Manufacturing Location & Technology Changes: Implications for Innovation and the Nature of Work

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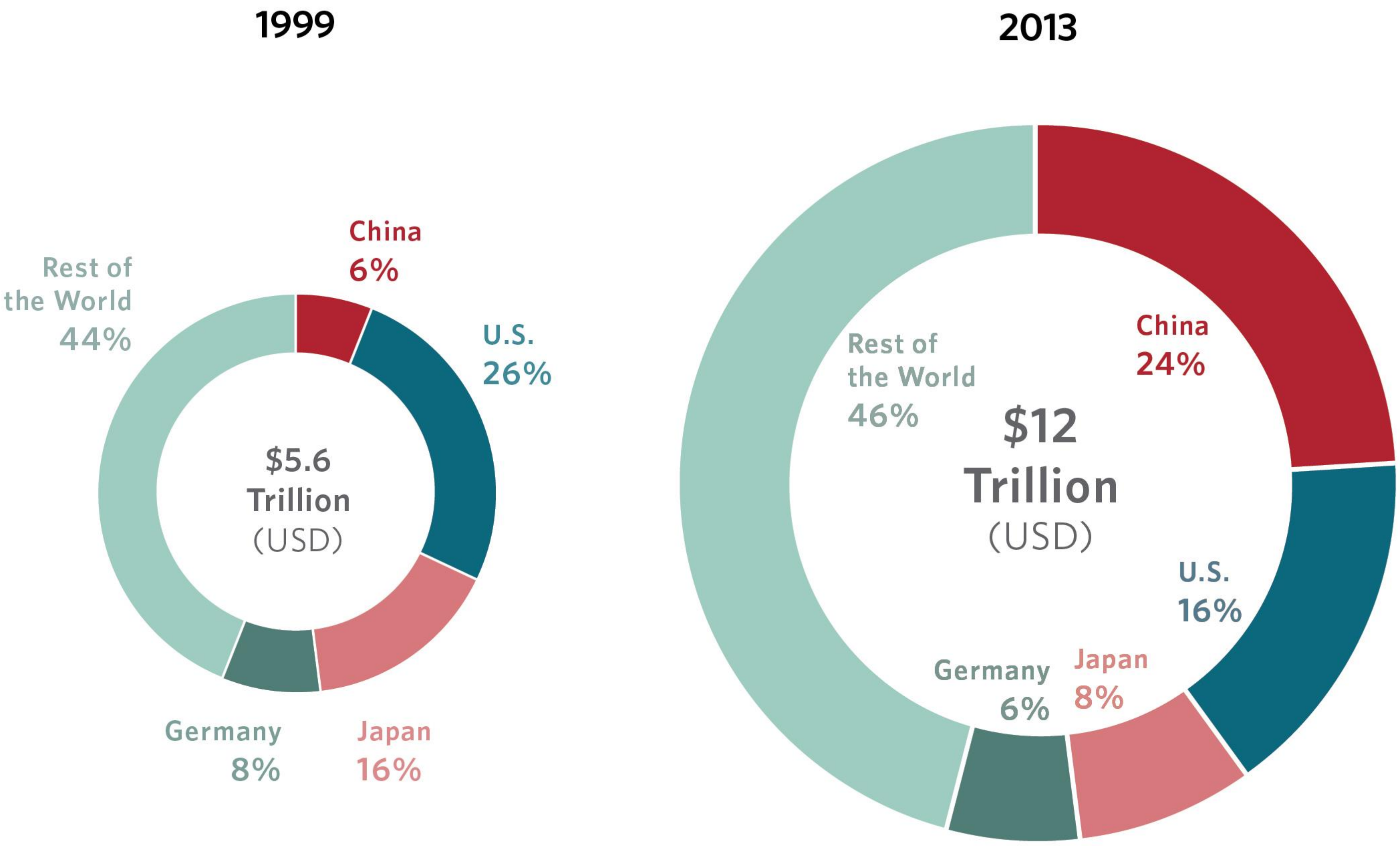
Forces changing manufacturing

