

# CLASS 12 - THE FUTURE OF WORK - THE EMPLOYMENT-PRODUCTIVITY DEBATE

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INNOVATION SYSTEMS FOR SCIENCE,  
TECHNOLOGY, MFG., ENERGY & HEALTH

# ERIC BRYNJOLFFSON (PROF. MIT SLOAN SCH.) AND ANDREW MCAFEE (PRIN. RESEARCH SCIENTIST, MIT) THE RACE AGAINST THE MACHINE (RESEARCH BRIEF, MIT CENTER FOR DIGITAL BUSINESS JAN. 2012)



Image courtesy of [New America](#) on Flickr.

- After the Great Recession, economy was “not putting people back to work”
- Recession wasn’t a standard business cycle, where employees were rehired
- Not cyclical, was it “STAGNATION” – long term decline in US ability to innovate and increase productivity?
- Third explanation: not stagnation - NOT TOO LITTLE INNOVATION, TOO MUCH – Jeremy Rifkin 1995: “end of work” was the cause – technological job displacement
- Computers displacing people: even making inroads in “urbanized driving,” “complex communication” – ex.: Google’s driverless car, Watson’s Jeopardy
  - Kurzweil’s The Age of Spiritual Machines: When Computers Exceed Human Intelligence” (2000)
    - EXPONENTIAL GROWTH IN COMPUTING IS ON US – Computers are thousands of times better than 30 years ago
  - But: computers not good at combined physical and knowledge yet, not general problem solving, not at creative abilities – but exponential progress

# BRYNJOLFSSON AND MCAFEE, CON'T

- Given exponential computing improvement causing technological displacement: *two strategies:*
- **1) ORGANIZATIONAL INNOVATION**
- “inventing new organizational structures, processes, and business models that leverage ever-advancing technology and human skills”
- The stagnation of median wages and polarization of job growth is an **opportunity for creative entrepreneurs.**
- They can develop new business models that combine the swelling numbers of mid-skilled workers with ever- cheaper technology to create value.
  - There has never been a worse time to be competing with machines, but there has never been a better time to be a talented entrepreneur .
- Digital technologies create enormous opportunities for individuals to use their unique and dispersed knowledge for the benefit of the whole economy. But are there enough opportunities for all these entrepreneurs?
- Are we running out of innovations? When businesses are based on bits instead of atoms, then each new product adds to the set of building blocks available to the next entrepreneur instead of depleting the stock of ideas...

# BRYNJOLFSSON AND MCAFEE, CON'T

- we need not only organizational innovation, orchestrated by entrepreneurs, but also a second broad strategy: investments in the complementary human capital:
- **2) INVESTING IN HUMAN CAPITAL:**
- Improve “the education and skills required to get the most out of our racing technology.”
- Unfortunately , our educational progress has stalled and this is reflected in stagnating wages and fewer jobs. Although the United States once led the world in the education of its citizens, it has fallen from first to tenth in the share of citizens who are college graduates.
- It’s not a coincidence that the **educational sector also lags as an adopter of information technologies**. The optimistic interpretation is that we have tremendous upside potential for improvements in education.”
- **THERE IS A - THIRD INDUSTRIAL REVOLUTION: COMPUTING AND INFORMATION, AND INFORMATION DOESN'T GET USED UP**

DAVID AUTOR (PROF. OF ECONOMICS, MIT), WHY ARE THERE STILL SO MANY JOBS? THE HISTORY AND FUTURE OF WORKPLACE AUTOMATION, *JOURNAL OF ECONOMIC PERSPECTIVES* V. 29, N. 3 SUMMER 2015, 3-30.

- Traditional Economics: **technological advance**, since the industrial
- revolution, including automation, **always creates net new jobs** – has **that now changed?**
- COMPLEMENTARITY: "automation has not wiped out a majority of jobs over the decades and centuries. Automation does indeed substitute for labor— as it is typically intended to do. However, automation also complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply. Indeed, a key observation of the paper is that journalists and even expert commentators tend to overstate the extent of machine substitution for human labor and ignore the strong complementarities between automation and labor that increase productivity, raise earnings, and augment demand for labor."

