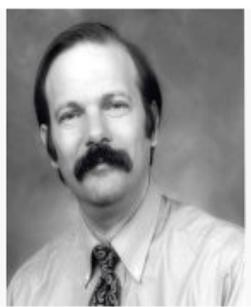


# ***Humans, Machines, and Work: The Future is Now***

***Moshe Y. Vardi  
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***vardi@cs.rice.edu***

***Follow me on social media!***



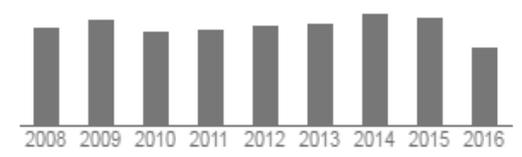
# Moshe Y. Vardi

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<a href="#">Reasoning about knowledge</a>	R Fagin, JY Halpern, Y Moses, M Vardi MIT press	4346	2004
<a href="#">An automata-theoretic approach to automatic program verification</a>	MY Vardi, P Wolper Proceedings of the First Symposium on Logic in Computer Science, 322-331	1789	1986
<a href="#">The complexity of relational query languages</a>	MY Vardi Proceedings of the fourteenth annual ACM symposium on Theory of computing ...	1507	1982
<a href="#">Reasoning about infinite computations</a>	MY Vardi, P Wolper Information and computation 115 (1), 1-37	1129 *	1994
<a href="#">Simple on-the-fly automatic verification of linear temporal logic</a>	R Gerth, D Peled, MY Vardi, P Wolper Protocol Specification, Testing and Verification XV, 3-18	902	1996

### Co-authors [View all...](#)

- Orna Kupferman
- Ronald Fagin
- Joseph Halpern
- Pierre Wolper
- Yoram Moses
- Giuseppe De Giacomo
- Phokion Kolaitis
- Diego Calvanese
- Maurizio Lenzerini

# science Would you bet against sex robots? AI 'could leave half of world unemployed'

Scientist Moshe Vardi tells colleagues that change could come within 30 years, with few professions immune to effect of advanced artificial intelligence

- ['Public alienation undermines scientific efforts to improve lives'](#)
- ['Rogue scientists' could exploit gene editing technology, experts warn](#)



gton

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# ***Birth of Artificial Intelligence***

- ◆ 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.

# ***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 research funding
- ◆ The second AI winter 1987–1993: the “Japanese Fifth-Generation bust” and dearth of research funding

# ***AI Breakthroughs, I***

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



# ***AI Breakthroughs, II***

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



# ***AI Breakthroughs, III***

- ◆ 2016: AlphaGo beats Lee Se-dol to take Google DeepMind Challenge series!



# ***AI Breakthroughs, IV***

- ◆ 2017: Artificial intelligence goes deep to beat humans at poker!



# ***AI Develops Intuition***

- ◆ "AlphaGo combines tree-search techniques with search-space-reduction techniques that use machine learning."
  - In other words, AlphaGo develops "intuition" for Go playing.
- ◆ Machine learning provides a response to Polanyi's Paradox (1966): "We can know more than we can tell... The skill of a driver cannot be replaced by a thorough schooling in the theory of the motorcar"

# ***Automated Driving, I***

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



# AI Breakthroughs, II

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



# ***Automated Driving, III***



# ***Transportation Revolutions, I***

Approx. 5000BC: *invention of the wheel*



# ***Transportation Revolutions, I***

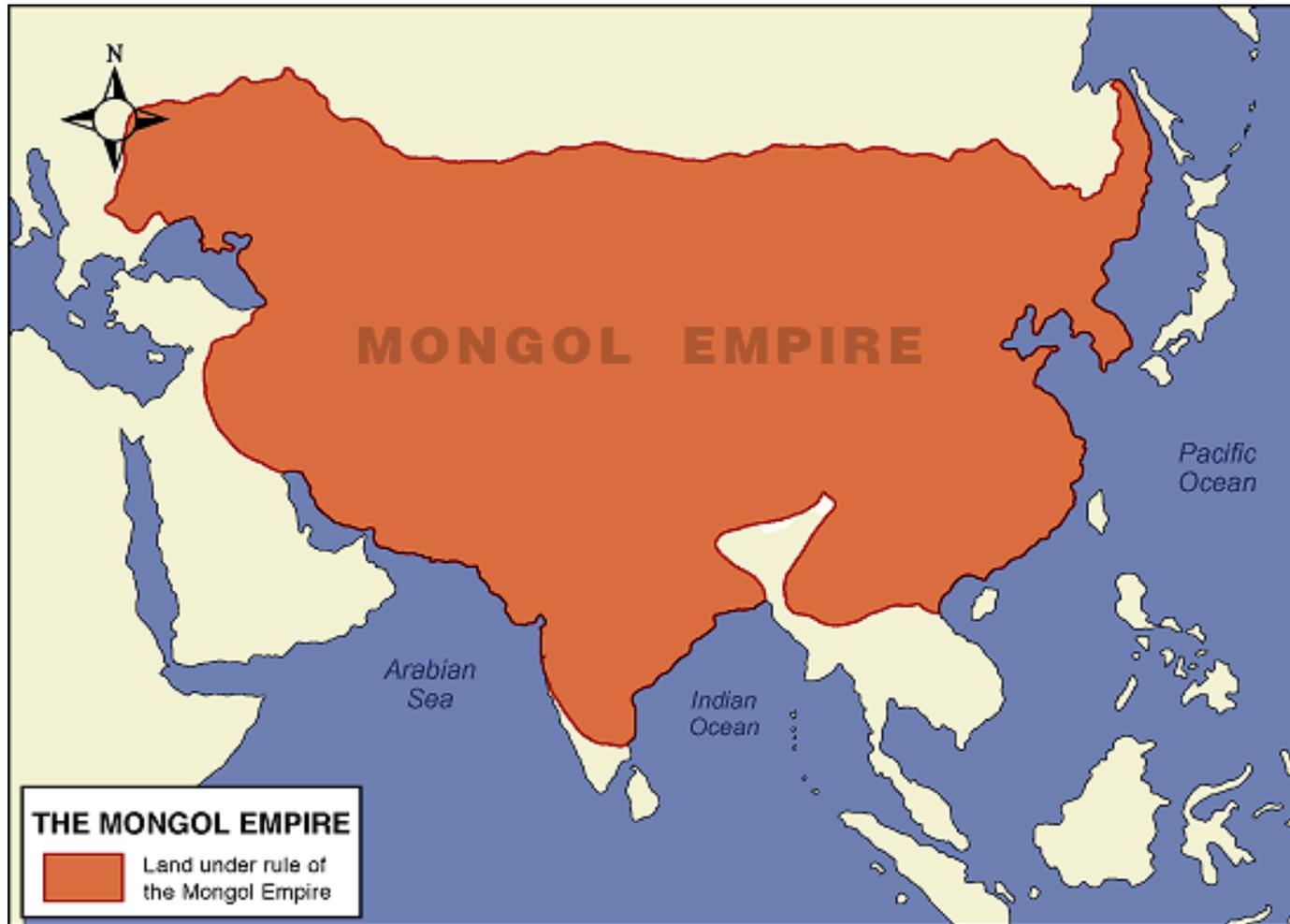


# ***Transportation Revolutions, II***

Approx. 3500BC: *domestication of the horse*



# ***Transportation Revolutions, II***



# ***Transportation Revolutions, III***

1804: *Steam Locomotive*



# ***Transportation Revolutions, III***



# ***Transportation Revolutions, IV***

1908: *Ford Model T*



# ***Transportation Revolutions, IV***



# ***Transportation Revolutions, IV***



# ***Transportation Revolutions, IV***



# ***The Automobile***

The most important industrial product of the 20<sup>th</sup> Century:

- ◆ Shaped US urban geography
- ◆ Gave rise to a mighty American industry
  - Led to victory in WWII
- ◆ "Car Culture" -
  - Adulthood and freedom!



# ***Automobile: Societal Cost***

## *Worldwide:*

- ◆ 1.25M deaths in 2013, 20-50M were injured or disabled, annual cost > \$0.5T
- ◆ More than half of all road traffic deaths occur among young adults ages 15-44
- ◆ Road crashes are the leading cause of death among young people ages 15-29,

# ***Humans: Unsafe at Any Speed***

***Human error accounts for more than 90% of car crashes!***

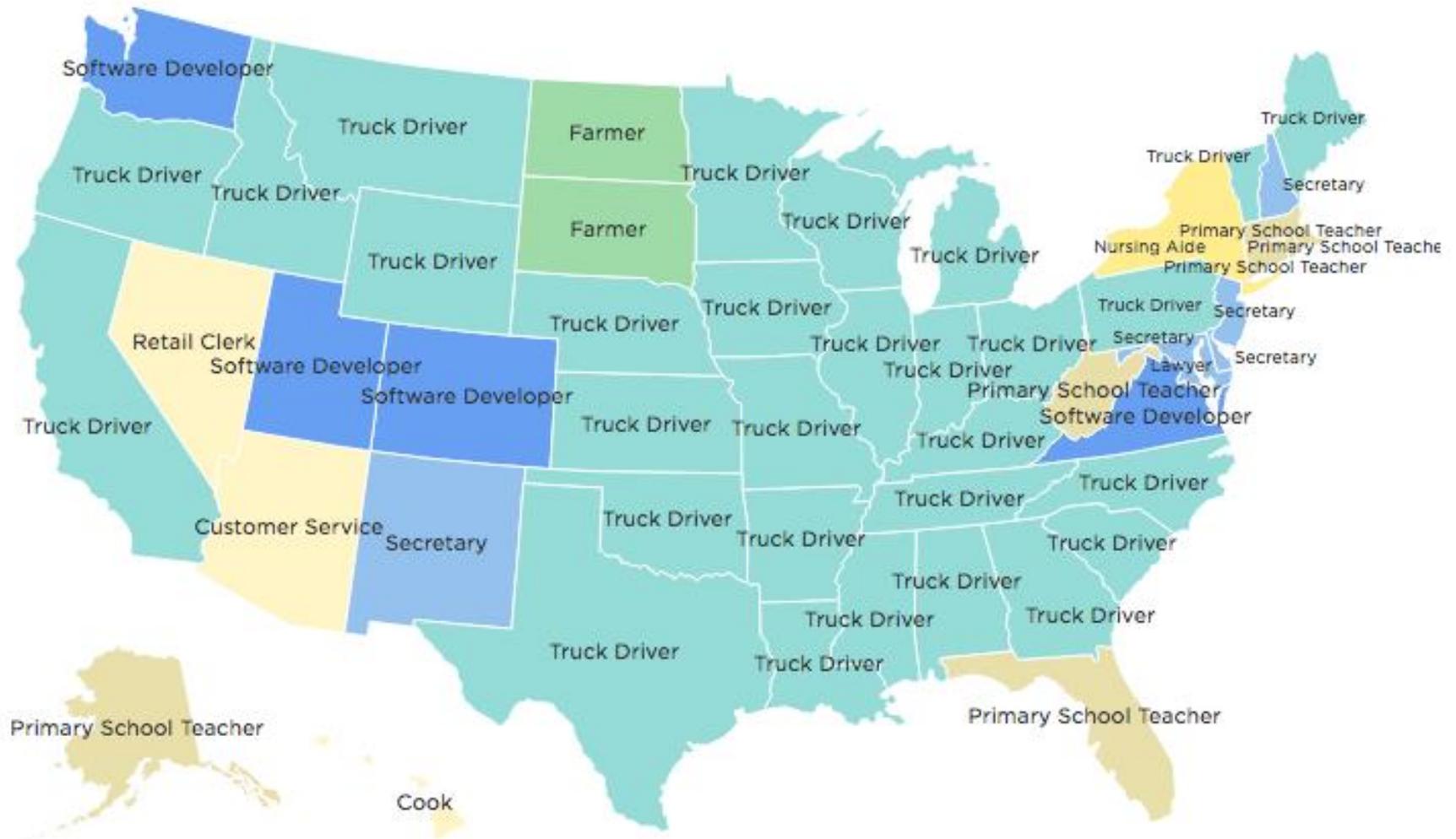
**Top Driving Behavior in Fatal Crashes (US, 2014):**

- ◆ Driving too fast - 18.8%
- ◆ Under the influence - 12.3%
- ◆ Failure to keep in lane - 8.5%
- ◆ Failure to yield way - 6.9%
- ◆ Distracted - 6.7%
- ◆ Careless driving - 4.8%

# ***The Automation of Driving***

- ◆ 30+ companies are now working on self-driving cars - *est. market: \$2-5T over next decade*
- ◆ Technical issues to be resolved in 5-15 yrs
- ◆ Many legal issues need to be resolved
- ◆ Profound business disruption:
  - Major industrial contraction (cars are now idle 90% of the time)
  - "Major loss of business" for insurance, legal, and medical industry
- ◆ ***Huge societal benefit: reduce accidents, liberate elders and the disabled***