- Globalization
- Technological Changes

Global Manufacturing Value Added

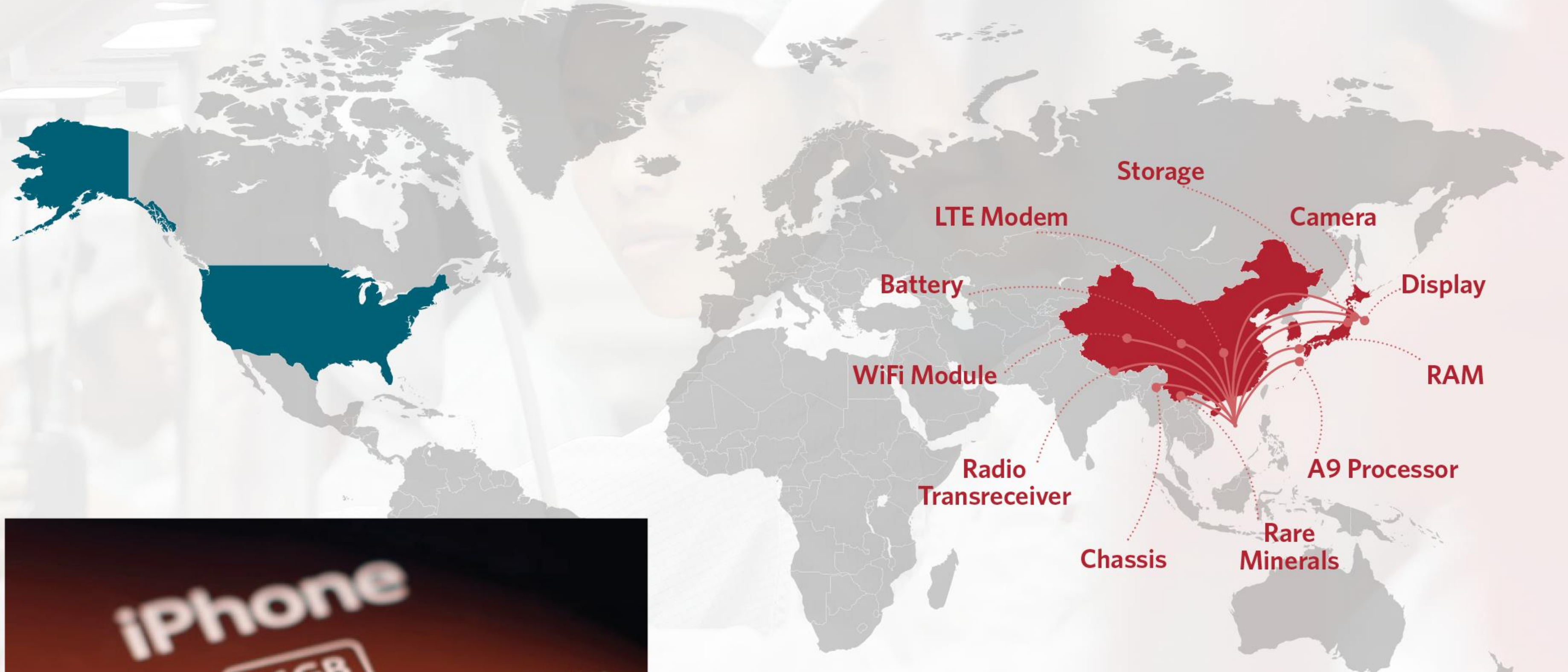


2013 is most recent data available

Global Location of Workforce

Invention

Manufacturing and Assembly



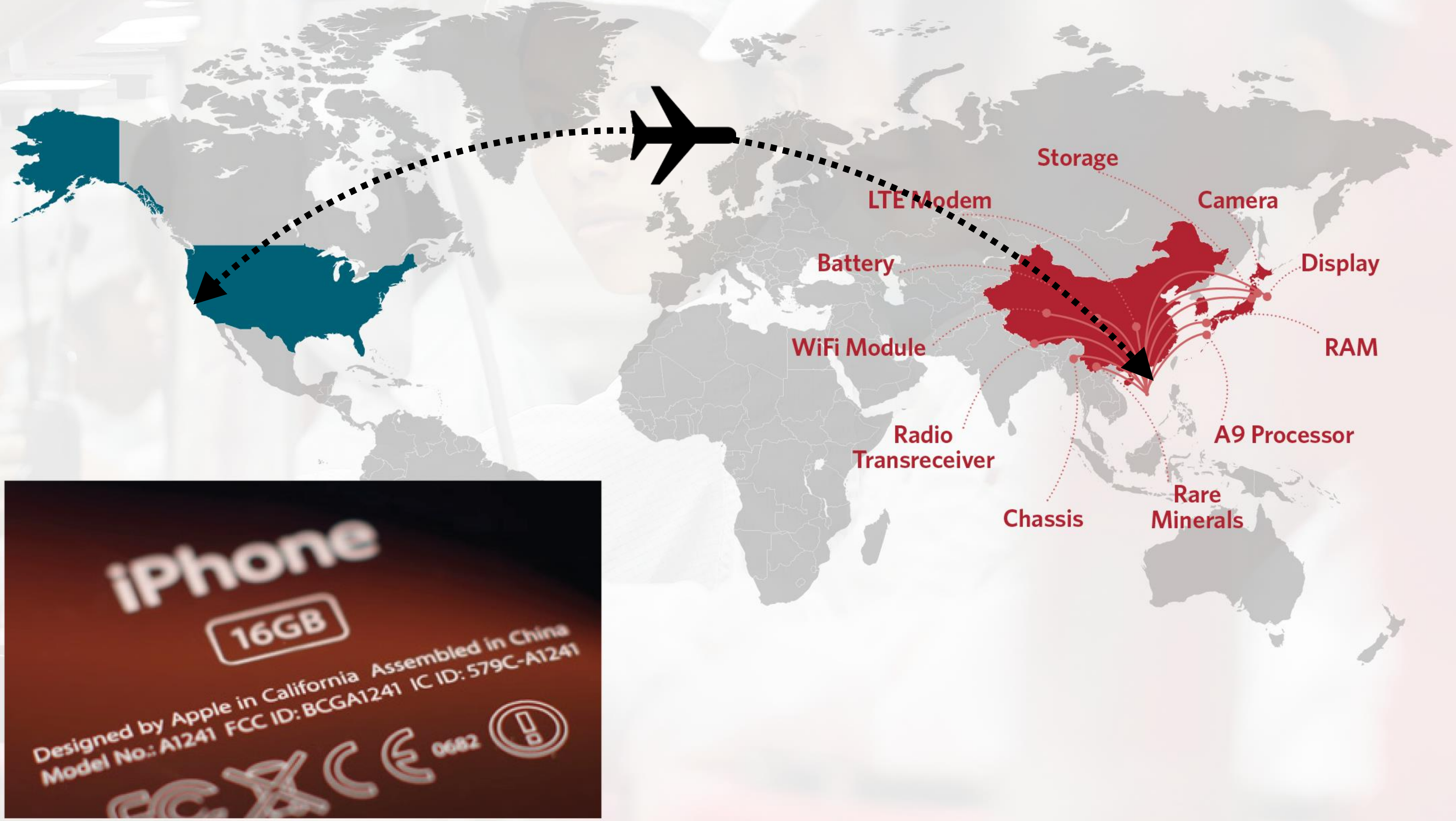
Does Separation Affect Innovation?

- Adverse consequences for firms and home nation's innovation
  - Distance, electronic dependence, time zone changes, and national differences reduce knowledge flows (Gibson and Gibbs 2006; Cummings, 2009)
  - Problem solving often requires physically present experts (Tyre and von Hippel 1997)
  - In certain industries, separation is extremely difficult or impossible (Lecuyer 2006, Pisano 2000, Bonnin-Roca 2017)
  - Spillovers, agglomeration economies … R&D may follow