# AUTOR, WHY ARE THERE STILL SO MANY JOBS?

- “Complementarity” – automation and people: **EXAMPLE:**
  - ATMs were introduced in the 1970s; their numbers in the US economy quadrupled from 100,000 to 400,000 between 1995 and 2010.
  - Did these machines eliminated bank tellers?
  - US bank teller employment rose modestly from 500,000 to approximately 550,000 over the 30-year period from 1980 to 2010
- Routine cash-handling tasks of bank tellers receded
- But: information technology also enabled a broader range of **bank personnel to become involved in “relationship banking.”**
  - Banks recognized the value of tellers enabled by information technology, not primarily as checkout clerks, but as salespersons, forging relationships with customers and introducing them to additional bank services like credit cards, loans, and investment products.
- NOTE: Over the very long run, gains in productivity have **NOT** led to a shortfall of demand for goods and services – THESE KEEP GROWING – this is an offsetting factor

# AUTOR, WHY ARE THERE STILL SO MANY JOBS?

- **Last three decades: “polarization” of the labor market**
  - Wage gains went disproportionately to those at the top
  - Employment growth was at the bottom of the income and skill distribution,
  - Not for those in the middle.
- **1940-1970:**
  - physically demanding, repetitive, dangerous, and cognitively monotonous work receded, because of extraordinary productivity gains in agriculture.
  - Rising consumer affluence spurred demand for manufactured goods and leisure complements.
  - Growth of technologically intensive corporations, health care services, and higher education created employment for credentialed professionals
    - and a cadre of supporting clerical, administrative, and sales workers.
  - automation was reducing labor demand across large number of occupations, but overall job prospects appeared broadly favorable during period.
- **1980-2010**
  - professional, technical, and managerial occupations—grew even more rapidly
  - Skilled blue-collar occupations shrank rapidly
  - clerical and sales occupations—the vulnerable “production jobs” of the information age—declined
  - low-paid personal services absorbed increasing share of non-college labor.

# AUTOR, WHY ARE THERE STILL SO MANY JOBS?

- In the Interplay between machine and human:
  - comparative advantage allows computers to substitute for workers in performing routine, codifiable tasks
  - But it also amplifies the comparative advantage of workers in supplying problem-solving skills, adaptability, and creativity.
- **Frontier of automation is rapidly advancing -**
  - challenge to substituting machines for workers in tasks requiring flexibility, judgment, and common sense remains immense.
  - In many cases, machines *both substitute for and complement human labor*.
- Focus only on what is lost misses a central economic mechanism -
  - automation affects the demand for labor by raising the value of the tasks that workers uniquely supply.



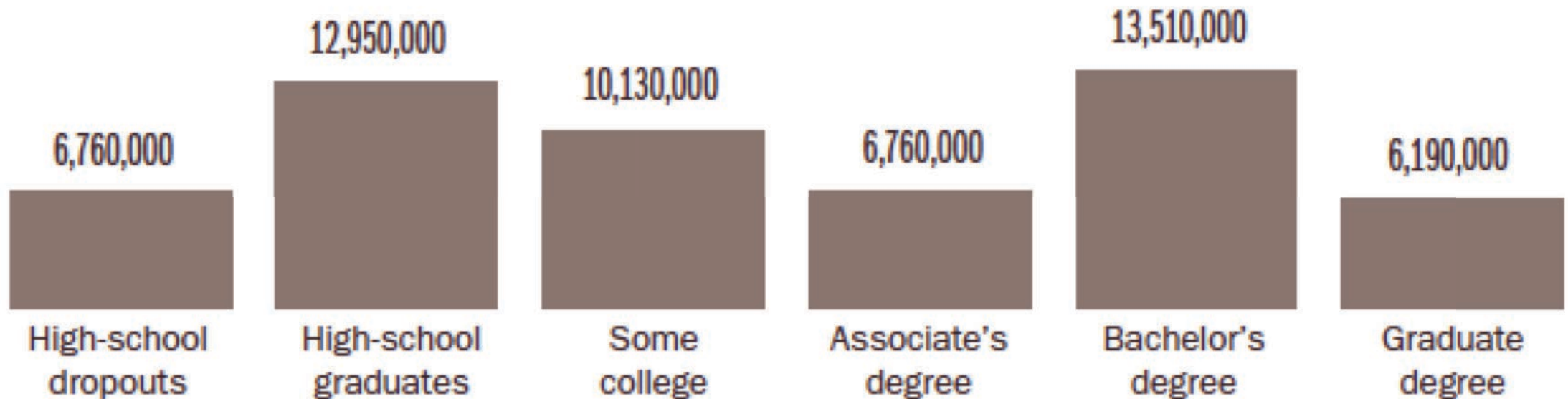
# DAVID AUTOR (PROF. OF ECONOMICS, MIT), SKILLS, EDUCATION AND THE RISE OF EARNINGS INEQUALITY *SCIENCE*, V. 344, N. 6186, MAY 23, 2014, 843-851