# The Most Common Jobs (2014)



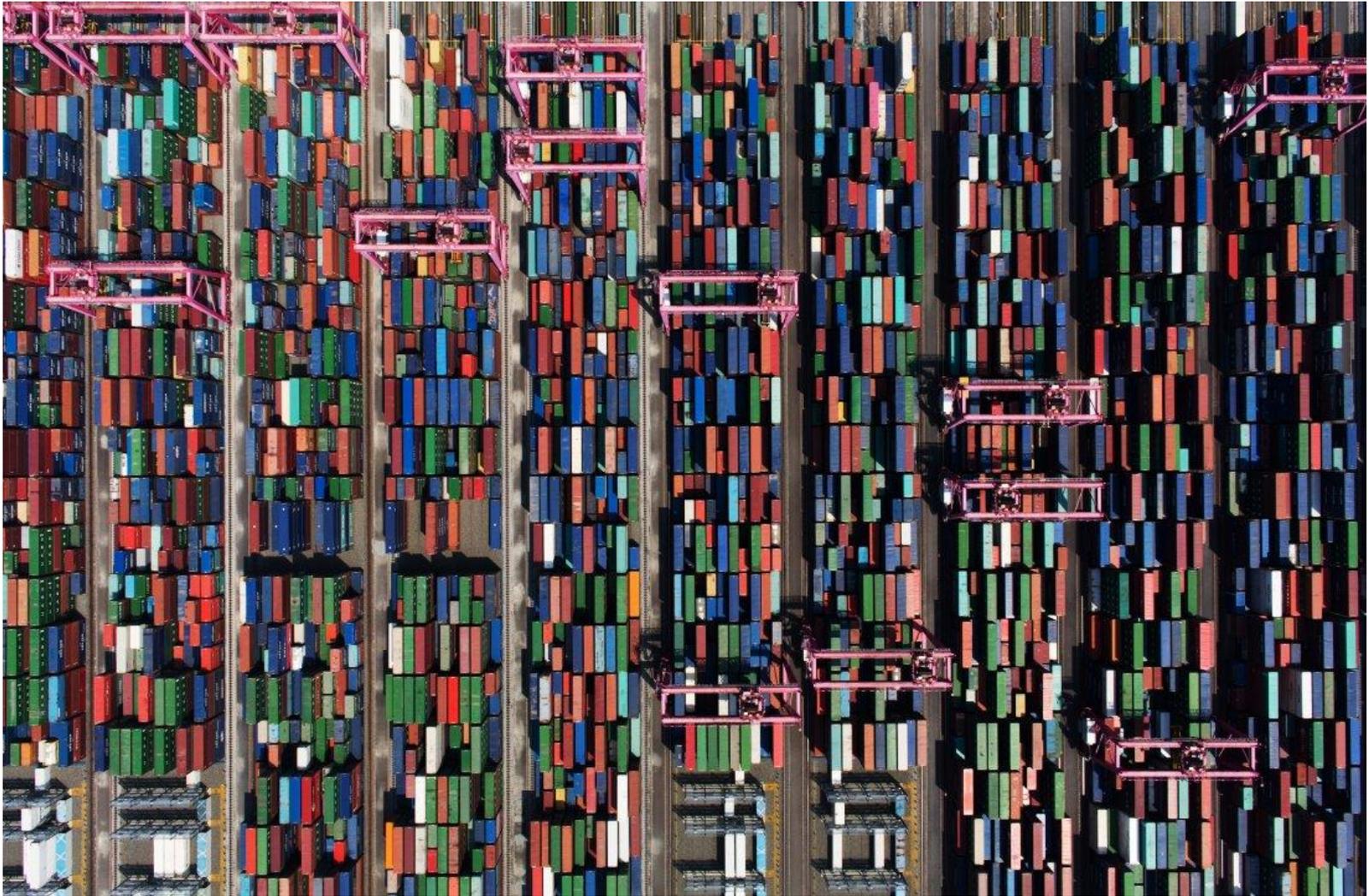
# ***What about the Drivers?***

- ◆ 4M truck+taxi drivers in the US
- ◆ 15M US jobs involve operating a vehicle
- ◆ Automation of the whole supply chain is expected: *cargo ships, ports, trucking, warehouses, delivery, ...*



- ◆ ***Bottom Line: Massive loss of jobs!***
  - But there will be new jobs. Right?

# ***Container Terminal in S. Korea***



# ***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 Neoluddites***

- ◆ 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 Debate in A Nutshell***

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

***Who is right?***

# ***Future of Work, I***

- ◆ McKinsey believes as much as 45% of current jobs could be replaced using technology that already exists;
- ◆ Gartner predicts one in three jobs will be converted to software, robots and smart machines by 2025;
- ◆ According to an Oxford University Study, about 47 percent of total US employment is at risk;
- ◆ OECD: Across the 21 OECD countries, only 9% of jobs are automatable.
- ◆ PwC: More than a third of U.S. jobs could be at "high risk" of automation by the early 2030s.

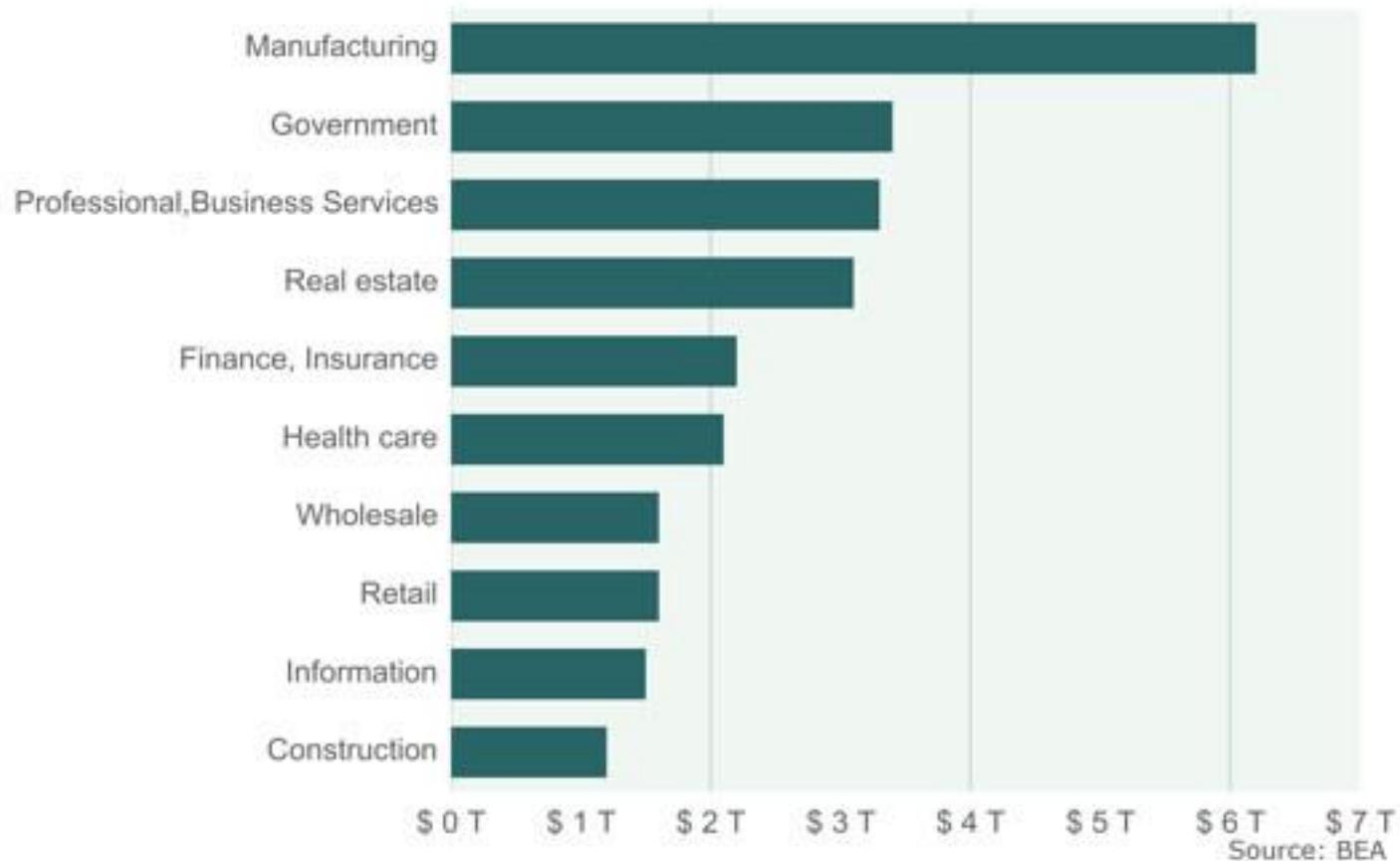
# ***Future of Work, II***

Why so many different predictions?

- ◆ “Predictions are easy, especially about the far future!”
  - Paraphrasing a Danish proverb.
- ◆ “***Correct*** predictions are hard, especially about the far future!”
  
- ◆ Let's consider the past!

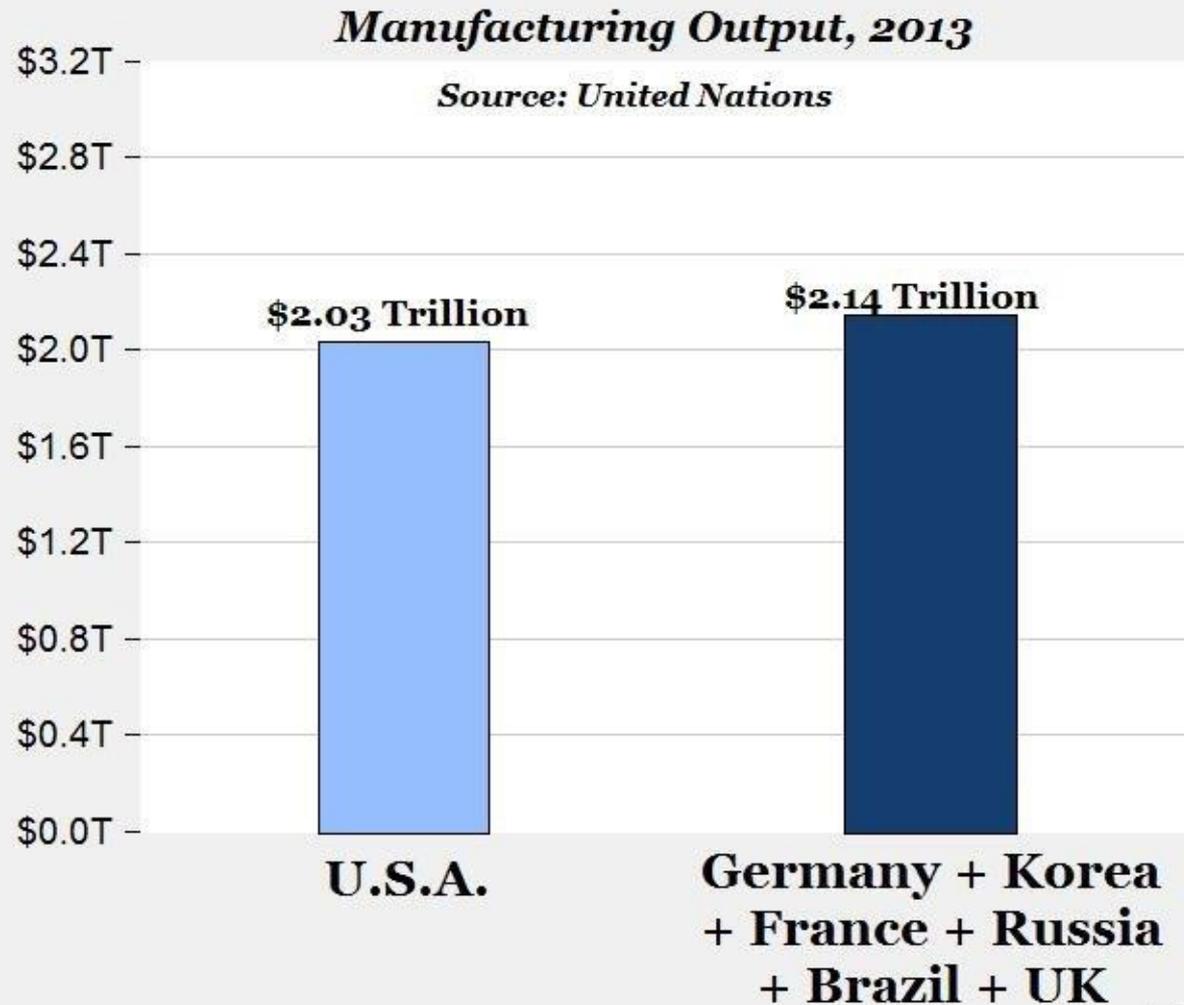
# Case Study: US Manufacturing

Manufacturing is largest sector



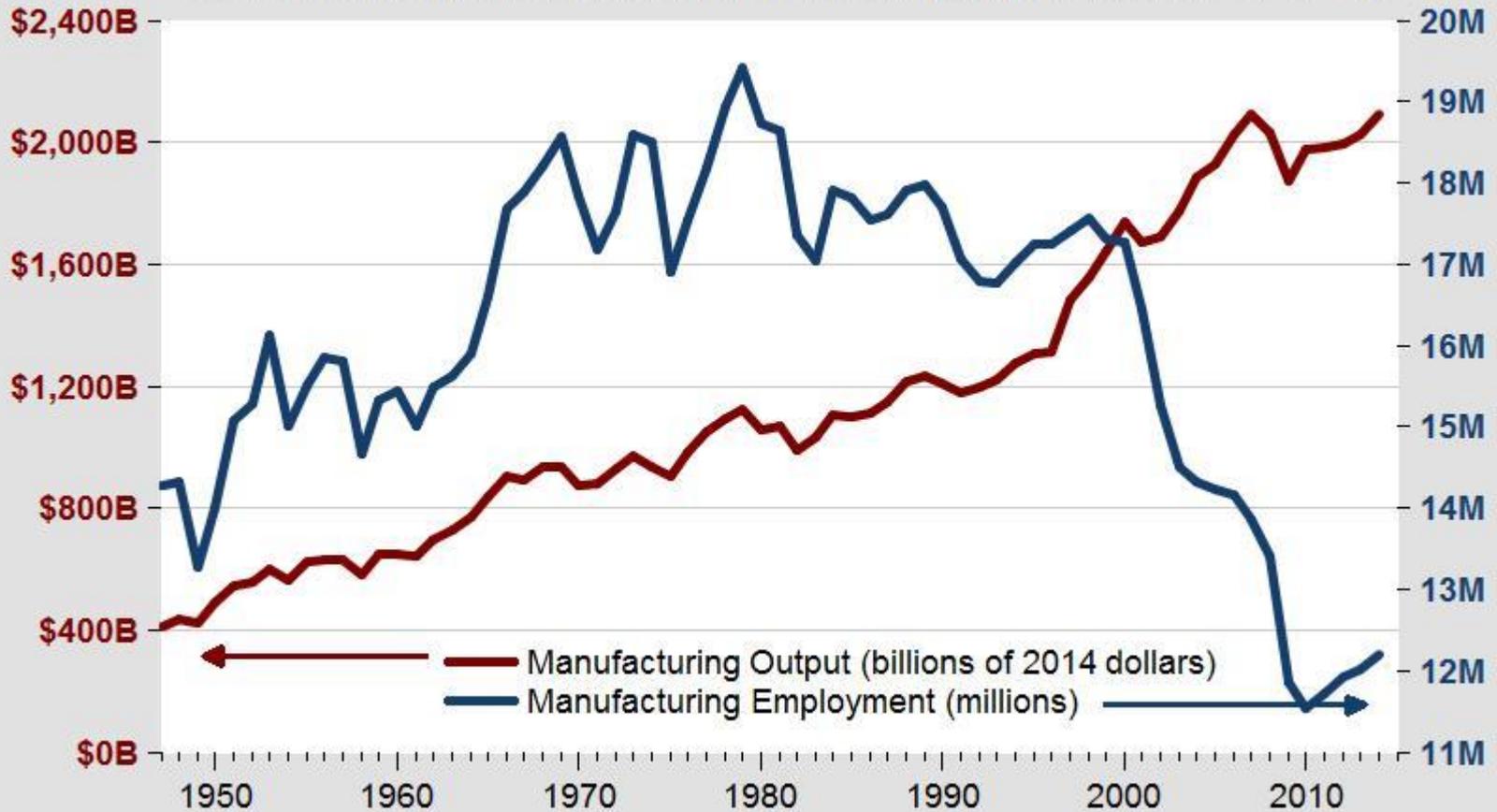
■ 2014 gross output, in trillions of dollars