Global Location of Workforce

Invention

Manufacturing and Assembly



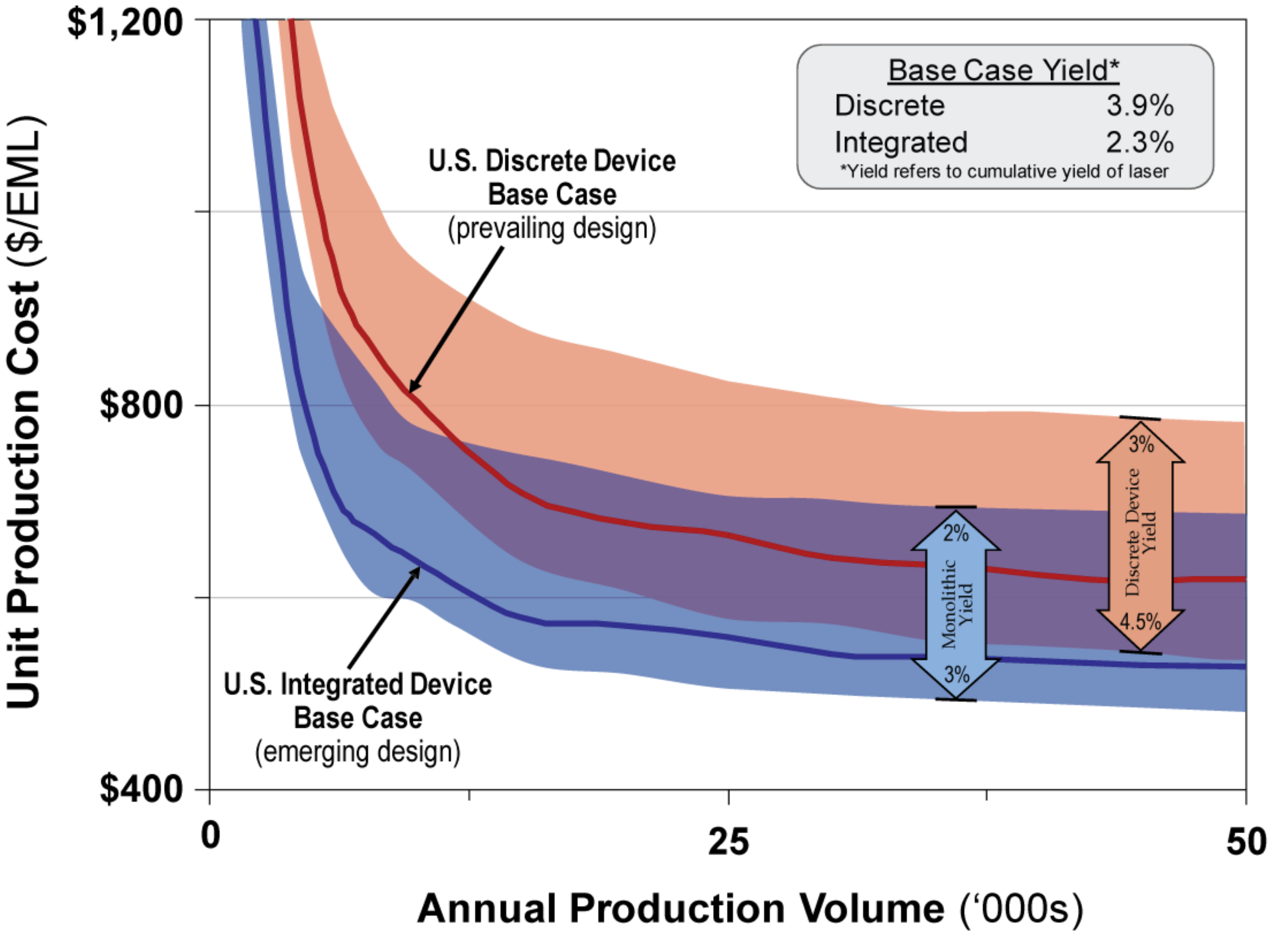
Global Manufacturing & Future of Technology

Does location change the costs of technologies, and thereby the