- Issue: steep, persistent rise of earnings inequality
  - in the U.S. labor market
  - and in developed countries generally
- **Why Look at Inequality?**
- **First**, earnings premium for education has risen across a large number of advanced nations
  - this rise contributes substantially to the net growth of earnings inequality
  - In the US, 2/3s of the overall rise of earnings dispersion between 1980 and 2005 is accounted for by the increased premium associated with schooling in general and postsecondary education in particular
- **Second**, literature finds that interplay between the supply and demand for skills provides insight into why the skill premium has risen,
  - specifically, the earnings gap between college and high school graduates has more than doubled in the United States over the past three decades.
- **Third** - skill premium offers insight into the evolution of inequality within a market economy,
  - Highlights the social costs – and gains of upper middle class
  - Clear role for public policy

# GEORGETOWN UNIV. CENTER ON ED AND THE WORKFORCE – UPCOMING JOB OPENINGS: *Demand* –

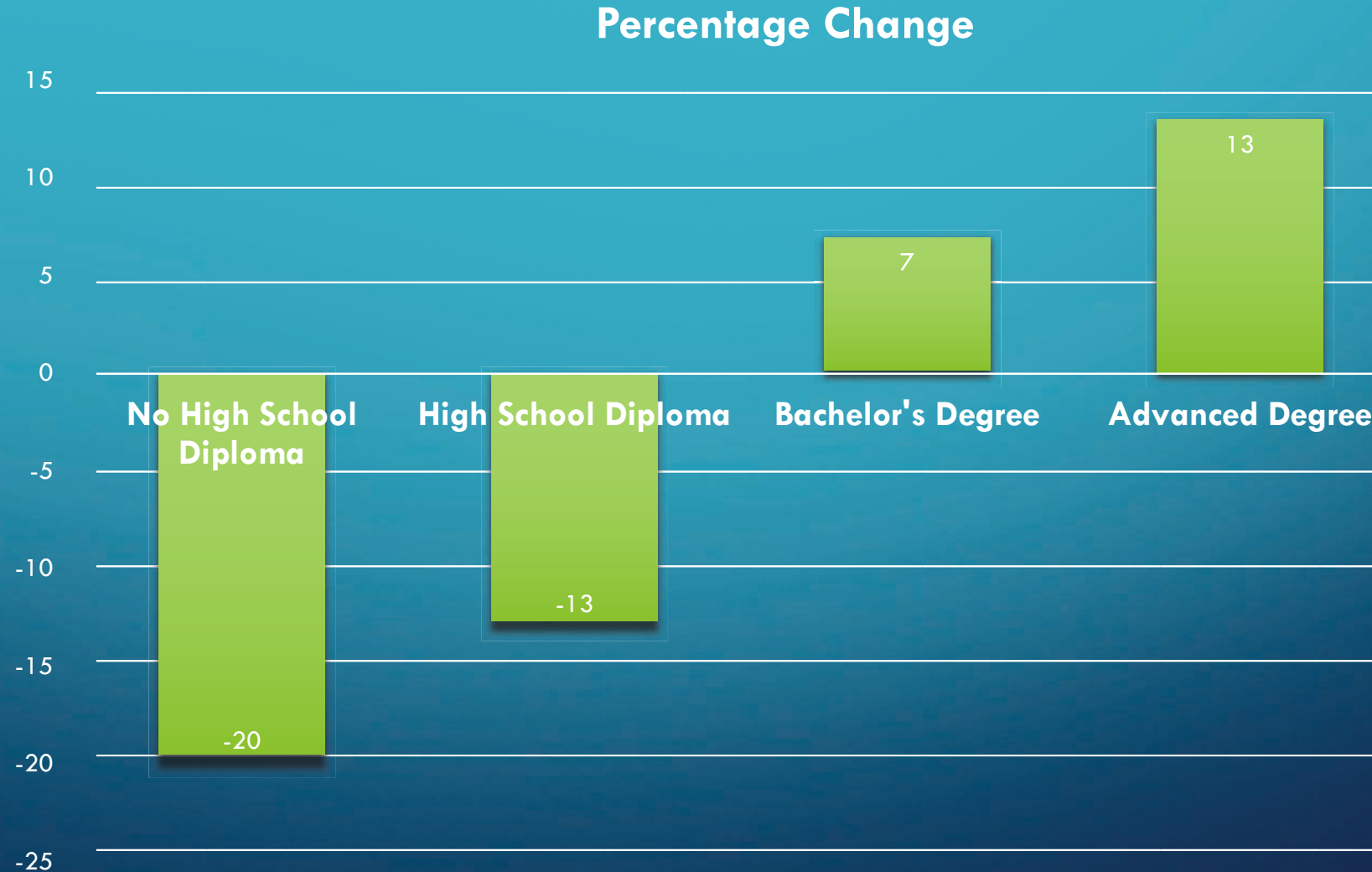
- High. Sch. Diploma & Less than High Sch. Diploma – 19.7m
- Some College, Assoc. Degree, College & plus Col. – 36.5m

