Empowering Innovators to Evaluate Labor Implications of Technology Choice

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October 19, 2022

Government-University-Industry Research Roundtable
National Academies Policy and Global Affairs Division

Based on "How It's Made: A General Theory of the Labor Implications of Technology Change" (2022) Combemale, Ales, Fuchs and Whitefoot and "New Technology, New Hierarchy?" (2022) Combemale

Not All Technological Change is Equal

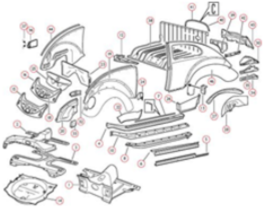
20th Century Assembly Line

Source: Ford Motor Company

21st Century Assembly Line

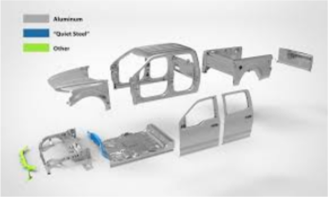
Source: Getty Images

20th Century Auto Body



Source: Volkswagen

21st Century Auto Body



Source: SAE international

Decisions by Innovators and Adopters Affect Labor Demand

- **Skill-biased technological change**: largely driving demand low to high skill (Katz and Murphy 1992, Graetz and Michaels 2018); polarizing from mid-skill (Autor and Dorn 2013, Goos, Manning and Salomons 2014)
- Examples of SBTC (including de-skilling) varying with time (Card and Dinardo 2002), context (Brynjolfsson, Mitchell and Rock 2018), and technology (Goldin and Katz 1997)
- **What characteristics of technology lead to different effects on labor demand?**

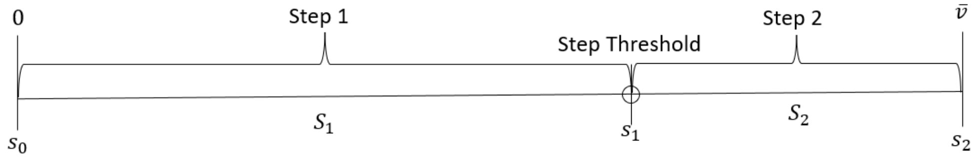
A General Theory of How Technology Changes Work

- Effect of Technology is Mediated by Tradeoffs:
  1. **Rate vs. complexity**: greater complexity reduces feasible rate of work
  2. **Division of Labor:** reduce complexity of steps... but pay fragmentation costs

- Technology changes characteristics of performers and production:
  - Sensitivity of performers to rate of production
  - Sensitivity of performers to complexity
  - Cost of reassigning performers to utilize full capacity
  - Cost of fragmenting production

Firms Break Tasks into Steps

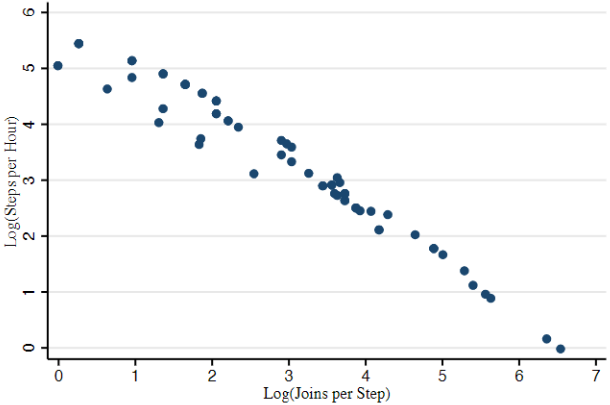
- **Firm makes product of given volume for least cost by:**
  - Breaking tasks $(0,\bar{v})$ into steps
  - Assigning performers (human, machine)
  - Determining the rate of production (and thus **ability demand**)



- Length of steps (more tasks) drives complexity from variation of random issues
- Fragmentation costs depend on which tasks begin and end a step