technology trajectory of the firm and the industry?

Manuf. Location → Manufacturing Characteristics → Product Design Decisions → Technology Trajectory

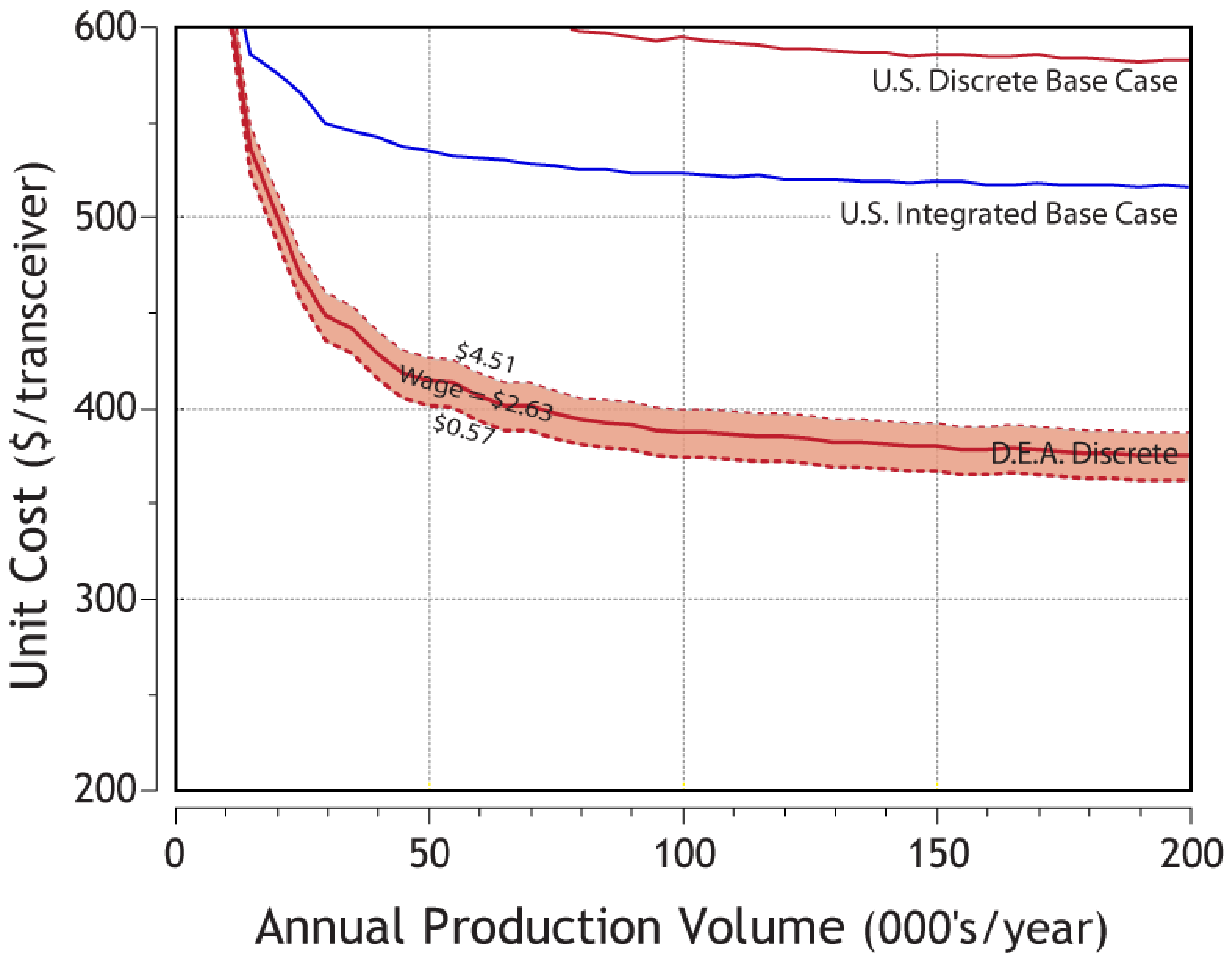
Design for Location (2010)