# US Manufacturing



# Manufacturing: Output vs. Jobs

*US Real Manufacturing Output vs. Employment, 1947 to 2014*

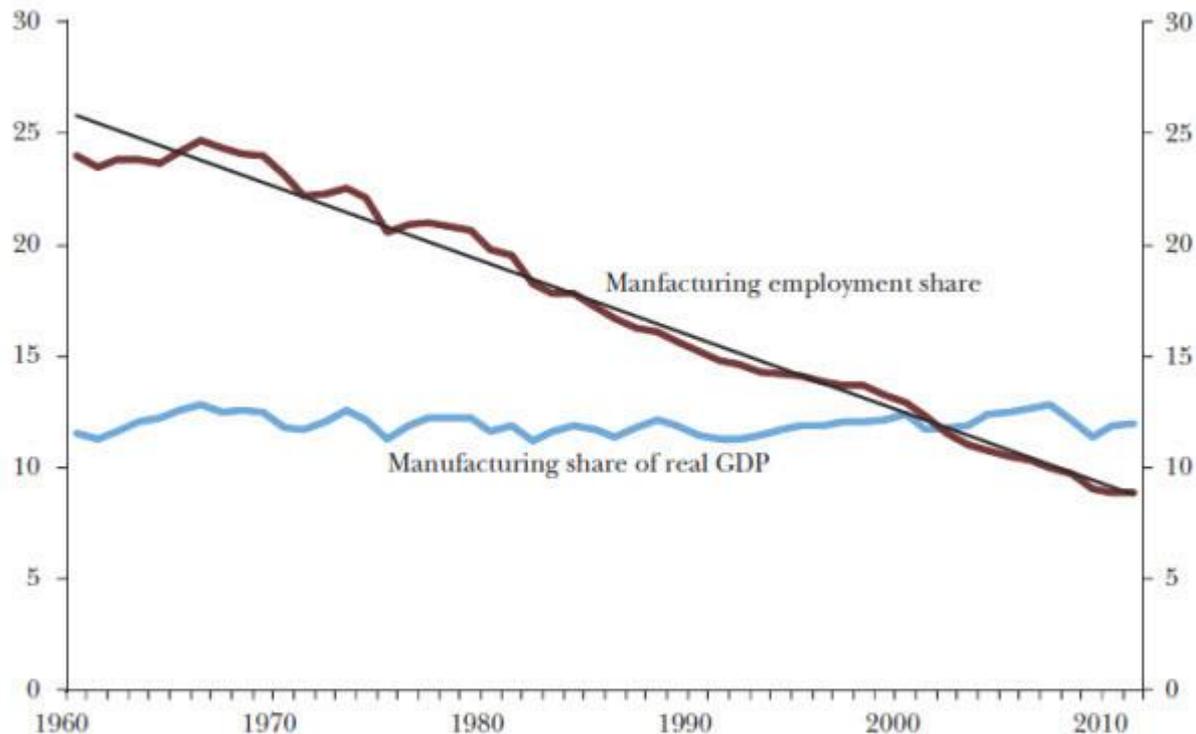


# Manufacturing: GDP vs. Jobs

Figure 1

Manufacturing Value Added and Employment as a Share of the Total US Economy, 1960–2011

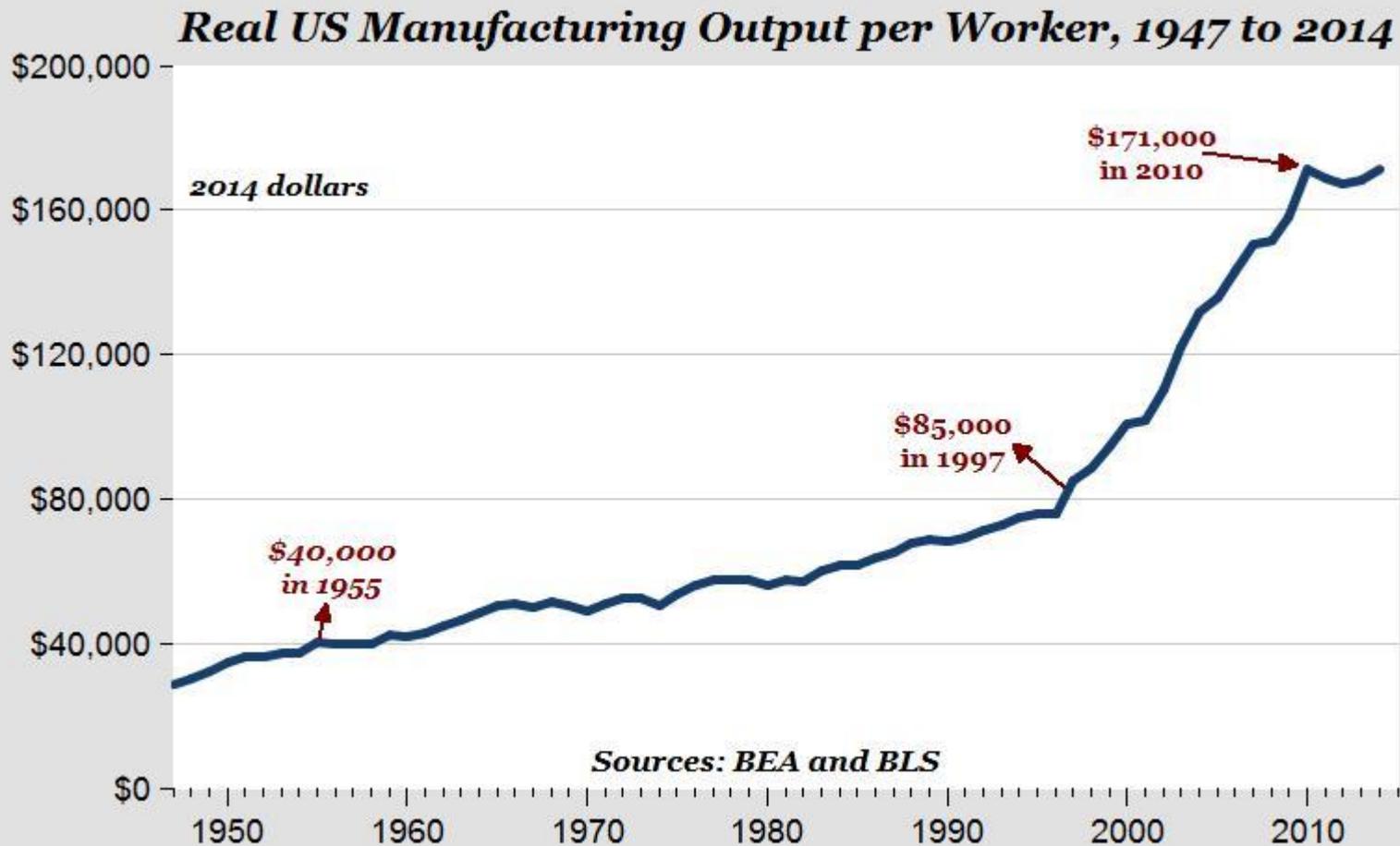
(in 2005 prices)



Source: Industry Accounts of the Bureau of Economic Analysis.

Note: Output is measured as value added in 2005 prices, and employment is reported as persons engaged in production (full-time equivalent employees plus the self-employed).

# Driving Force: Automation



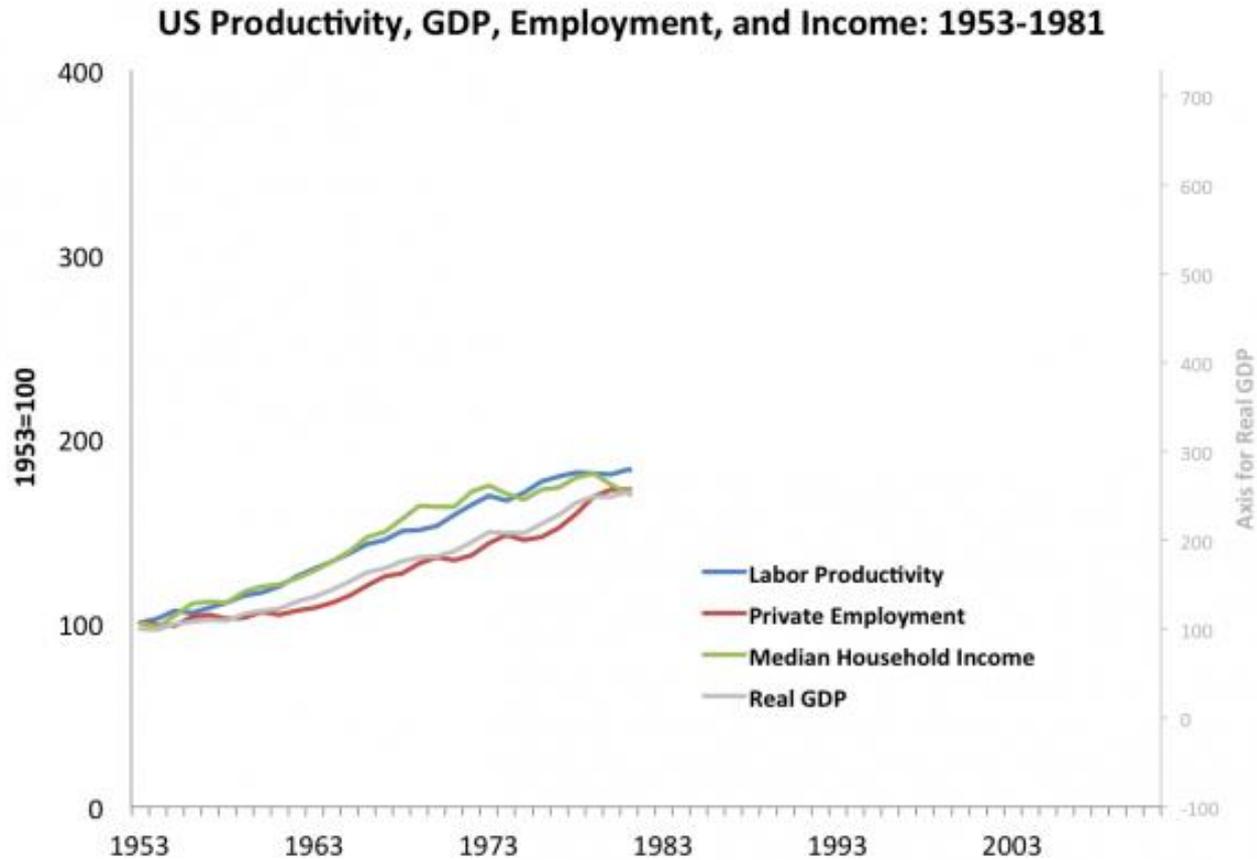
# ***Tesla Model S Factory Floor***



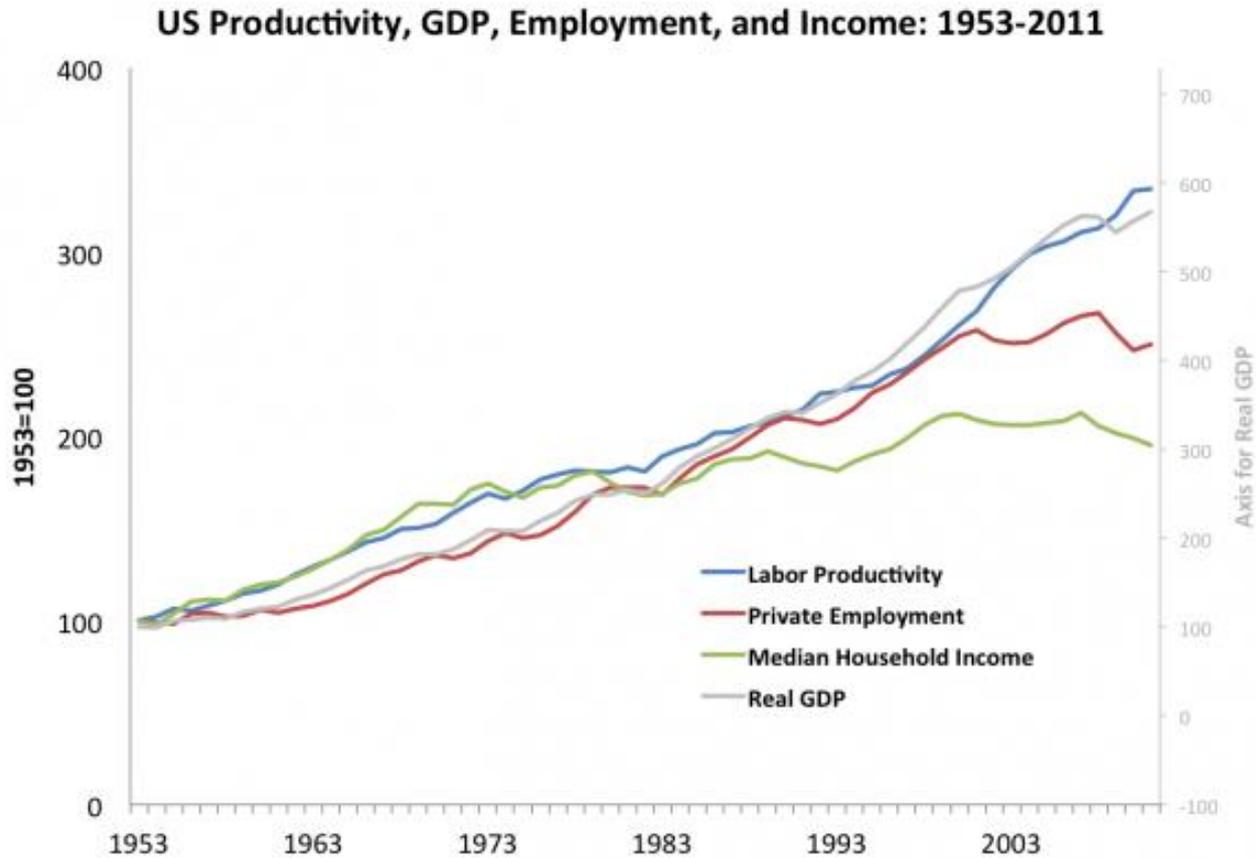
# ***The Future is Now!***

- ◆ Over the past 40 years, automation has had a ***very harsh impact*** on middle- and working-class Americans!
- ◆ **William Galston, WSJ, July 6, 2016:** "Educated professionals—including most politicians—live in an economic and cultural bubble, and they all too easily assume that what they see and hear around them represents the entire country."

