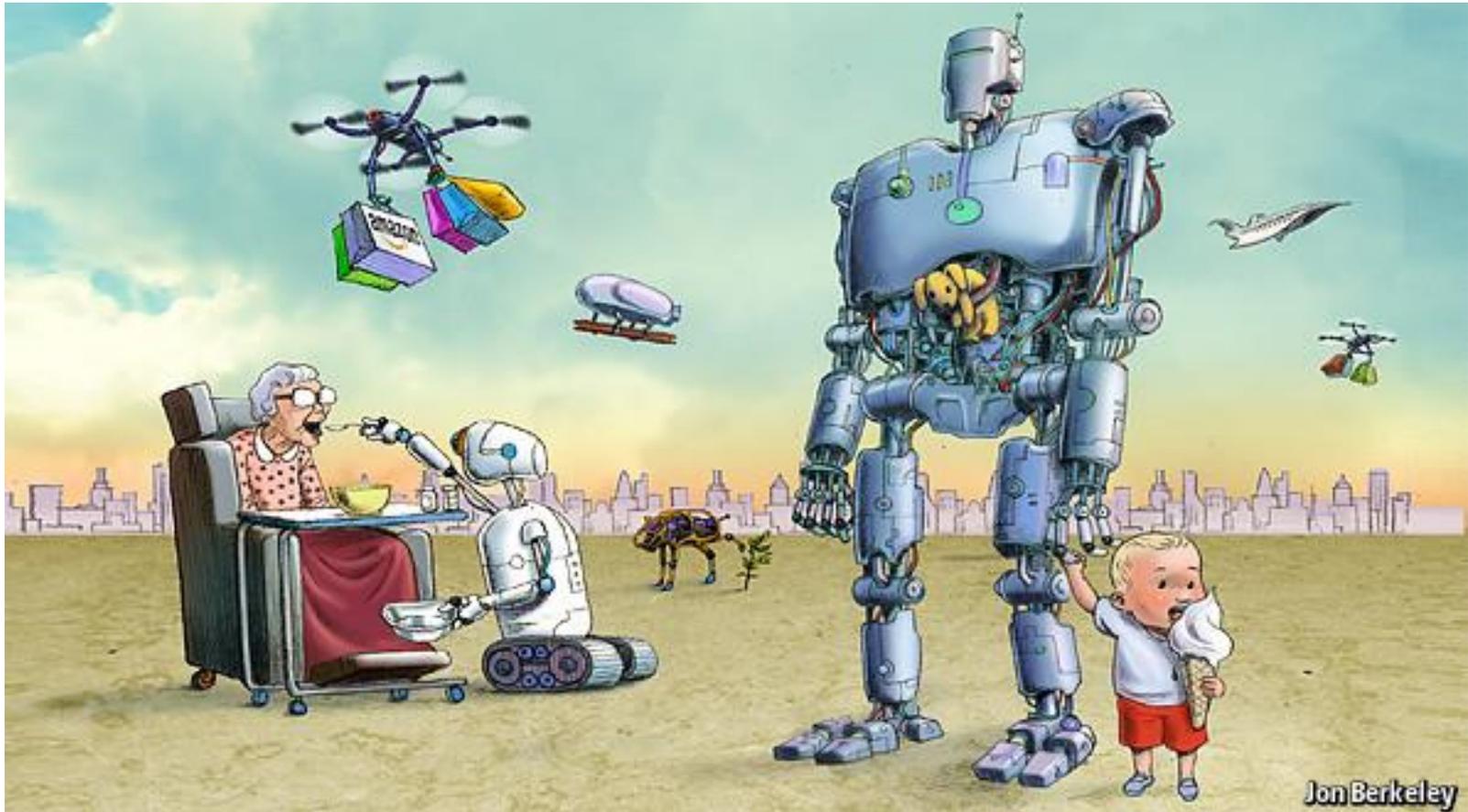
- ◆ Oxford's Programme on the Impacts of Future Technology, 2013: "45 percent of America's occupations will be automated within the next 20 years."
 - 1st wave: transportation/logistics, production labor, administrative support, services, sales.
 - 2nd wave: management, science and engineering, the arts

http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

Popular Angst

- ◆ "More Jobs Predicted for Machines, Not People"
- ◆ "Will Robots Steal Your Job?"
- ◆ "Marathon Machine: unskilled workers are struggling to Keep up with technological change"
- ◆ "It's a Man vs. Machine Recovery"
- ◆ "The Robots Are Winning",
- ◆ "The Rise of the Robots".

The Economist: Rise of The Robots



The Big Question

If machines are capable of doing almost any work humans can do, what will humans do?

- ◆ When? "Predictions are hard, especially about the future."
- ◆ Say, 2045
 - Not near future
 - Not too far future

“Losing a Job”

Cristobal Young, Stanford, 2012: “This study explores the non-pecuniary cost of unemployment by tracking people who enter and exit unemployment. The main result is very clear: unemployment is a trigger event that sets off a large shift in people’s subjective well-being, on an order of magnitude greater than the effect of changes in family structure, home ownership, or parental status. Loss of work seems particularly hard to take.”

“The Coming Jobs War”

Jim Clifton, Chairman and CEO of Gallup:

"The primary will of the world is no longer about peace or freedom or even democracy; it is not about having a family, and it is neither about God nor about owning a home or land. The will of the world is first and foremost to have a good job. Everything else comes after that."