U.S. Production: Emerging Wins



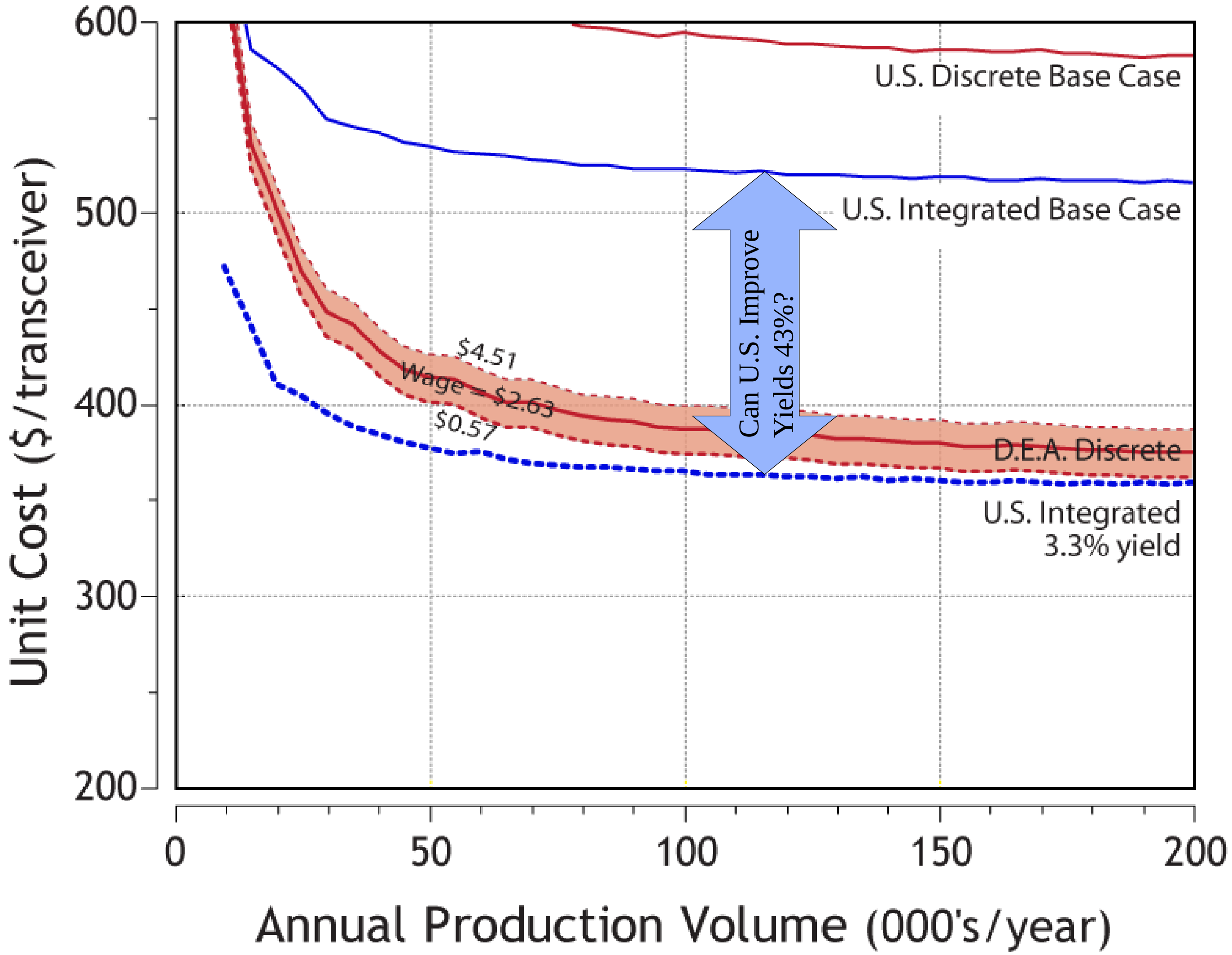
Fuchs, Bruce, Ram, Kirchain (2006) Process-Based Cost Modeling of Photonics Manufacture *Journal of Lightwave Technology*. 24(8): 3175-3186.