# The Great Coupling



# The Great Decoupling



# Real Median Income

## Real median yearly incomes, white men with no college degree

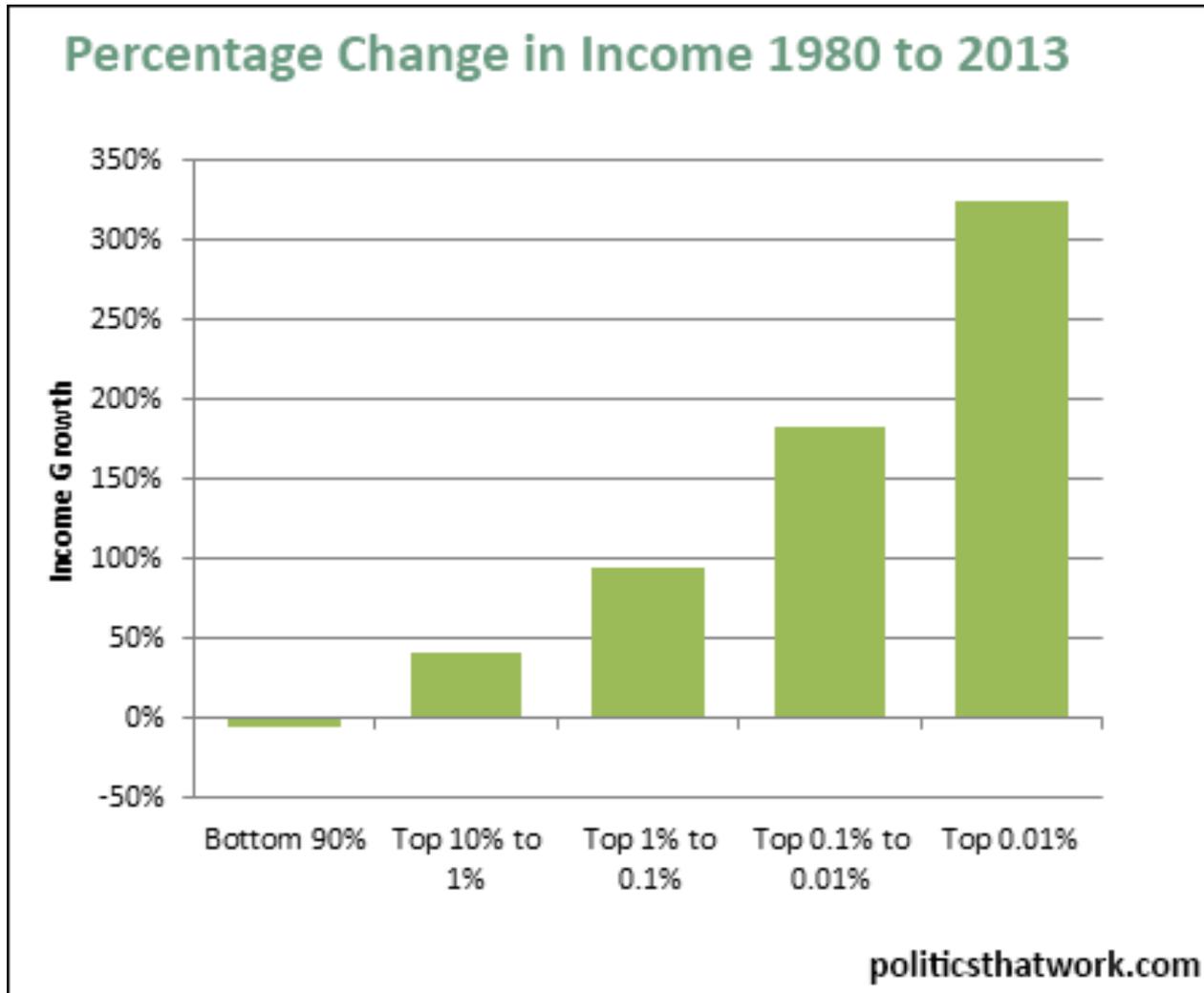
Non-Hispanic white men saw their best income growth in more than a decade in 2015 - but they're still way down from 1975 levels, after adjusting for inflation



Source: CBPP analysis of Census Bureau data

WAPO.ST/WONKBLOG

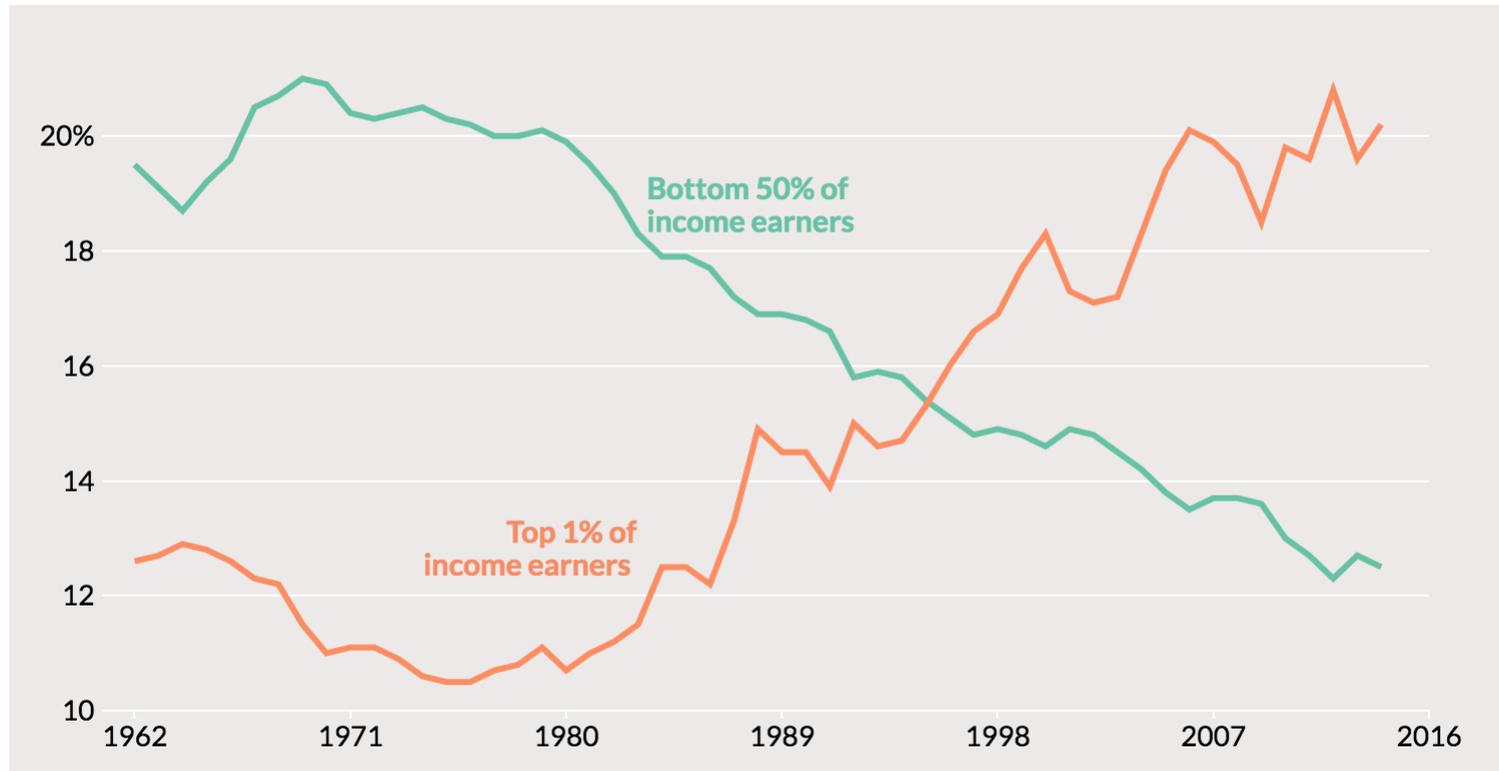
# ***Growing Inequality, I***



# Growing Inequality, II

## A tale of two countries

The share of U.S. pre-tax income accruing to the bottom 50 percent and top one percent of income earners, 1962-2014



Source: Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, "Distributional National Accounts: Methods and Estimates for the United States," 2016, Cambridge, MA: National Bureau of Economic Research

Note: The unit is the individual adult and incomes within married couples are split equally.

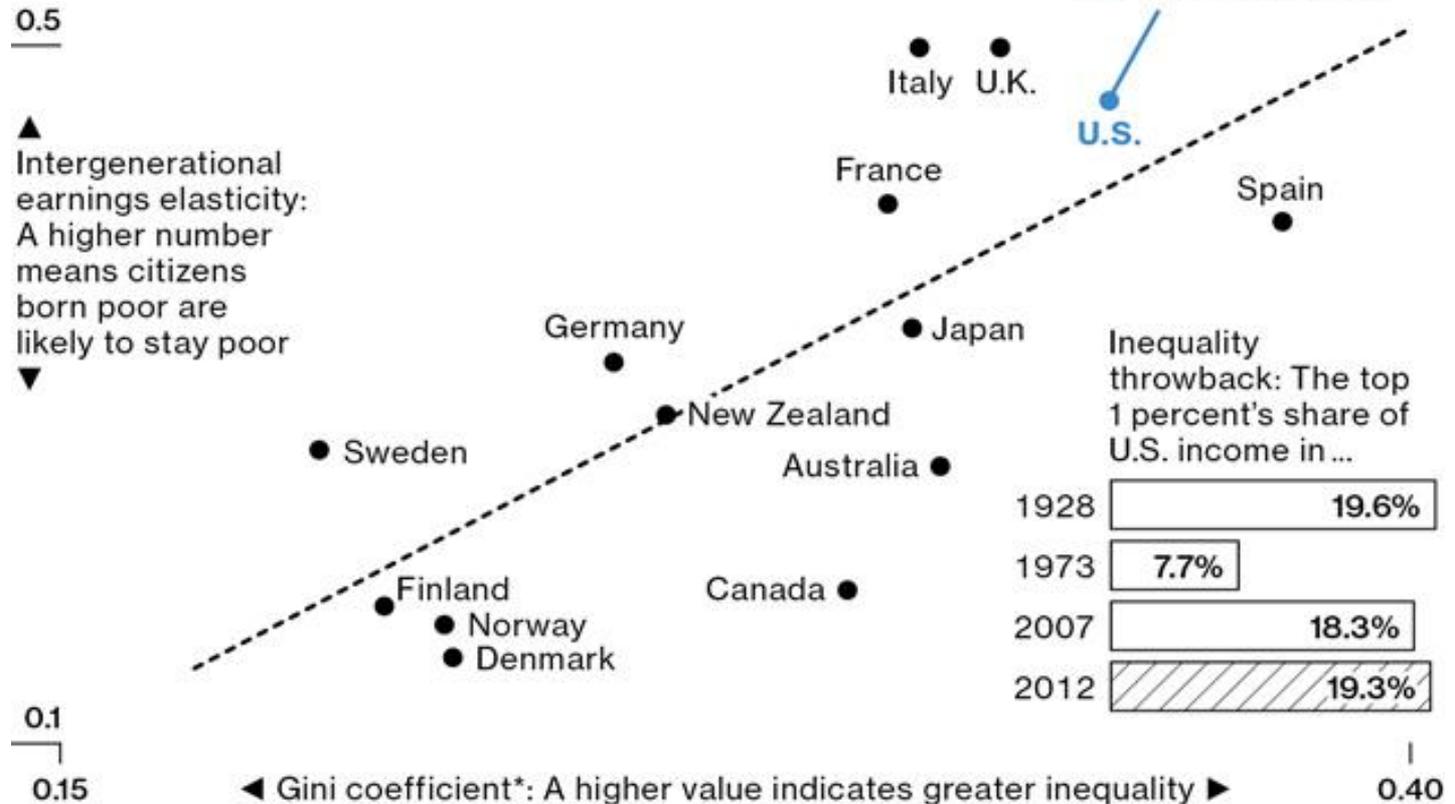


# Inequality vs Social Mobility, I

## The Great Gatsby Curve

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

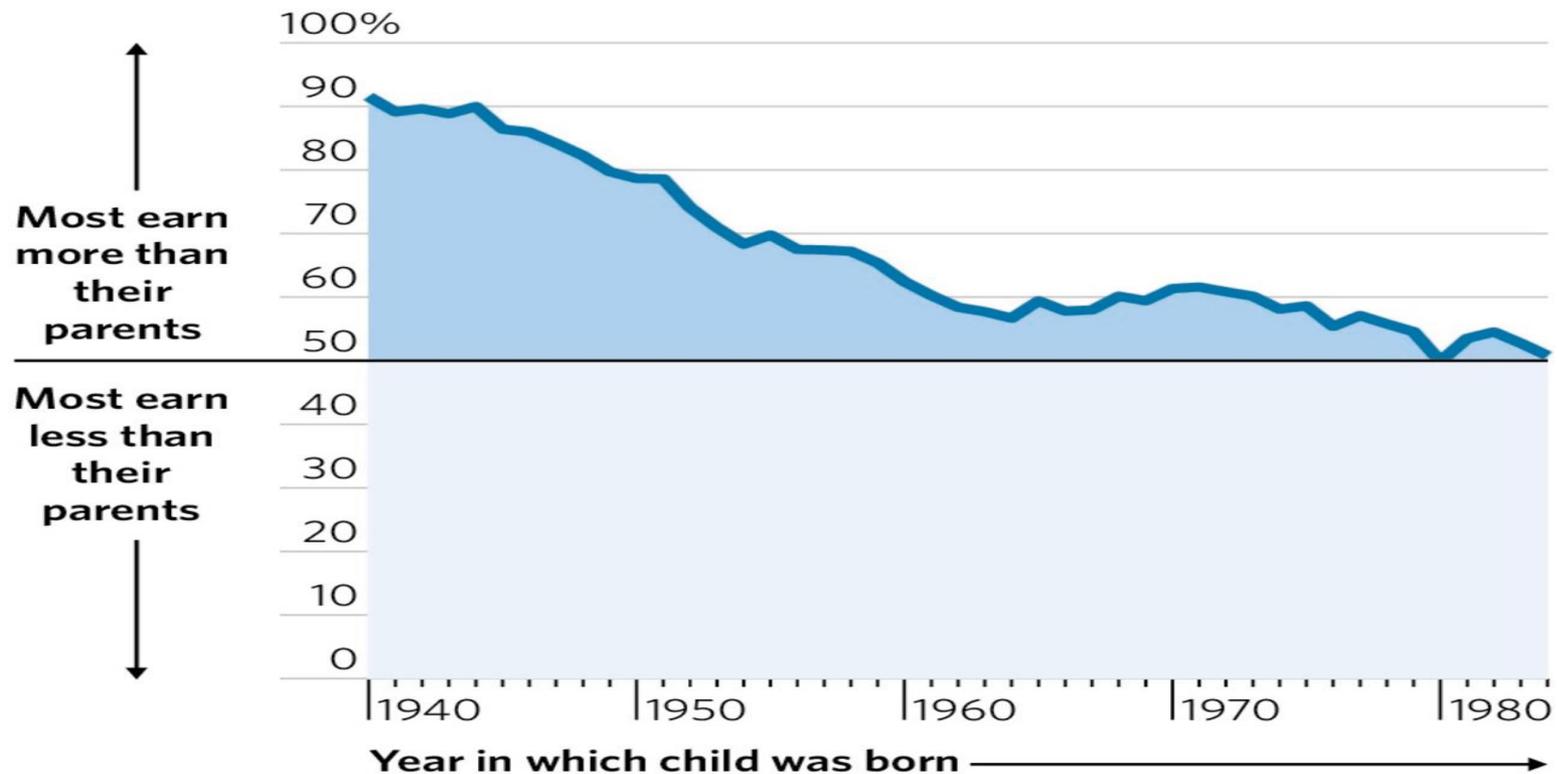
The U.S. has the worst of both worlds: low social mobility and rapidly increasing inequality