Origins of Ability Demand: Rate-Complexity Tradeoff

Differences in ability demand come from steps of different length



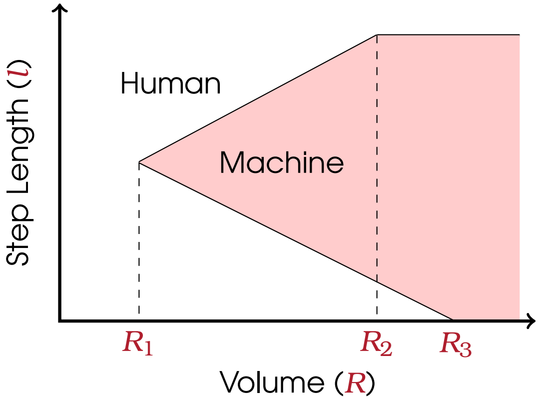
Automobile Welding: Lower Rate at High Complexity

(Combemale, Ales, Whitefoot and Fuchs 2022)

- Working faster requires a higher level of ability to complete steps successfully
- Higher complexity requires the same performer to reduce rate
- High rate reduces performer demand... but volume must be high or performer must be flexible enough to be reassigned

Applying Theory: Which Steps Are Automated?

Humans less sensitive to complexity, more to rate, more flexible than machines

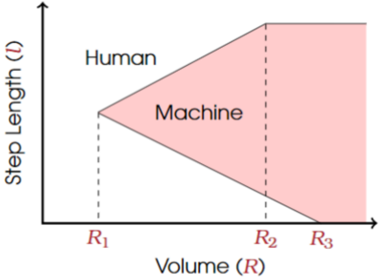


Combemale, Ales, Whitefoot and Fuchs (2022)

- Upper bound of automation driven by complexity
- Lower bound of automation driven by underutilization of inflexible machines

Which Steps Are Automated? Historical Case

Mechanization of production, substitution of power sources (1880s-1890s)



Theory: Cone of Automation
(Combemale et al. 2022)

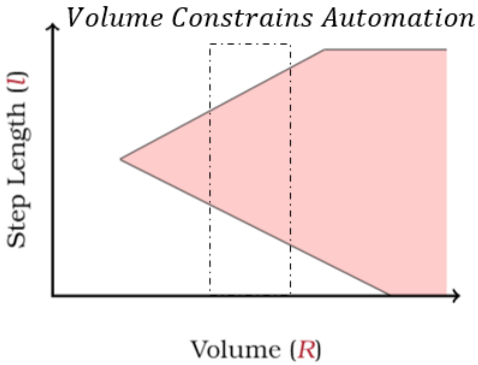
Relative Wage (Step Length)

17%	29%	17%	25%	30%	33%	44%	40%
25%	21%	35%	14%	47%	58%	63%	74%
25%	52%	50%	40%	52%	48%	58%	93%
17%	Insuff. Data	30%	57%	63%	40%	78%	91%
35%	60%	56%	70%	62%	68%	76%	91%
38%	53%	59%	44%	67%	68%	91%	91%
39%	42%	40%	35%	72%	71%	76%	77%
30%	41%	40%	41%	29%	65%	65%	64%

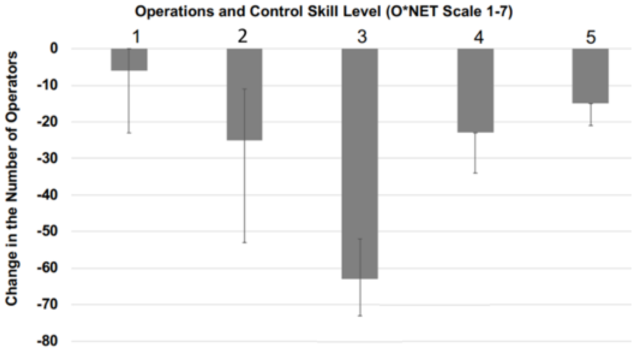
Performer Utilization (Maximum Productive Rate)

Empirics: Rate of Automation
(Data: Hand and Machine Labor)
(Wright 1898)

Which Steps Are Automated? Contemporary Case



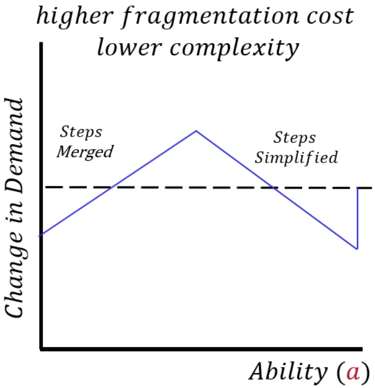
Theory: Polarization at Middle Volumes
(Combemale et al. 2022)