Global Production: Prevailing Wins



Fuchs and Kirchain (2010) Design for Location: The Impact of Manufacturing Offshore on Technology Competitiveness in the Optoelectronics Industry. *Management Science*. 56(12): 2323-2349.

Can U.S.-Based Emerging Compete?



Fuchs and Kirchain (2010) Design for Location: The Impact of Manufacturing Offshore on Technology Competitiveness in the Optoelectronics Industry. *Management Science*. 56(12): 2323-2349.

Majority Inventors: Leave field, stop innovating

“These days… you cannot find a research-type job. There are very very very few. It’s not like the old days that companies spend a lot of money on research. It’s more… development engineering.”

“It was a tough time in the job market and so I was happy to just find a job. I… [joined] the yield group [in a computing company]… it was my first non-optical-electronics job.”

“They offer[ed] some positions in the headquarters but nobody took it…. families are here, right,… and the positions they were offering were not related to what we did before.”

(Yang, Nugent, Fuchs (2015) Gains from Others Losses: Technology Trajectories and the Global Division of Firms. *Revise & Resubmit, Research Policy*.)

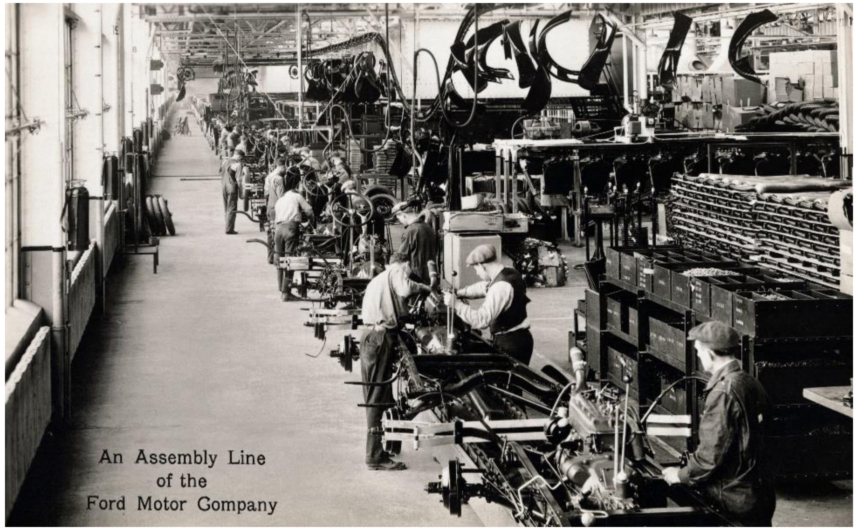
Policy Implications: Location & Innovation

- Recognize "opportunity cost" of innovation trajectory due to globalization in certain industries
  - When difficult separating manufacturing from R&D
  - Typical of small, process-based, high-tech firms? (Pisano 1997, Bohn 2005, Lecuyer 2006)

- Particularly important when the "lost" technology trajectory can have large benefits for social welfare