# Inequality vs Social Mobility, II

## Stalling Out

Average share of U.S. 30-year-olds who earn more, after adjusting for inflation, than their parents did at age 30



Source: Raj Chetty, David Grusky, Maximilian Hell, Nathaniel Hendren, Robert Manduca, and Jimmy Narang

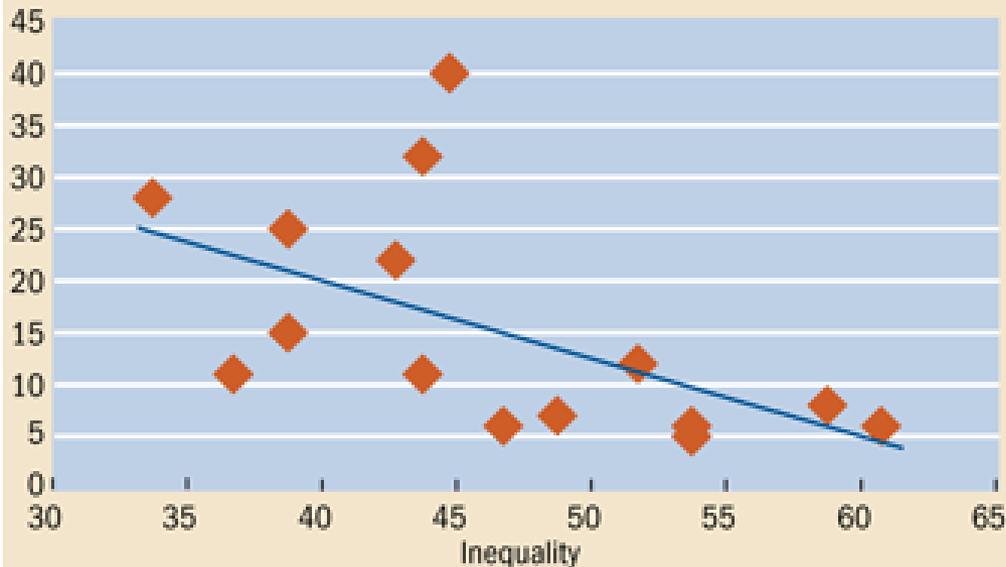
**THE WALL STREET JOURNAL.**

# Inequality vs Growth

## Lasting effects

More inequality seems to spell less sustained growth.

(years in growth spell)



Sources: Penn World Tables; and Wide World Inequality Database.

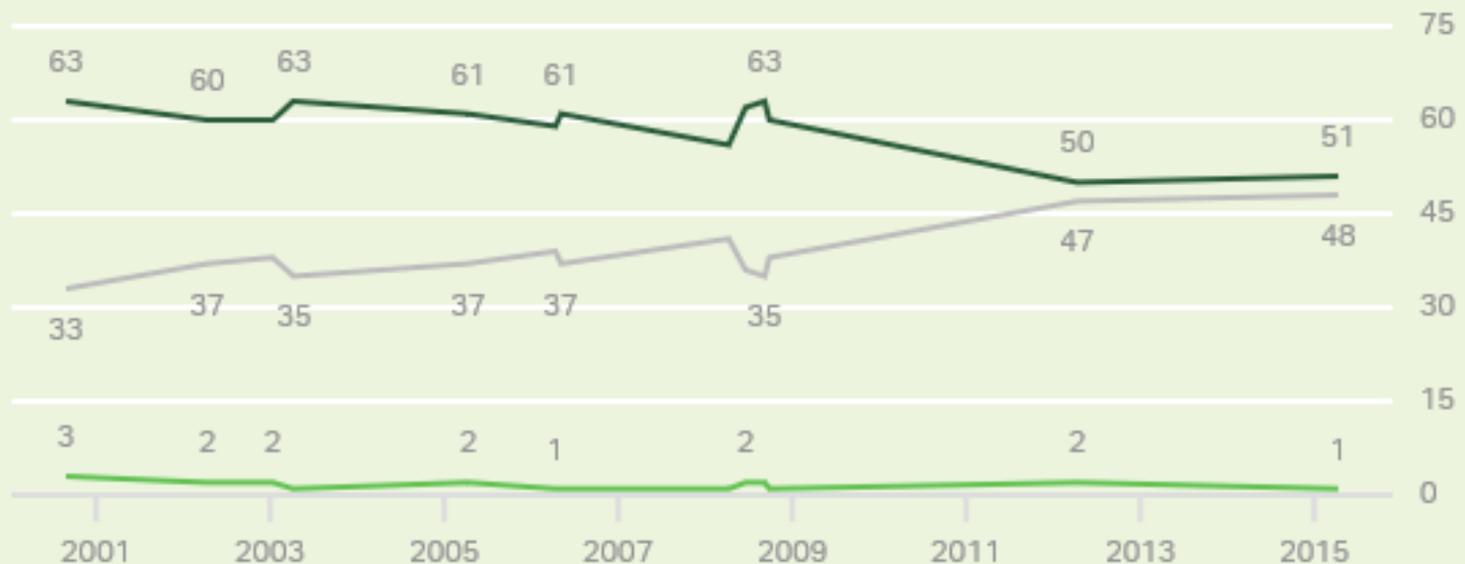
Note: Inequality is measured by the Gini coefficient, which ranges from zero, where all households have the same income, to 100, where one household has all the income. All spells lasted a minimum of five years. No incomplete spells are included. The data cover the period from 1950 to 2006. Countries in the sample include Belgium, Brazil, Cameroon, Colombia, Ecuador, El Salvador, Greece, Guatemala, Jamaica, Jordan, Pakistan, Panama, Singapore, Thailand, and Zambia.

# The middle class is shrinking

## Social Class Self-Identification

Middle class based on self-identification as upper-middle or middle class. "If you were asked to use one of these five names for your social class, which would you say you belong in: upper class, upper-middle class, middle class, working class or lower class?"

■ % Upper class ■ % Upper-middle and middle class ■ % Working and lower class



GALLUP

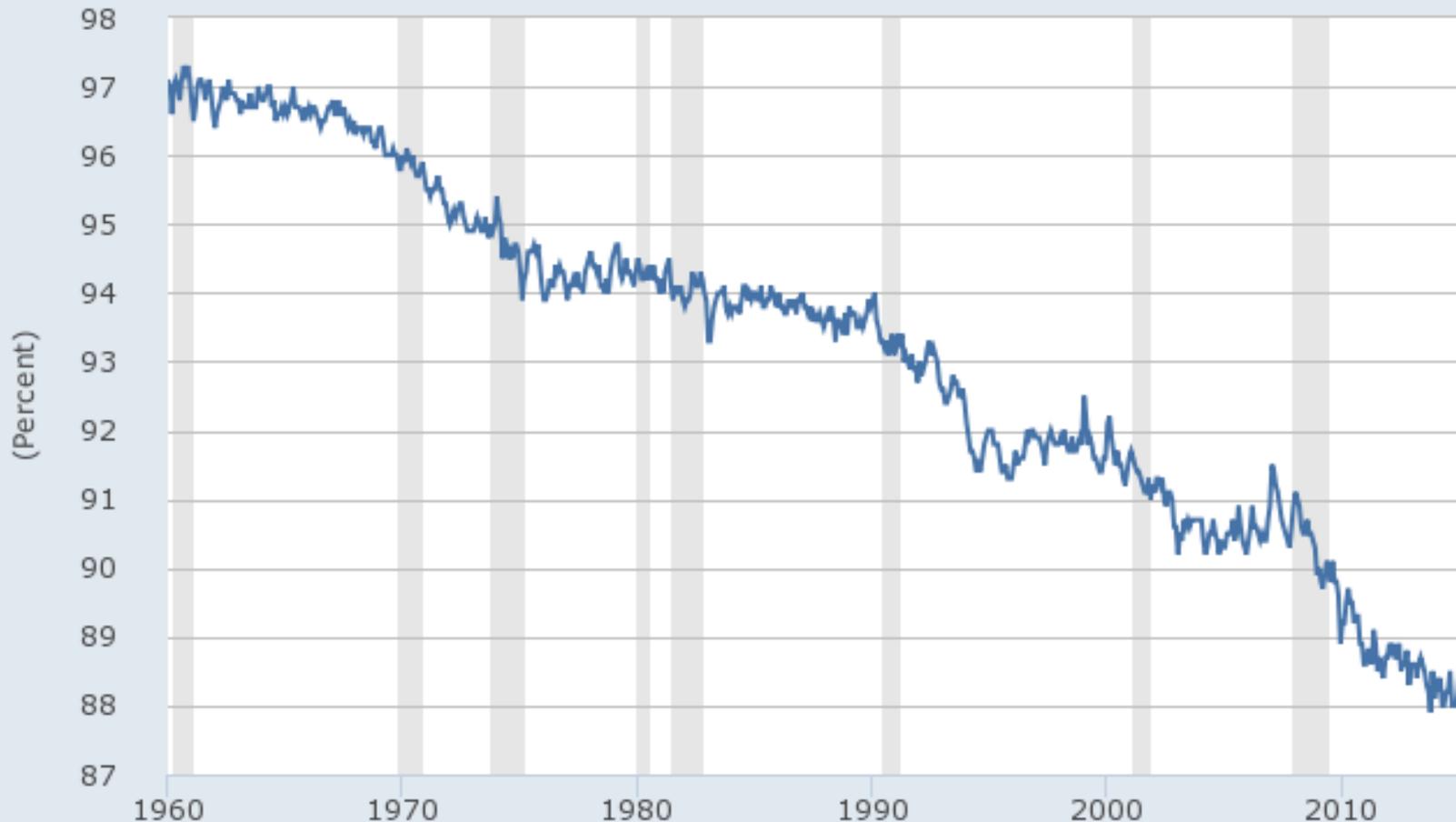
# ***The Age of Precariousness***

- ◆ ***"The Secret Shame of Middle-Class Americans"***: Nearly half of Americans would have trouble finding \$400 to pay for an emergency. (The Atlantic, May 2016)
- ◆ ***"Americans Living on the Financial Edge"***: two-thirds of Americans would have trouble immediately paying an unanticipated bill of \$1,000. (Associated Press, May 2016)

# Labor-Force Participation - Men

FRED 

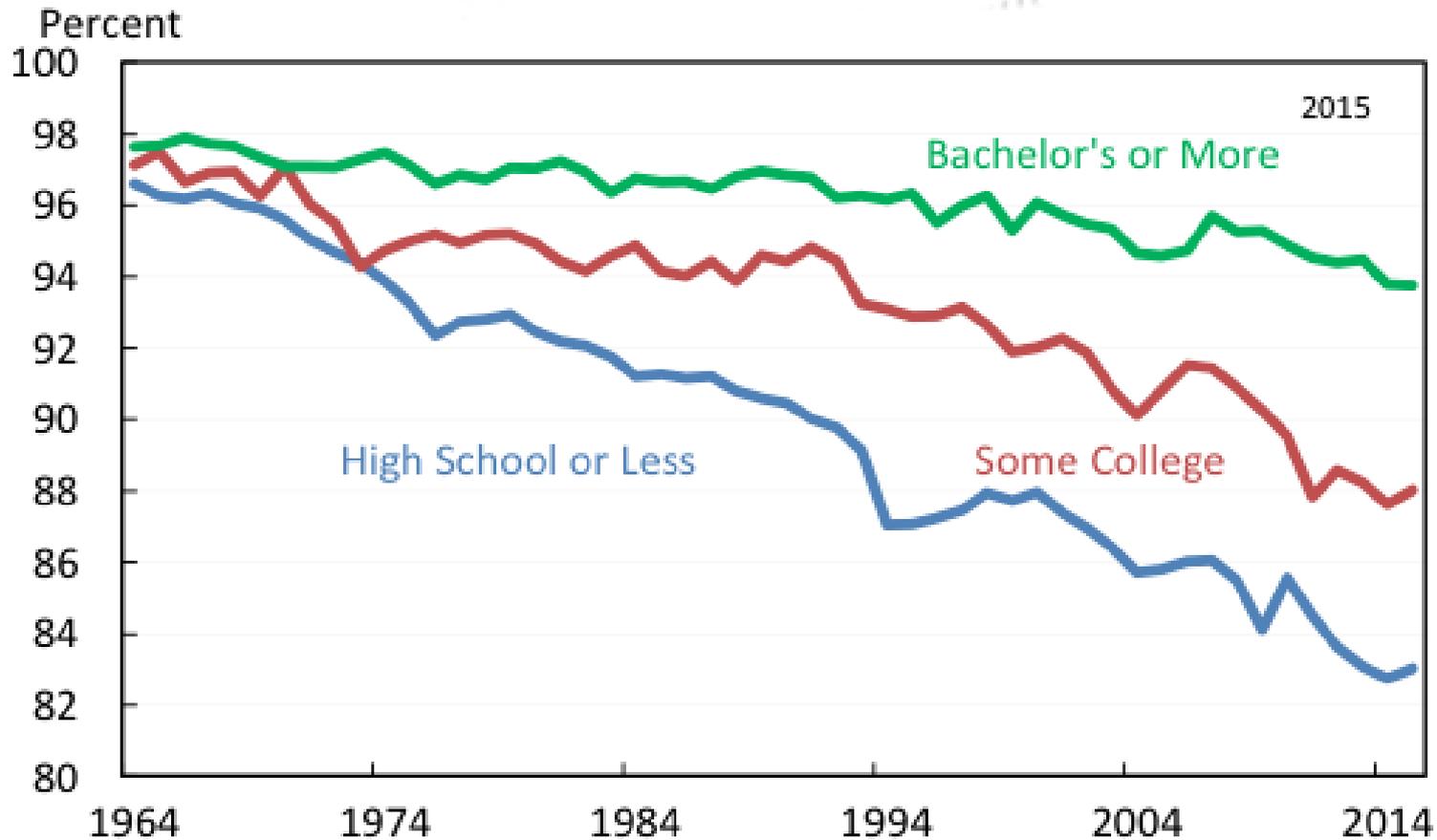
— Activity Rate: Aged 25-54: Males for the United States©