## EDUCATION LEVEL NEEDED FOR PROJECTED JOB OPENINGS, 2024



SOURCE: Georgetown University Center on Education and the Workforce analysis of U.S. Bureau of Labor Statistics data

# U.S. MEN WITH HIGH SCHOOL AND LESS THAN HIGH SCHOOL: DECLINE IN MEDIUM INCOME, GROWTH IN INEQUALITY



# AUTOR, SKILLS, EDUCATION AND THE RISE OF EARNINGS INEQUALITY, CON'T

- Rising demand for educated labor in advanced economies, including US
- If the supply of educated labor does not keep pace with persistent outward shifts in demand for skills, the skill premium will rise.
  - In the words of the Red Queen in Lewis Carroll's Alice in Wonderland, "...it takes all the running you can do, to keep in the same place."
- When the rising supply of educated labor began to slacken in the early 1980s (college graduation rate stabilizes between 1975-1982, only starts rising again in 2004), a logical economic consequence was an increase in the college skill premium.
- That factor is a significant one in accounting for income inequality in the US
- Public policy response: Up-skilling

# DAVID MINDELL (PROF., MIT STS), *OUR ROBOTS OURSELVES – ROBOTICS AND THE MYTH OF AUTONOMY* (2015) 1-11, 191-218 (CHAPTS. 1 AND 6)

- Mindell takes an in-depth look at human-robot interaction in four major areas of robotics advances:
  - undersea operations,
  - space exploration,
  - drones, and
  - driverless cars.
- In each, he finds **deep complementarity between robots and people**—each has skill sets that enhance the other's.
- Fits the famous 1960 work on computing by J. C. R. Licklider (the theorist behind the Internet and personal computing).
- **Licklider saw computing on a human-computer continuum, a “man-machine symbiosis” where both sides together optimize a greatly improved combined performance, which indeed has been the overall history in this sector to date.**

# MINDELL, OUR ROBOTS, OURSELVES

- Mindell's vision is that there can be a much **richer space when people and robotics are joined** –
  - A much **richer understanding and ability to make perceptions and judgements**
  - That is what has been worked out as **optimal in undersea, space, UAVs** – that is **40 years of learning**
- This new environment is what the **future will be about between people and machines, not machines displacing people**
  - It will be better than just a machine world or people world – it will be integrated
- People get inside the robots and **the robots are extensions of themselves**, they are on site with the robots, as though they were the robots and the robots extensions of themselves –
  - that is the UAV/drone story, the undersea exploration story, the space story<sup>14</sup> – it **will be the driverless car story**

# MINDELL, OUR ROBOTS OURSELVES

- For **driverless cars**, he envisions
  - a much **richer driver experience**, much more engagement with the surroundings, much greater information and knowledge access, much better safety and comfort, reduced driver tension, a learning experience,
  - but because of the demands of people in the constant decision process, the **driver cannot sleep in the trunk**
- **Note: A chessmaster and a computer always beat either a person or a computer in chess – it will be a symbiosis**

## WILLIAM B. BONVILLIAN AND PETER SINGER, ADVANCED MANUFACTURING – THE NEW INNOVATION POLICIES (MIT PRESS – PUBLICATION PENDING DEC. 2017), CHAPTER 9

- Starting with the Luddites in 1815, long been workforce concern about automation
- The largest workforce disruption in US history was in agriculture occurred between 1810 and 1960, where ag workforce dropped from 80% to below 10%
- 1950 – MIT's Norbert Wiener introduced term “cybernetics”, concern about computer displacement of people
- 1960s – major anxiety about workforce automation
- 2015 - concern is back – AI, machine learning, robotics mix – threatening
- Economist John Maynard Keynes - “Thus we have been expressly evolved by nature—with all our impulses and deepest instincts—for the purpose of solving the economic problem. If the economic problem is solved, making will be deprived of its traditional purpose.” Will the economy ever achieve high enough productivity level to cut work hours? No sign of this yet – US average workweek is 47 hours.