Technological Changes and Skill Demands

20th Century Assembly Line

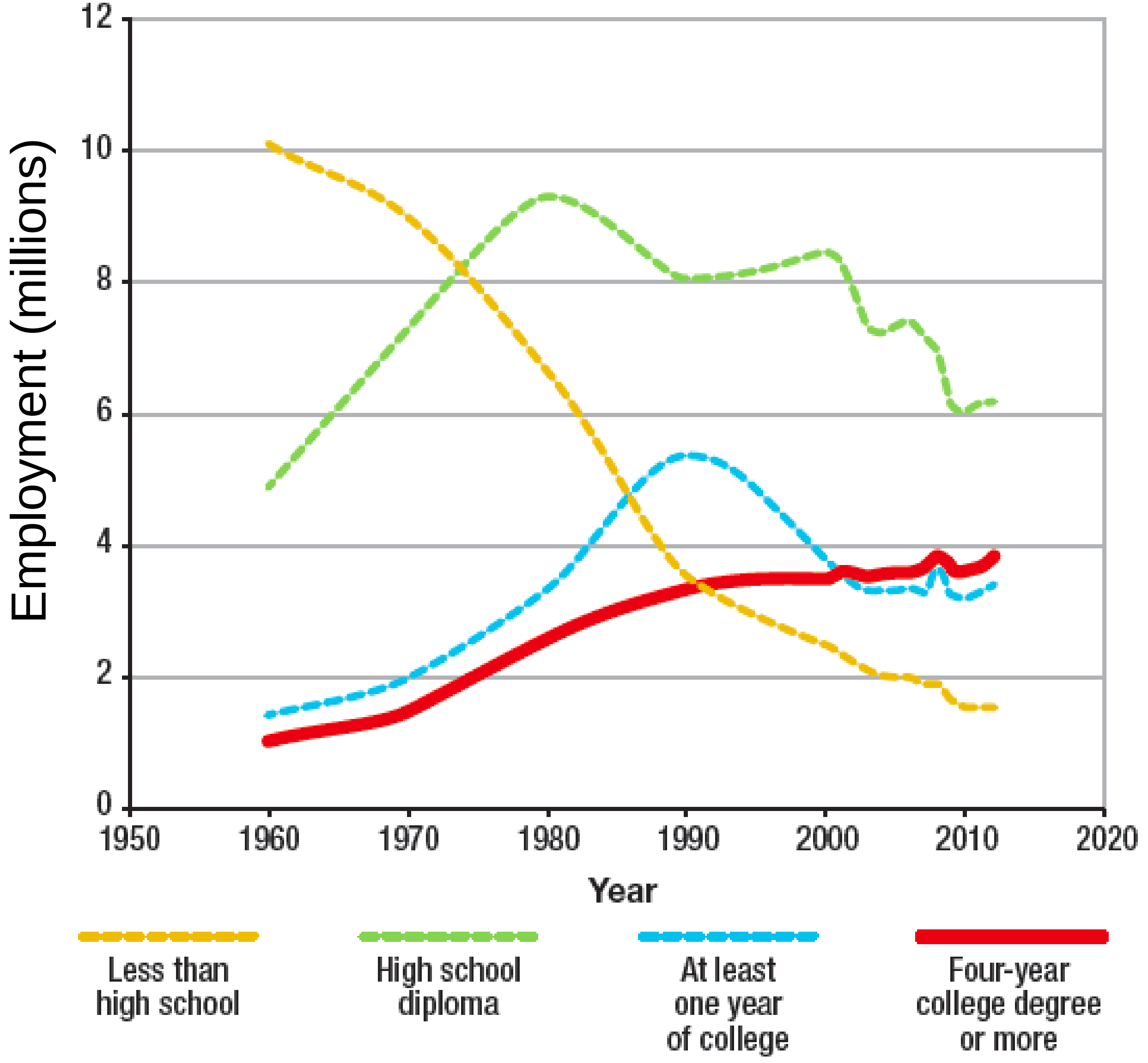


Source: Ford Motor Company

21st Century Assembly Line

Source: Getty Images

Trends in Employment in the Manufacturing Sector by Education



*Employment data points between 1960 and 2000 are decadal. From 2000 to 2012, data are annual. SOURCE: IPUMS-USA, University of Minnesota, www.ipums.org.

Donofrio and Whitefoot, 2015

Not All Technologies Are Created Equal

- **Automation**: decrease in routine manual tasks, with skill demands shifting to non-routine high-skill occupations (Acemoglu and Autor 2011; Autor and Dorn 2013)
- **Parts Consolidation**: preliminary research suggests may not affect manual tasks but reduce more automated tasks instead (Combemale, Fuchs, Whitefoot)
- **Mass Customization**: may increase demand for specialized manual tasks as well as process-monitoring and problem-solving skills