Source: Organization for Economic Co-operation and Development

Shaded areas indicate US recessions - 2015 research.stlouisfed.org

# Labor-Force Participation - Men



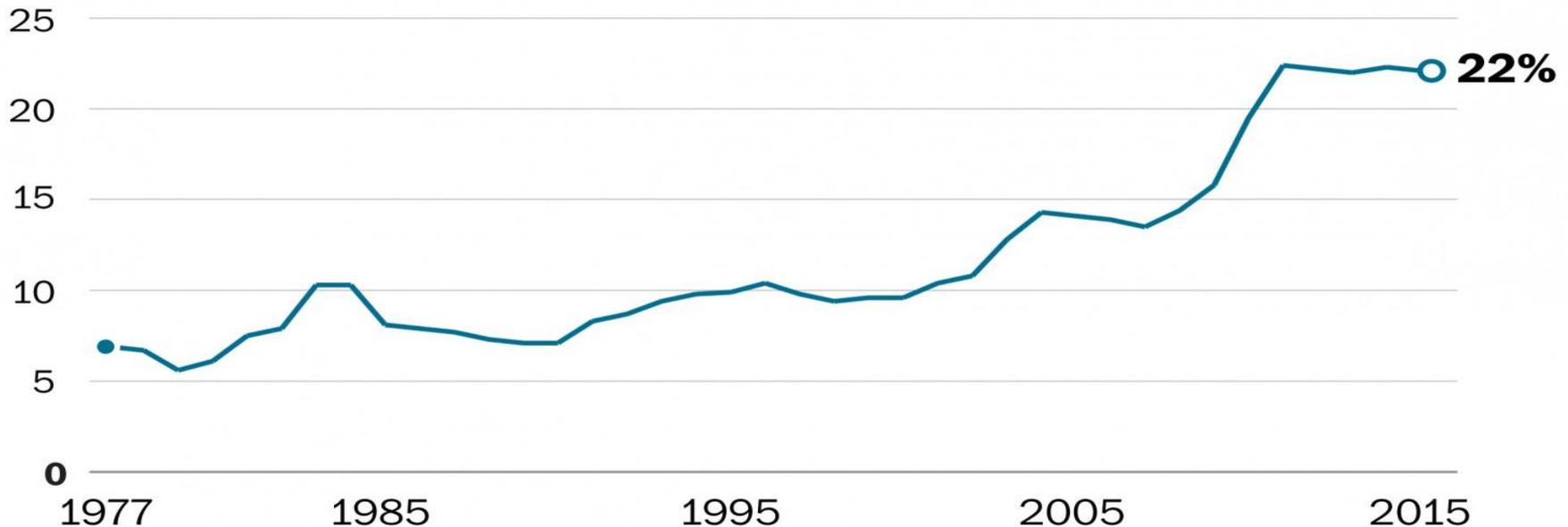
Source: Bureau of Labor Statistics, Current Population Survey (Annual Social and Economic Supplement); CEA calculations.

# Young Men without Work

## Unemployment of young men on the rise

The percentage of young men who say they did not work in the previous year has more than tripled since the 1970s.

### PERCENT NOT WORKING



Note: Data are for men age 21-30 with less than a bachelor's degree.

Source: Aguiar, Bills, Charles and Hurst. "Leisure Luxuries and the Labor Supply of Young Men".

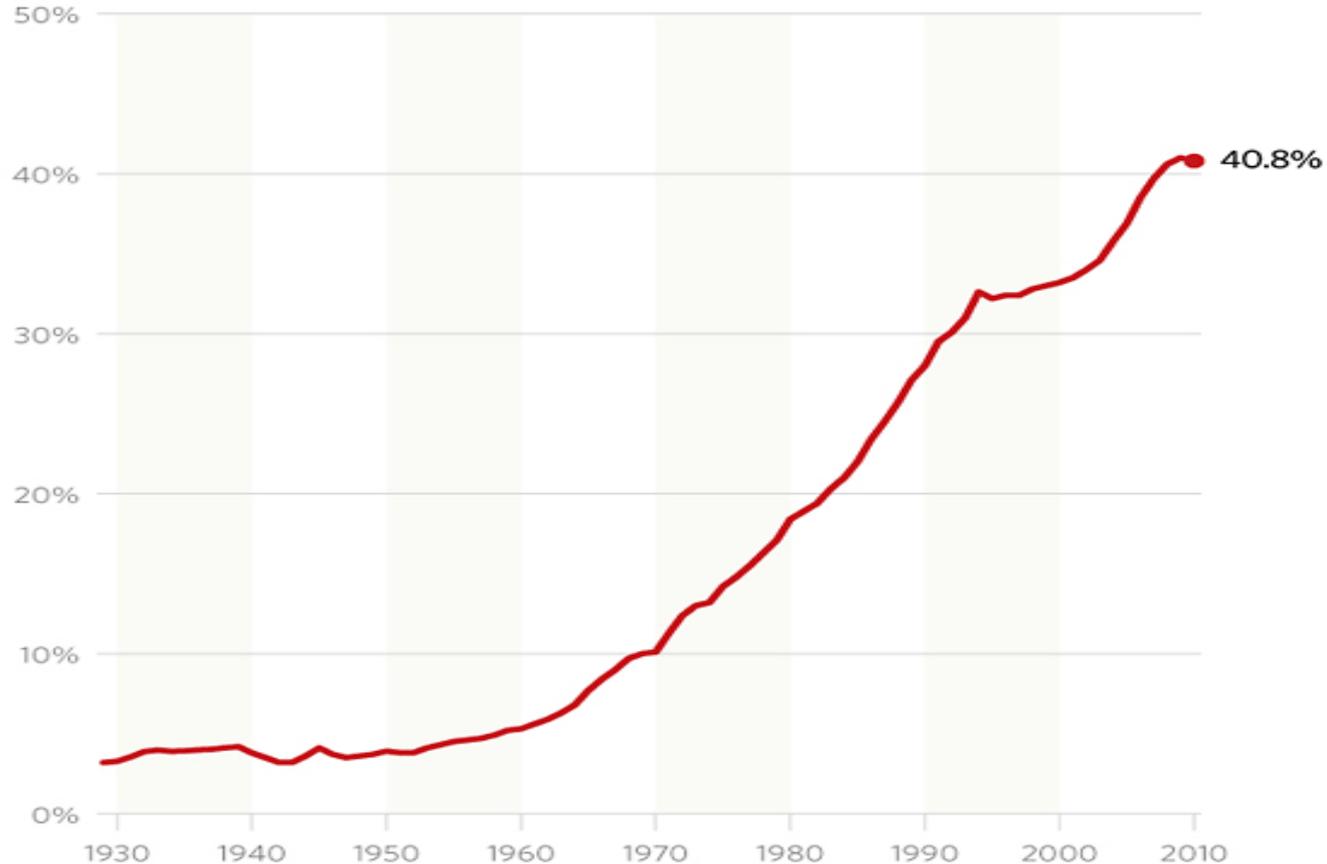
THE WASHINGTON POST

# The End of Marriage

CHART 3

## Growth of Out-of-Wedlock Childbearing in the United States, 1929-2010

PERCENTAGE OF CHILDREN BORN OUT OF WEDLOCK



Source: U.S. Government, U.S. Census Bureau, and National Center for Health Statistics.