# BONVILLIAN AND SINGER – FUTURE OF WORK

## CHAPTER 9, CON'T

- **Backdrop: significant work disruption** – 1/3 of manufacturing jobs lost, 2000-10
  - Median income of those without high school diploma down 20% between 1990-2013; median income of those with high school diploma or some college down 13%
  - Bar bell problem: thriving upper middle class with significantly growing incomes, thinning middle being shunted to lower paid lower end services sector
  - Great majority of jobs created since end of the 2007-08 recession went to college grads
- **Brynjolfsson and McAfee** led the tech displacement concern: growth of IT advances unparalleled and unprecedented; **software has near zero marginal cost for expansion; mix of AI, machine learning, robotics will disrupt work**
- **Martin Ford:** “winner take all distribution” – tendency of software toward monopoly, and
  - “computers do more than they are programmed for” – deep learning
  - lower end pushed out

# BONVILLIAN AND SINGER- FUTURE OF WORK

## CHAPTER 9, CONT'

- **David Cowen**
- technological displacement means **country likely to be divided into two distinct classes,**
- Property values in most cities too expensive, separate low income communities
- “In essence, we would be recreating a Mexico-like or Brazil-like environment in part of the US”
- **Brynjorffsson and McAfee (in *Second Machine Age*):**
- new jobs, mostly **low skilled,** replace the middle skill jobs that are displaced by technology
- But view rising **inequality as more manageable – tax policy can help:**
- Pigouvian taxes (tax on business for engaging in specific negative activity), carbon tax, and taxes on economic rents, on land or superstars, ameliorate the problem.
- Over the long run, they advocate for **a negative income tax,** as the best way to guarantee a basic income while maintaining an incentive for work.
- [Note: these taxes: politically unlikely]