The Immigration Answer



The Leisure Answer, I

- ◆ *What is the problem? Machines will do all the work and we will spend our time in leisure activities.*
 - Shorter work week
 - Basic Income Guarantee

Shorter Work Week

Larry Page, 2014: "The extension of that is you have widespread unemployment. You just reduce work time. Everyone I've asked- I've asked a lot of people about this. If I ask them, 'Would you like an extra week of vacation?' They raise their hands, 100-percent of the people. 'Two weeks vacation, or a four-day work week?' Everyone will raise their hand."

Reminder: Keynes predicted a 15-hours work week.

Needed: legislation

Basic Income Guarantee

Definition: a social-security system in which all citizens or residents regularly receive an *unconditional* sum of money in addition to any income received from elsewhere.

- ◆ First Muslim Caliph, introduced a guaranteed minimum income, granting each man, woman, and child ten dirhams annually
- ◆ In 1795, Thomas Paine advocated a Citizen's Dividend to all US citizens as compensation for "loss of his or her natural inheritance, by the introduction of the system of landed property"

The Conservative Case for BIG

- ◆ Charles Murray, 2006: eliminate all welfare transfer programs, including Social Security and Medicare, and substitute an annual \$10K cash grant to everyone 21 years and older.
 - fight poverty and reduce government spending and intrusion.
 - The Alaska Permanent Fund, funded by state oil revenues, sends annual dividend checks to state's residents.

The Leisure Answer, II

- ◆ Larry Page: "I think there's also a social problem that a lot of people aren't happy if they don't have anything to do. So we need to give people things to do. We need to feel like you're needed, wanted and have something productive to do."
 - Can one live leisure-only "good life" (*a philosophical term for the life that one would like to live*)? Recall "panem et circenses."

Bread and Entertainment



The Eloi

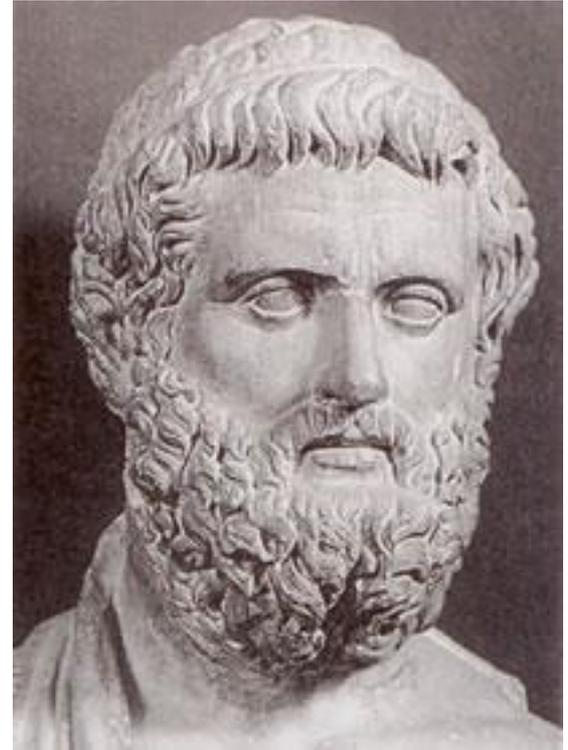
- ◆ H.G. Wells, 1895: "The Time Machine"
 - The Eloi: with no real challenges, they have lost the spirit, intelligence, and physical fitness of humanity at its peak.



Theodore Herzl, 1904: "Solon in Lydia", I

Solon: An Athenian statesman,
638 BC - 558 BC

"It's flour," said Eukosmos, "
Flour that I myself have
created!"



"And what is your advice, Solon?" "Slay him!"

“Solon in Lydia”, II

“The men were lazy and thereby restless. They had less to worry about, and therefore gave themselves to all sorts of dangerous pastimes. They were quarrelsome and licentious, as they were not exhausted from work. They also applied to politics, in an unruly, rebellious kind, and began to murmur against Croesus.”

“Solon in Lydia”, III

“Well, Eukosmos,” Solon said, “You're still of the opinion that you can make the people happy? You hear the commotion down there. Do you want them still to have bread without worry, without work? Empty this drinking bowl! Drink it for the welfare of mankind!”

And Eukosmos drank.

The Policy Challenge

- ◆ Brynjolfsson and McAfee: "There is no economic law that says that everyone, or even most people, automatically benefit from technological progress."
- ◆ Richard Murnane and Frank Levy: "*The central domestic policy challenge* of the 21st century is how to ensure middle-class prosperity and individual success in an era of over-intensifying globalization and technological upheaval."

Heaven or Hell?

- ◆ Nigel Cameron: "Will a world without work be heaven - or hell? Now is the time to think it through!"
 - Genesis 3:19: "In the sweat of thy face shalt thou eat bread."

Our Social Responsibility

- ◆ Turing, 1950: "We may hope that machines will eventually compete with men in all purely intellectual fields ... we can see plenty there that needs to be done."
 - We cannot rush with technology without preparing for the consequences.
 - We have done it with fossil fuels, and we cannot deal with the consequences.
 - What is our social responsibility as computer scientists?