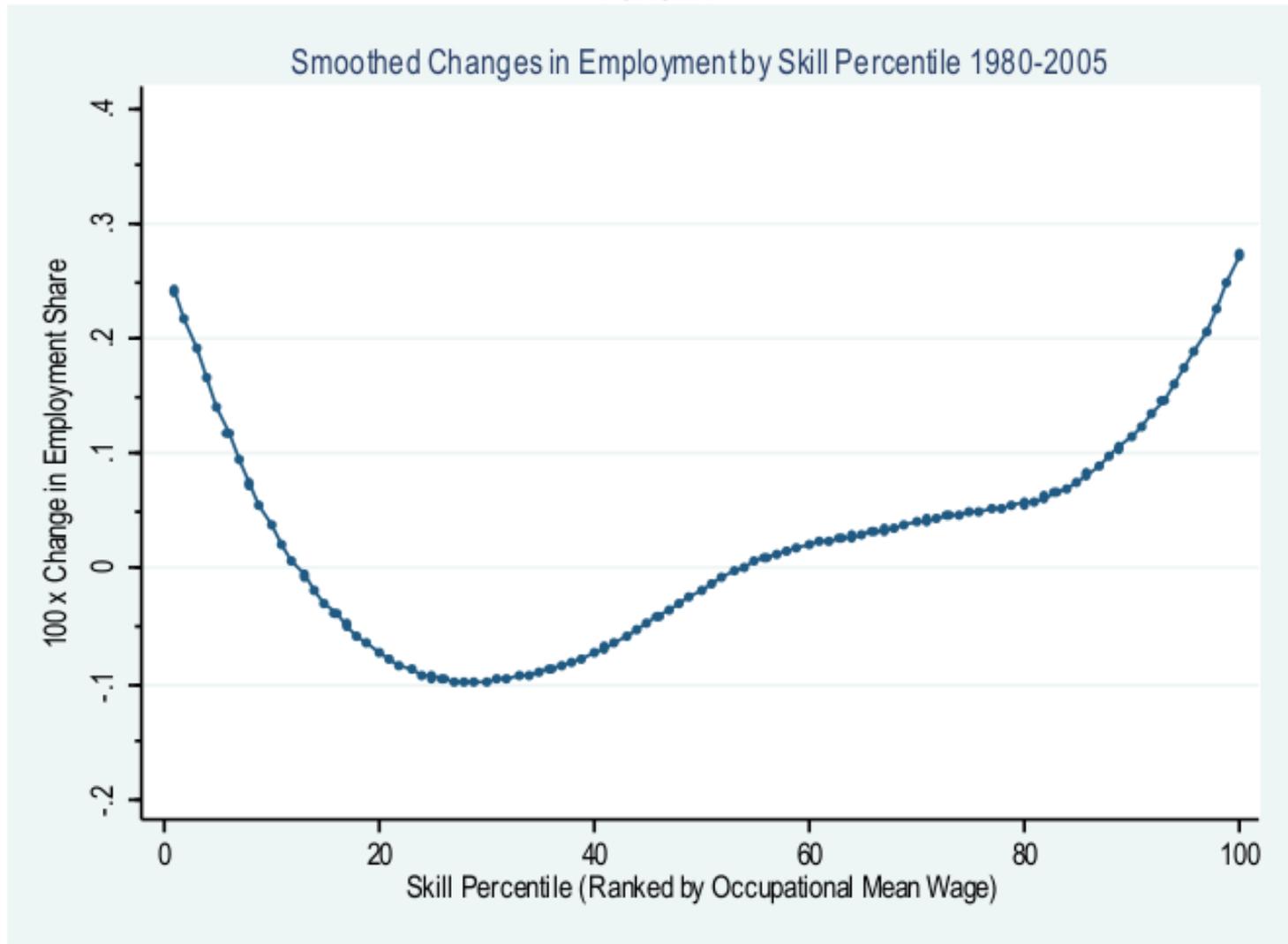
# Labor Share of National Income

Labor's share of US national income

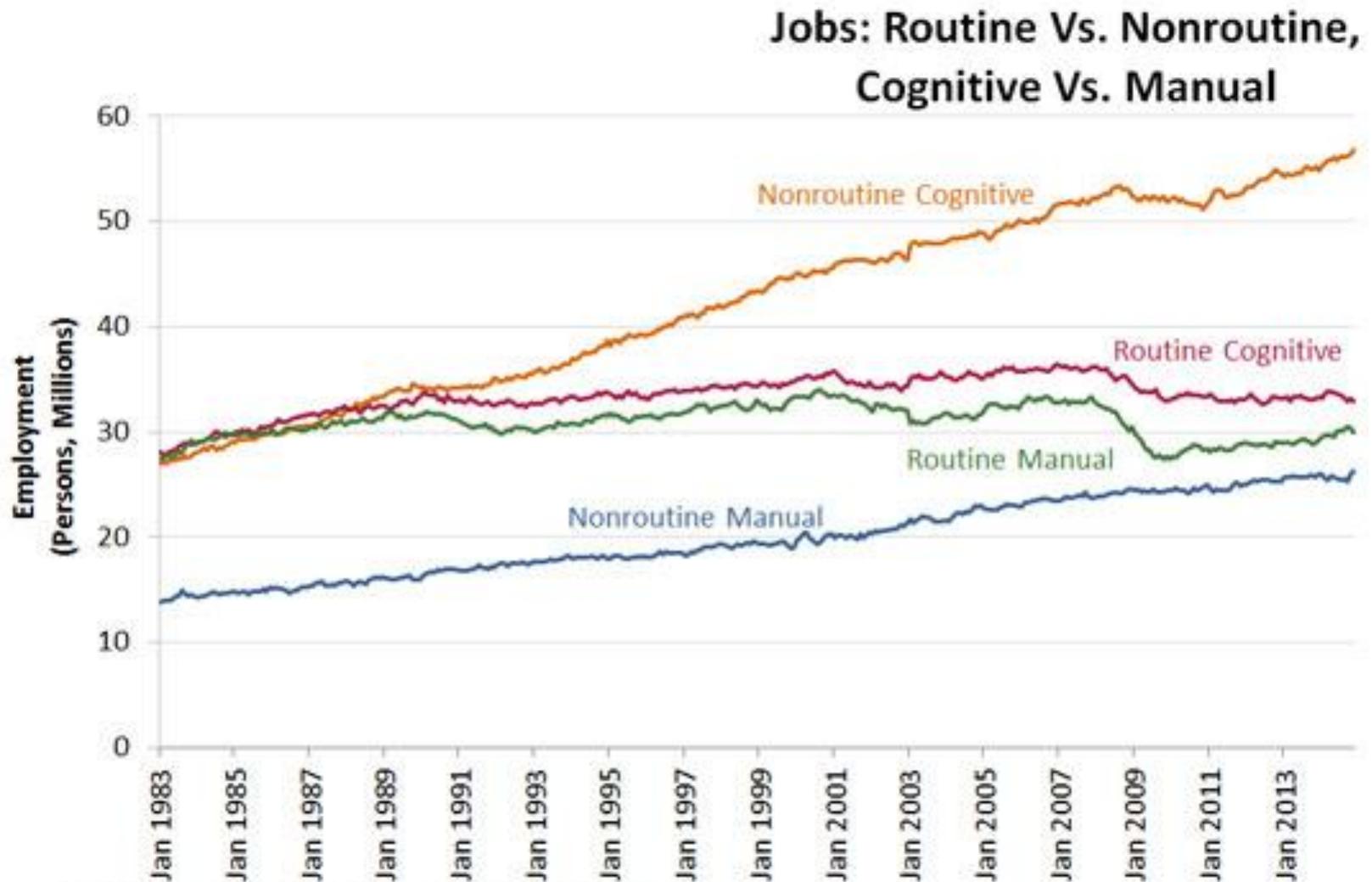
51% of GDI



# Job Polarization

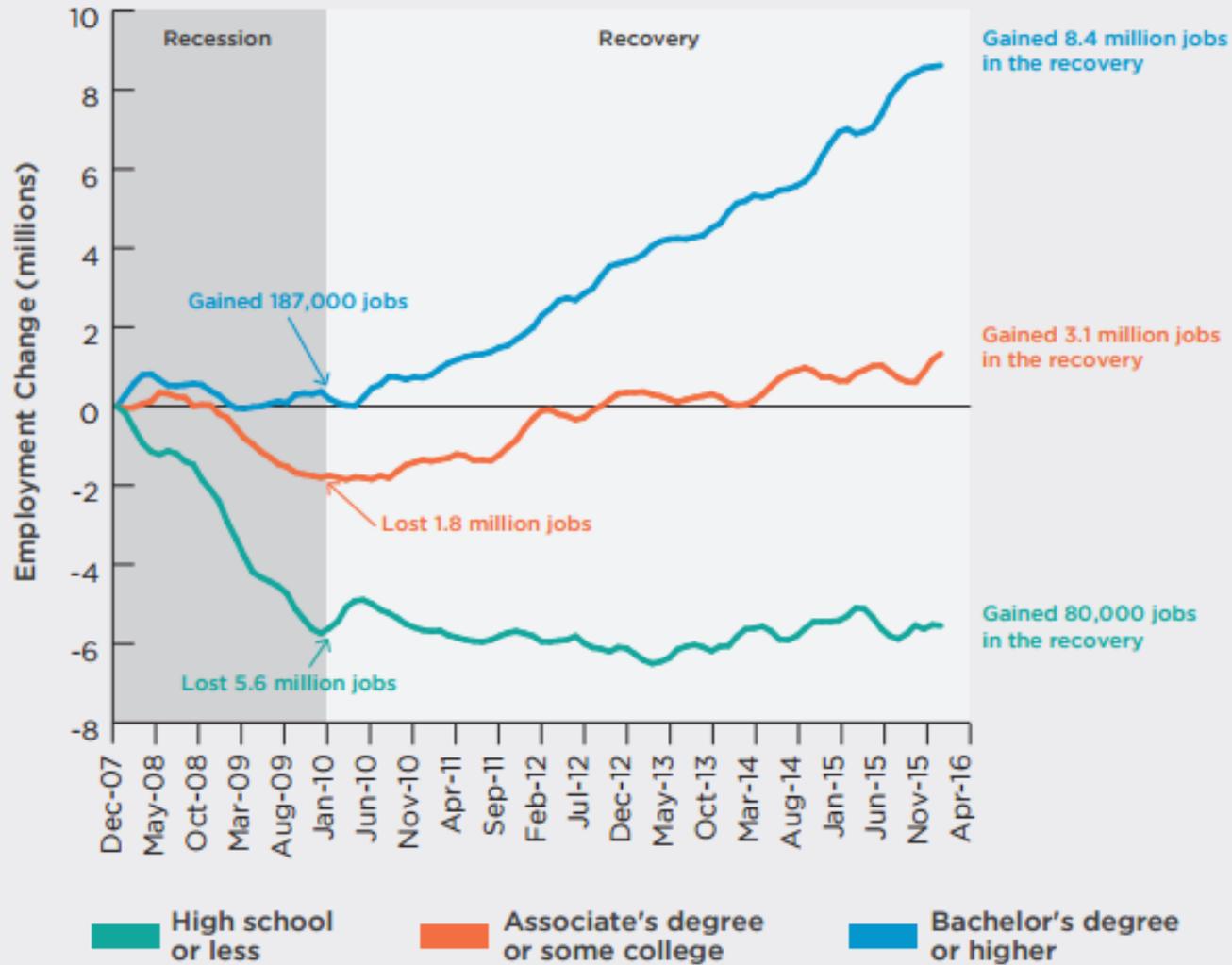


# Routine vs Non-routine Jobs



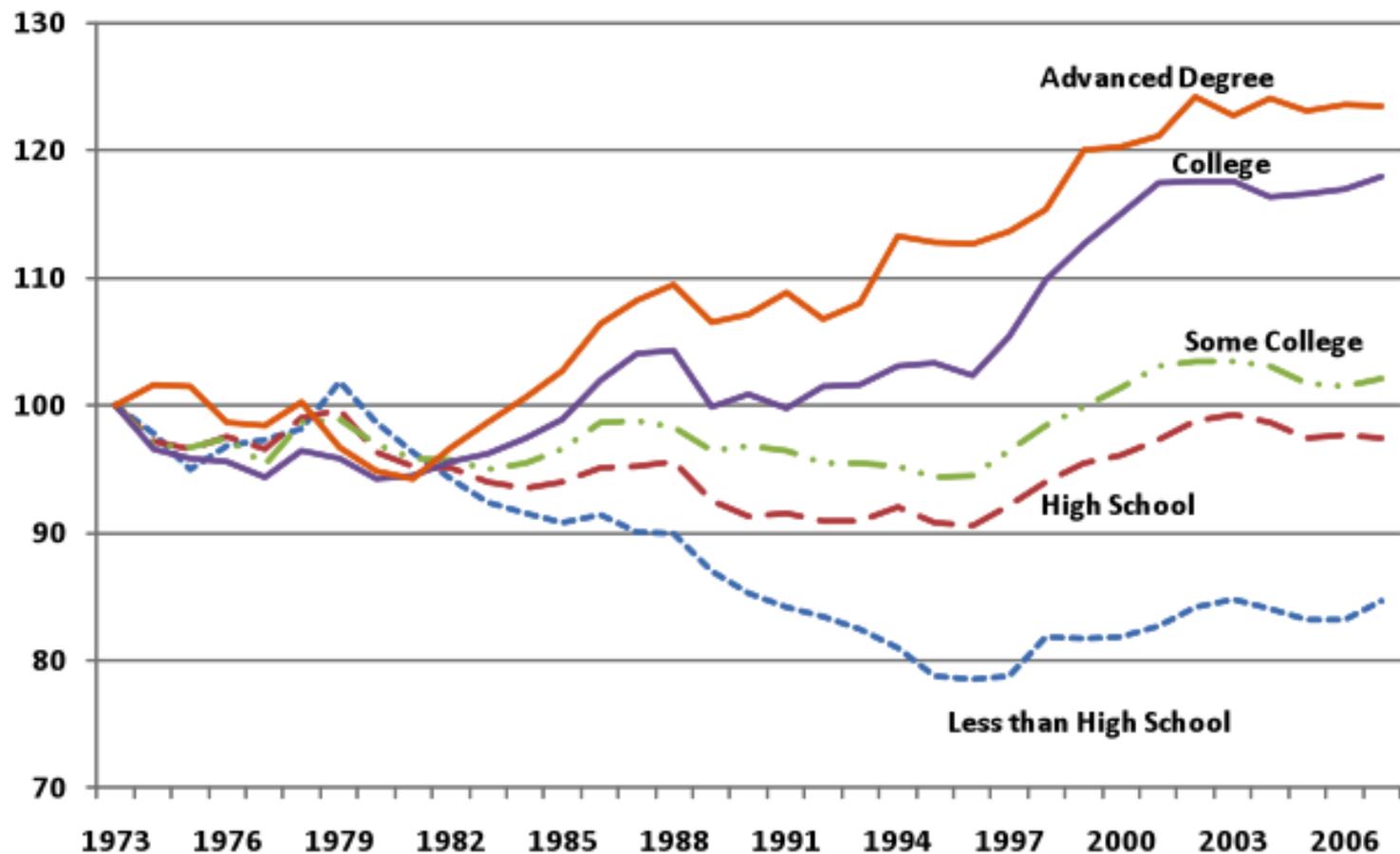
SOURCE: Current Population Survey and author's calculations.

# Jobs and Education



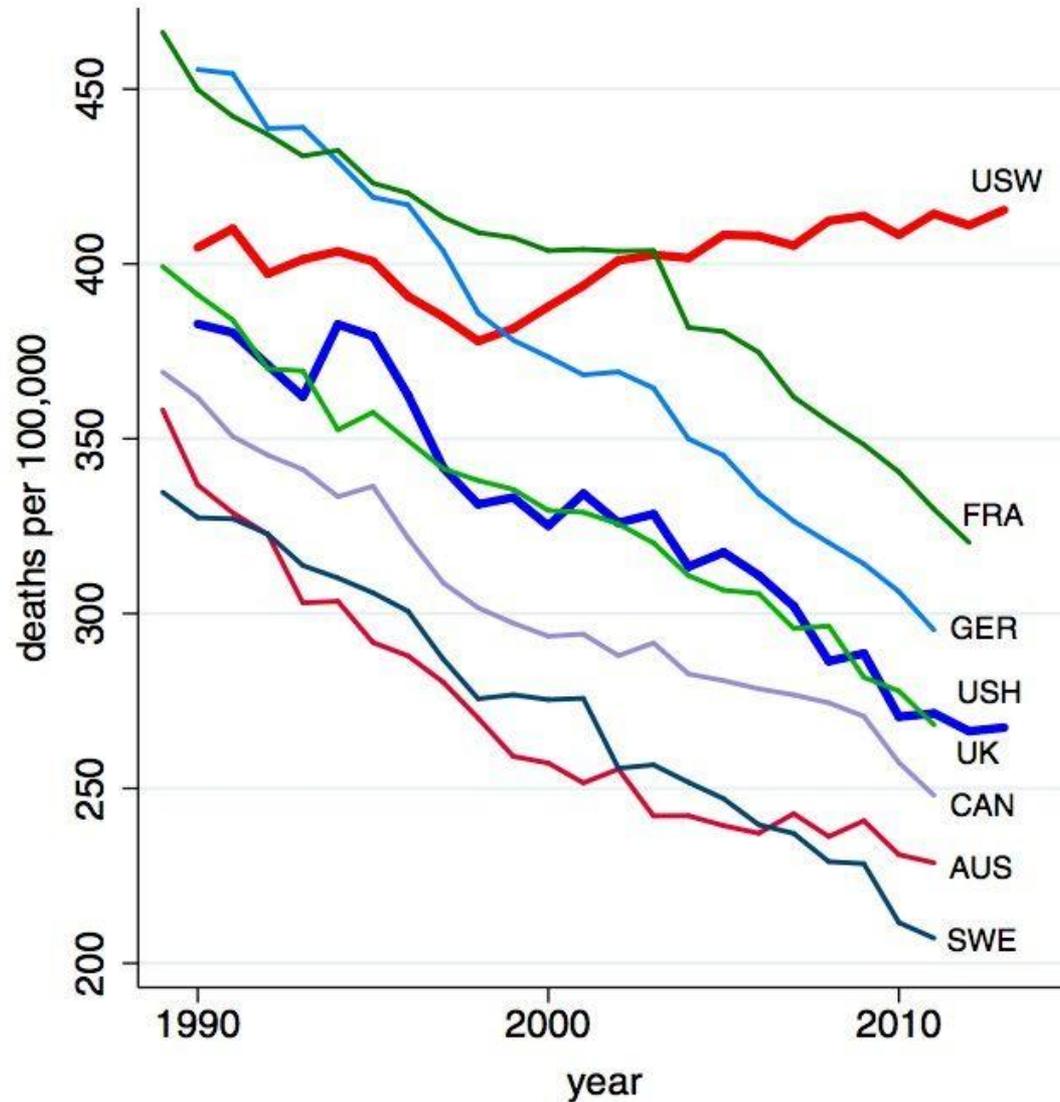
# Real Hourly Wages by Education

Figure 4 - Real Hourly Wages by Education, 1973 - 2007  
(all workers, normalized 1973=100)



Source: Economic Policy Institute

# US White Mortality, 45-54



# ***Death vs Trump***

◆ Washington Post, March 4, 2016:

"Eerie correlation in the voting data: it seems that Donald Trump performed the best in places where middle-aged whites are dying the fastest."