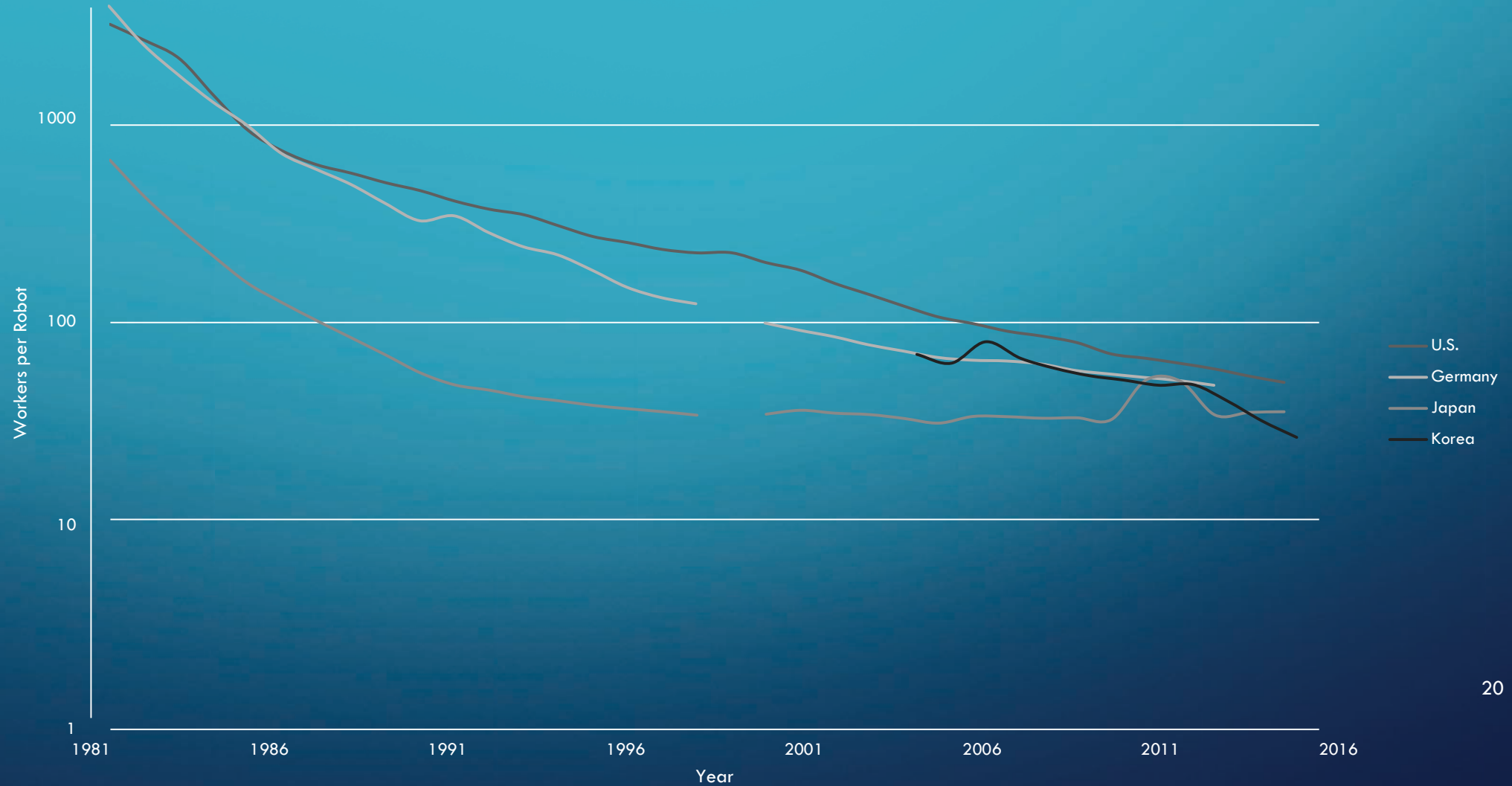
# BONVILLIAN AND SINGER, FUTURE OF WORK

## CHAPTER 9, CON'T

- **Frey and Osborne** (Oxford): look at occupational definitions –
  - based on this find 47% of US jobs have high likelihood of being replaced by automation
- **Rob Atkinson, ITIF:**
  - Attacks Frey and Osborne: their list of **occupations to be replaced are experiencing low productivity gains**
  - they assume a highly unlikely 3% labor productivity rate – haven't seen since 19<sup>th</sup> century
  - They also assume there is a fixed amount of work (“lump of labor” fallacy)
  - but work is more dynamic, unemployment can be offset by the introduction of new goods or more goods into the market, by shorter working days, or by a combination of the two that is decided by society.
- **OECD Study – 2016**
  - Looked not at occupational definitions, but at what workers in categories were actually doing – much richer story, were doing much more than occupational definition
  - Found in 22 OECD nations, 6 to 12% of jobs lost IT – US was 10% over expended period – manageable
- **Note: we're in a period of low productivity and low capital investment** –
  - no sign of a ramp-up to widespread automation – yet [note: Pratt/Leonard driverless car ex.]
- **Nauna Hejlund, VP Danish Conf. of Trade Unions:**
  - “New technology is not the enemy of workers, old technology is.” (2016)