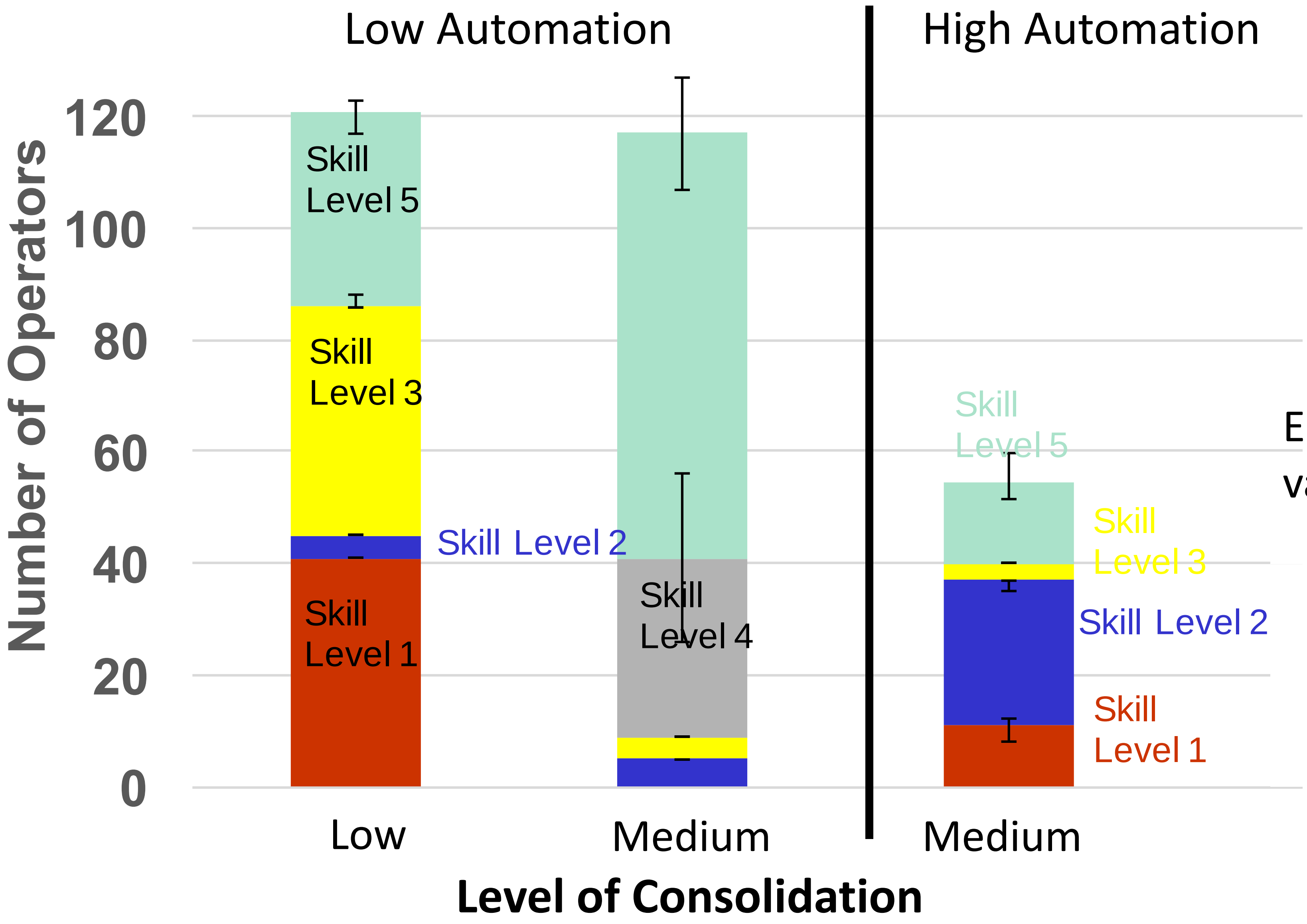
Not All Skills Are Created Equal

- **Education:** Historically, an increase in education has kept the wage differential across workforce in check in response to technology change (Goldin and Katz, 1995)
- **Experience:** Some technological advances require more managerial workers relative to production workers (Chandler, 1977; Goldin and Katz, 1996)
- **Trainable Skills:** On-the-job training and workplace practices (e.g., team problem-solving) can allow workforce to adapt to technological changes (Bartel, Ichniowski, Shaw, 2007)
- **Innate/Difficult-to-train Skills:** Could create wage differential between “haves” and “have nots”

Using Model of Factory to Separate Effects of Multiple Technology Changes

- Process-based cost modeling (used to inform decisions in industry)
- Simulate production using real-world data from 5 firms
  - Maps design (geometry, material, process) → inputs per step (equipment, labor)
  - Model validated with actual facilities data
- Survey labor education and aptitude requirements (e.g., dexterity, vision)

Parts Consolidation Increases Dexterity Demands, Automation Polarizes



Error bars represent variation across firms

Policy Implications: Technology Changes

- Need ability to understand skill requirement changes of upcoming technological changes
  - Not only automation, but parts consolidation, continuous processing, additive manufacturing, machine learning,…

- Fit policy to the type of “skill” bias
  - Education & training important to mitigate wage differentials for many technological changes
  - If innate (or costly to acquire) skill bias is significant, may warrant additional intervention (insurance against displacement, redistribution)