# Vitality and the Vote

## Vitality and the vote

United States, health metrics against swing to Donald Trump, by county



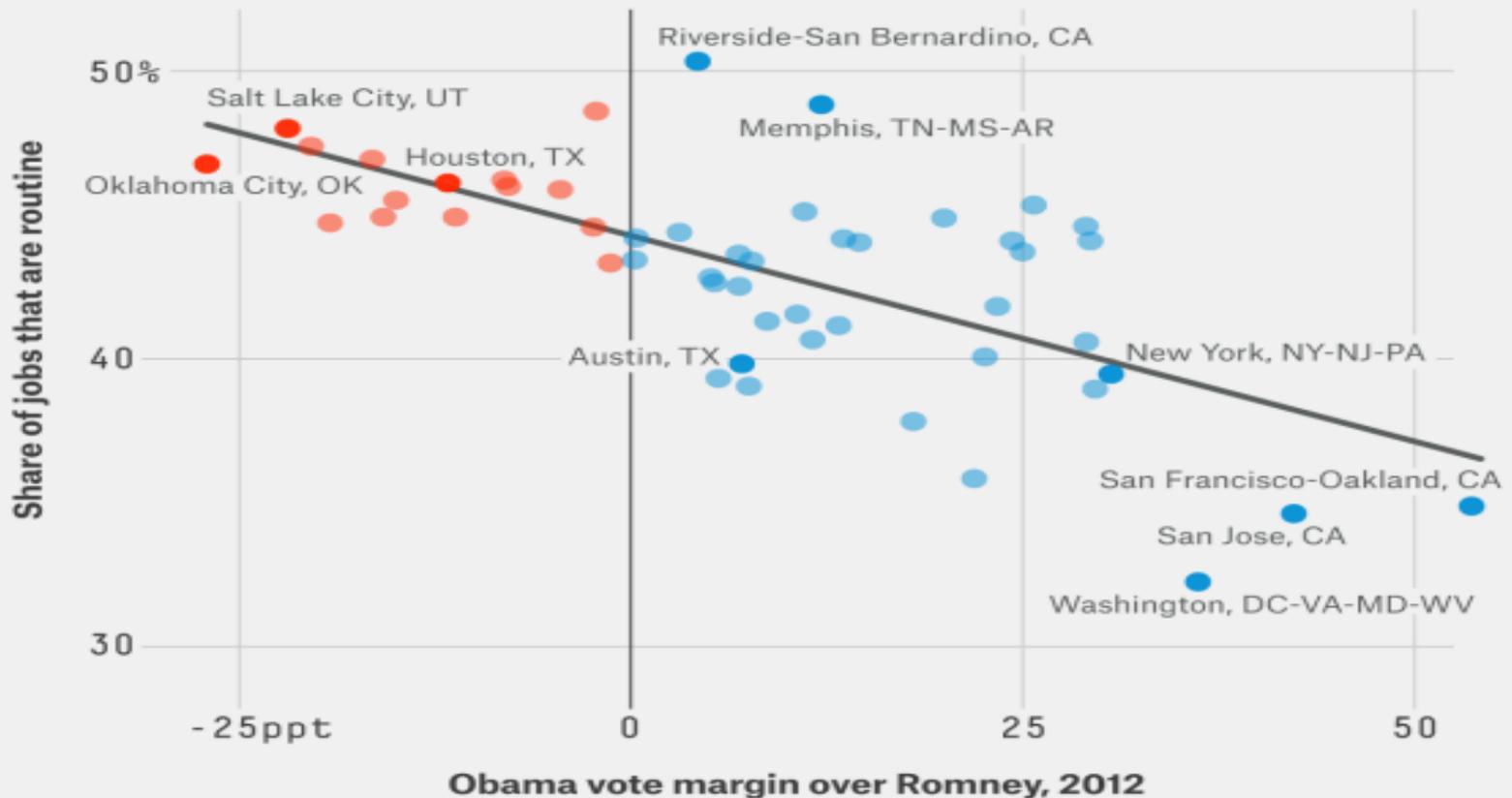
Sources: Atlas of US Presidential Elections; Census Bureau; IPUMS, University of Minnesota; Institute for Health Metrics and Evaluation; *The Economist*

\*Weighted index of obesity, diabetes, heavy drinking, physical exercise and life expectancy, 2010-12

# Political Consequences

## Republican-leaning metros have more routine jobs

Share of jobs that are routine vs. Obama's vote margin over Romney in the 2012 presidential election, by metropolitan area\*



\*Metropolitan area names have been shortened from the official census versions



BASED ON DATA FROM THE AMERICAN COMMUNITY SURVEY, DAVE LEIP'S ATLAS OF U.S. PRESIDENTIAL ELECTIONS

# ***All That Is Solid***

- ◆ "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."
- ◆ K. Marx, F. Engels, 1848: *The Manifesto of the Communist Party*

# ***2014 Economists Opinion Poll***

"Information technology and automation are a central reason why median wages have been stagnant in the US over the past decade, despite rising productivity."

- ◆ Agree: 43%
- ◆ Uncertain: 30%
- ◆ Disagree: 24%
- ◆ Strongly disagree: 4%

# ***This Time It May Be Different!***

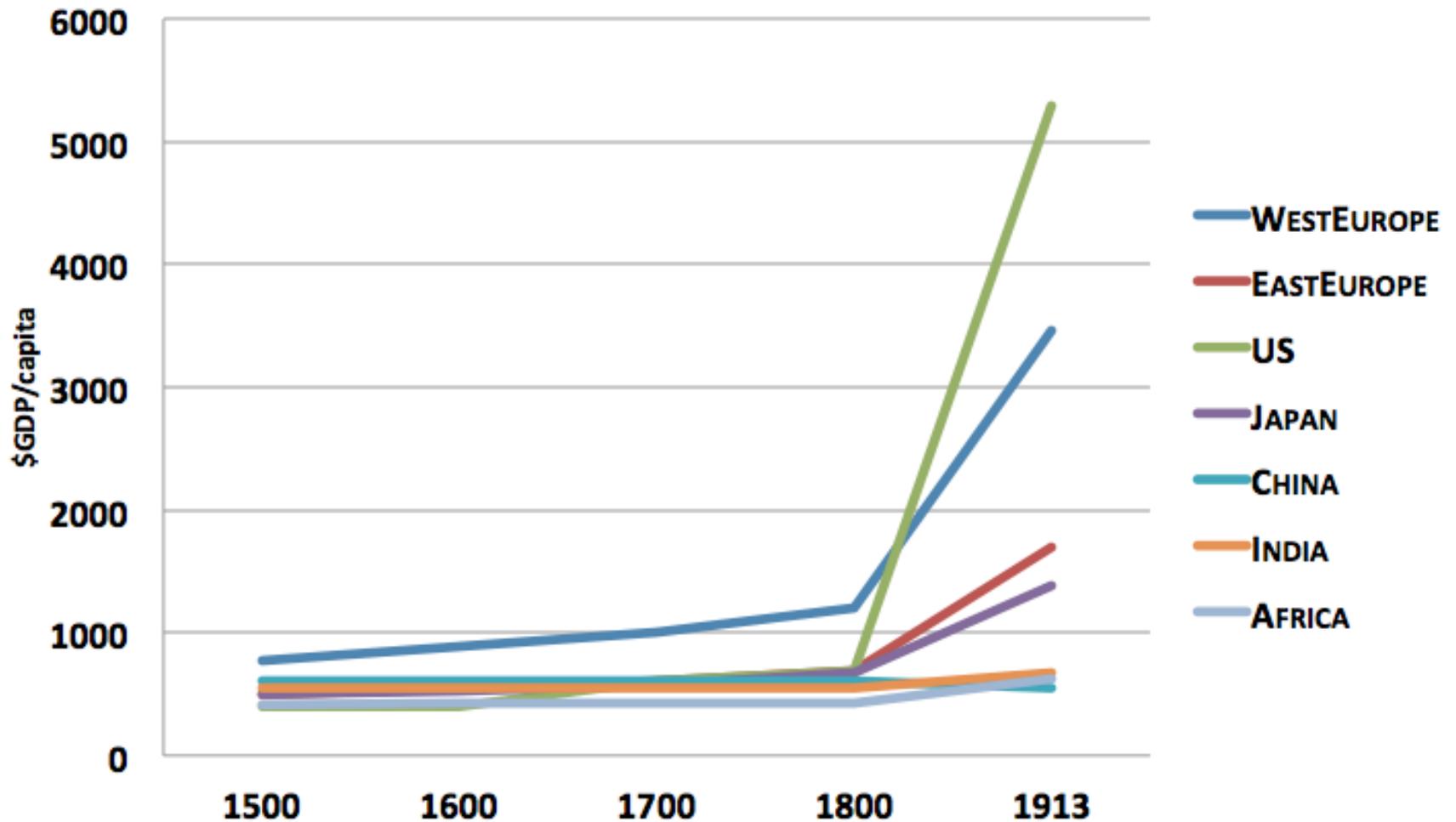
- ◆ Technology has been destroying jobs since the start of the Industrial Revolution, yet new jobs have continually been created.
- ◆ *But we have never faced machines that may be able to outcompete us in almost everything!*
- ◆ Thought experiment: Suppose that machines can do ***everything*** we can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

# ***The Tipping Point***

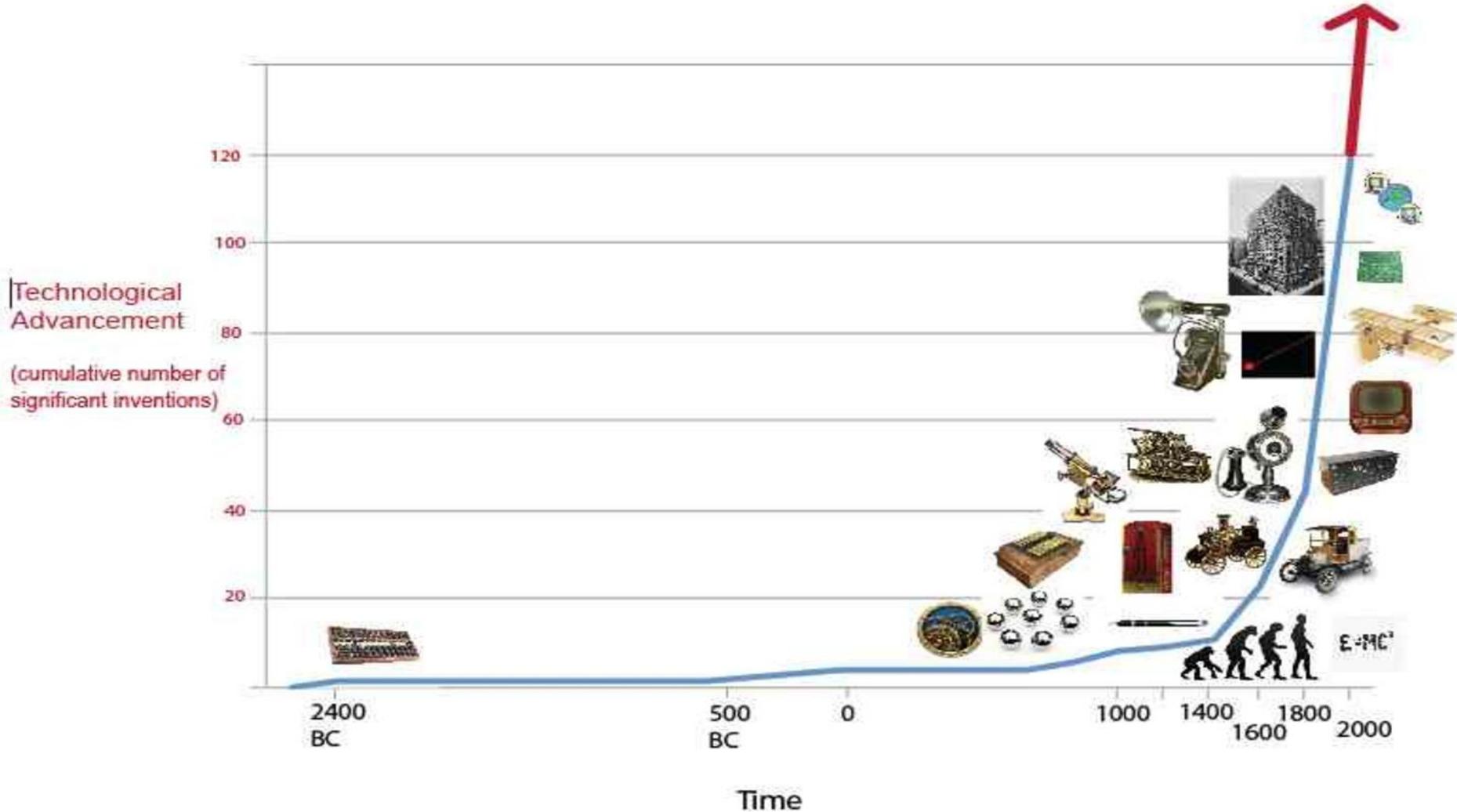
- ◆ Take water at room temperature and heat it up one degree per minute. It gets warmer and warmer, and then it suddenly boils!
- ◆ **Malcolm Gladwell, 2005:** "The tipping point is that magic moment when an idea, trend, or social behavior crosses a threshold, tips, and spreads like wildfire."

# ***Tipping Point: Industrial Revolution***

**The World Between 1500 and World War I**



# Technological Advancement



# ***Neoclassical Horses***

**W. Leontief, 1983:** Imagine a pair of horses in the early 1900s talking about technology. One worries all these new mechanical muscles will make horses unnecessary. The other reminds him that everything so far has made their lives easier: "Even if this car thingy takes off, there will be new jobs for horses we can't imagine."

**Fact:** The horse population peaked in 1915 -- from that point on it has been nothing but down.

# ***It's All about Relative Speed***

- ◆ A: Will technology destroy or downscale jobs? ***Yes!***
- ◆ B: Will technology create jobs or upscale jobs? ***Yes!***
- ◆ Will B offset A?
- ◆ What is the relative speed of A and B?
- ◆ What is the skill level of destroyed vs. created jobs?

# ***New Jobs?***

- ◆ **Detroit 1990:** The three largest companies had a combined market value of \$65 billion (real), with 1.2 million workers.
- ◆ **Silicon Valley 2016:** The three largest companies had a combined market value of \$1.5 trillion, with about 190,000 workers.

# ***Obama on Automation***

June 13, 2016: *Bloomberg News*

- ◆ "As we move toward an economy where, because of automation, you need fewer and fewer people to make more and more stuff, more and more of us are going to have to move into the service sector. The service sector historically has been a low-wage sector."
- ◆ "Because of automation, because of globalization, we're going to have to examine the social compact, the same way we did early in the 19th century and then again during and after the Great Depression."

## ***Renewing the Social Compact – Labor laws***

- ◆ 1842: Right to strike
- ◆ 1915: Right to unionize
- ◆ 1924: Abolish child labor
- ◆ 1938: 40-hour work week
- ◆ 1964: Equal pay for women and minorities
- ◆ 1970: Health and safety laws
- ◆ 2020: Universal basic income?

# ***The Past and the Future***

Jason Furman, Chairman, Council of Economic Advisers, July 2016:

"My worry is not that this time could be different when it comes to AI, but that this time could be the same as what we have."