# SPEED AT WHICH ROBOTS ARE BEING INSTALLED IN PRODUCTION HAS SLOWED SIGNIFICANTLY:

Number of Manufacturing Employees for Each Industrial Robot



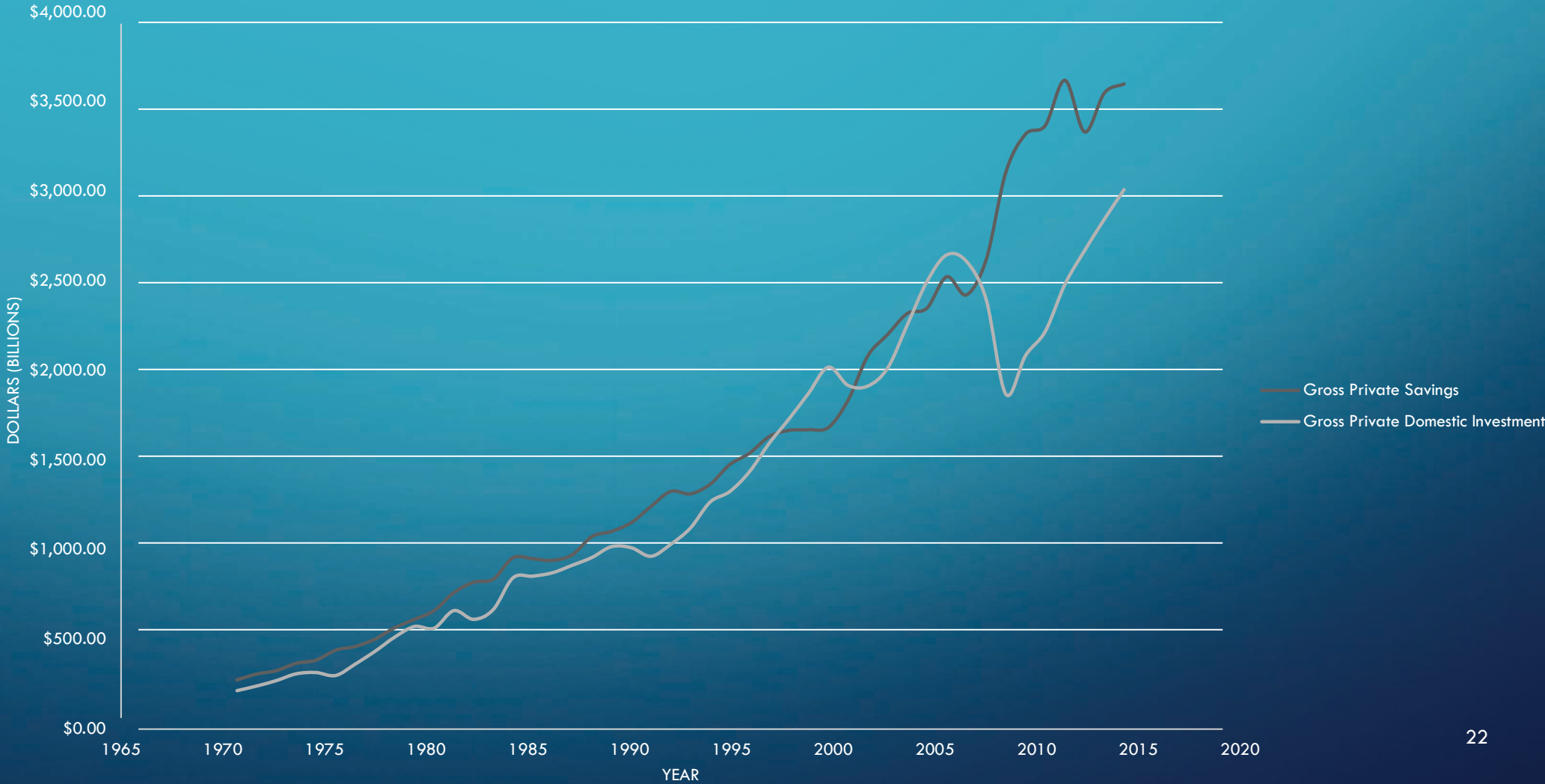
# BONVILLIAN AND SINGER, FUTURE OF WORK

## CHAPTER 9, CON'T

- The problem now is not automation it's "Secular Stagnation" –
  - Term developed in the 1930s by **Alvin Hansen** - economy ends up stuck with low growth and high unemployment because of a shortfall of investment
  - **Larry Summers** returns in 2013 to this theory - with interest rates around zero, U.S. output is insufficient to support full employment.
    - factors hampering investment demand: **decreasing population growth, a relative decrease in the cost of capital goods, and excess money being retained not used by large corporations.**
    - on savings side, **excessive reserve holdings among developing countries, post crisis financial regulations, inequality and increasing intermediation costs.**
    - excess of savings over investment slows growth and increases unemployment.
    - instead of supply creating its own demand, demand is unable to create sufficient supply
    - Calls for fiscal stimulus
  - Overall – US has: low productivity, low capital investment, low growth rate, growing inequality, declining middle class –
    - unemployment is below 5%, but structural unemployment, sizable part of workforce not in the economy

# EXCESS OF U.S. SAVINGS OVER INVESTMENT – LIMITED INVESTMENT SLOWS GROWTH

## SAVINGS AND INVESTMENT



# BONVILLIAN AND SINGER, FUTURE OF WORK

## CHAPTER 9, CON'T

- Robert Gordon (*Rise and Fall of American Growth*) - Contrary View on Secular Stagnation
  - current low growth and secular stagnation result not of insufficient demand but insufficient supply – ie, insufficient technological supply - the real drag on the economy.
  - declining overall total factor productivity growth in the U.S. (with 1990s exception) since 70s
  - Is it that the IT revolution just fading and we can temporarily expect to see low or no gains, or, Gordon suggests, is there a permanent decline in technological advancement?
  - Gordon's view that we have already picked the low hanging fruit of technological development and there are only limited advances ahead - controversial
  - How to fix this: Gordon says fixing societal “headwinds” is best option for improving growth: educational attainment, income inequality, changing demographics, government debt<sup>23</sup>, and social breakdown.

# BONVILLIAN AND SINGER, FUTURE OF WORK

## CHAPTER 9, CON'T

- Summers – Solution is Fiscal Stimulus – Infrastructure Bill

- Fixing the growth rate is tied to growing productivity, which is tied to technological innovation
- Problem: traditional infrastructure (repairing roads, sewers) isn't technological innovation – it is not productivity enhancing
  - Yet we have have a big productivity growth problem a traditional infrastructure bill won't fix
- We already rode those surface transportation innovation waves, they largely played out
- And how much can we do? Obama Stimulus was only able to spend \$25 billion on transportation – not that many “shovel ready projects
- It's not bad – could help in unemployment in lower skilled working class, but a high growth rate fixes a lot of problems, and this won't do that

- ALTERNATIVE – Invest in “Innovation Infrastructure”

- Advanced manufacturing is a good example – helps in employment
- Applied R&D in key areas of technology advanced - energy



# COURSE WRAP-UP:

- **CLASS 1: Direct Innovation Factors: R&D (Solow) and Talent (Romer)**
- Indirect Factors - ecosystem
- **CLASS 2: Innovation Systems**
  - Look at innovation actors - Nelson
  - Culture
- 3rd Direct Innovation Factor?
  - Organization of the Innovation System
    - Pipeline system: technology push - Vannevar Bush - radical/ breakthrough innovation - strong federal role
    - Induced innovation - industry led - tech pull - incremental advance
    - Innovation organization - the third key - aligning the innovation actors
- **CLASS 3&4 – Mfg. as a case study - link between innovation/production**
- **CLASS 5: Innovation at the Institutional Level**
  - How does the R and D and Prototyping handoff occur?
  - US system - V. Bush split R and D
  - Basic Research was federal science agency task; industry had the later stages
- **CLASS 6: Result: Valley of Death between R and D**

# CLASS WRAP-UP, CON'T --

- **CLASS 7: Innovation at the Face to Face Level**
  - People innovate not institutions
  - "Great Group" theory
- **CLASS 8: DARPA: the connected science model**
  - Breakthrough science to prototype stage
  - Bridges Valley of Death - right/left translational model
- **CLASS 9: The NIH story: case study in institutional organizational problems**
  - Basic research only, so valley of death problem
  - Stovepipes prevent cross-cutting tech advance
  - Industry issues: organized for blockbusters not for small disease populations diseases, infectious disease, or 3rd world disease
  - Biothreat model - create incentives for counter-market
- **CLASS 10: Energy Technology:**
  - The challenge of innovation within an established, complex *Legacy* sector
  - Have to look at Front End and Back End of innovation system
  - Fill gaps in innovation institutions

# CLASS WRAP-UP, CON'T

## • CLASS 11: EDUCATION

- **Freeman:** talent base will affect innovation performance/growth
- **Romer** point: Gov' t policy focused on capital supply and R&D incentives
  - Missing focus on inputs to R&D: talent - proof: GI Bill and Sputnik multiplied science talent base
  - Could turn around the number of college grads studying science/math and solve problem
- **Katz and Goldin:** tech advance/education disconnect = income inequality
- **Bamol:** educating for incremental advance not breakthrough advance - how do you educate for the latter?
- **MIT Online Ed Report** –merge research, learning engineers, change agents
- **Bonvillian/Weiss** – online ed offers rev in learning – blended reforms

## • CLASS 12: FUTURE OF WORK

- **Brynjolfsson and McAfee** – future of IT is technological displacement
- **Autor** – but “complementarity” – higher skills req'd but automation complements work and employment – goods/services expand, and automations fills this, but expands work too
- **Autor** – economy requires upskilling - inequality tied to policy failures in upskilling
- **Mindell** – robotics: will be human/machine symbiosis – like computing
- **Bonvillian and Singer** – jobless future is not upon us, have time, need to resolve secular stagnation, and technology advances could play big role

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