Empirics: Changing Ability Demand
(Data: Optoelectronic Semiconductors)
(Combemale, Whitefoot, Ales and Fuchs 2021)

Technology Choices can Reduce Inequality Within a Firm

Consolidation of parts and streamlining of process design (2000s-2010s)



Theory: Changing Ability Demand
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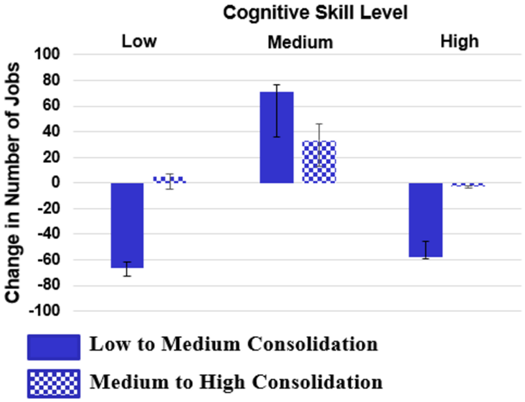

Empirics: Changing Ability Demand
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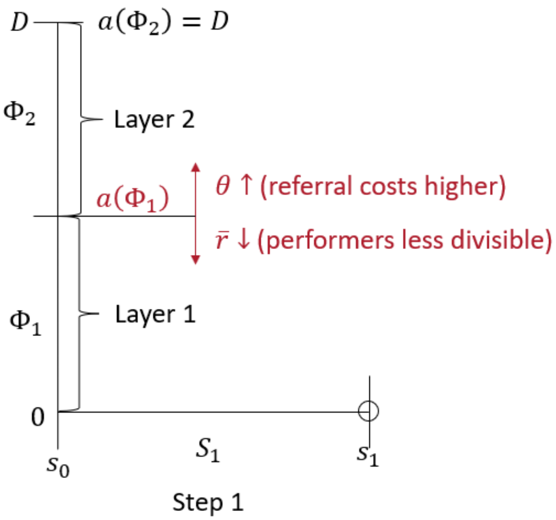
A Tool for Mapping Labor Implications of Technology Choice

1. **Division of Labor Realizes Gains from Rate-Complexity Tradeoff**
2. **Technology Change Affects Skill Demand By Shifting This Tradeoff**
    - Process complexity
    - Cost of dividing production
    - Sensitivity of performers to complexity and rate
    - Cost of reassigning underutilized performers
3. **Theory Supports a Taxonomy to Explain Effects of New Technology**
    - Identify cost-effective use cases for new technology
    - Tradeoff between fitting technology to process or process to technology
    - Labor-Conscious adoption and development

Extension

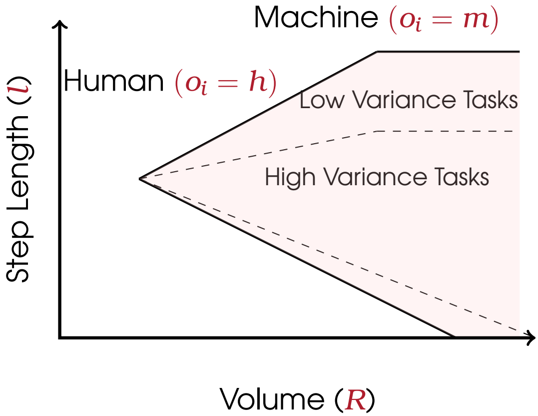
Based on Combemale, Whitefoot, Ales and Fuchs "Not all Technological Change is Equal: How the Separability of Tasks Mediates the Effect of Technological Change on Skill Demand" Industrial and Corporate Change 30.6 (2021)

Analysis: Inequality Within a Managerial Hierarchy



- Work passes from one layer to the next when difficulty sufficiently high
- Inequality between layers is greater when this difficulty threshold is low
- Inequality decreases as performers become **more divisible**
- Inequality increases as referral costs **decrease**

Analysis: How Task Biases Can Drive Skill Bias



- As task-specific variance (Y) increases: complexity $c(l|\rho)$ decreases for all ρ
- Complexity differential of machines and humans $c(l|\rho^m) - c(l|\rho^h)$ increasing in Y
- Variance **constricts** the cone of automation (Combemale et al 2022): Lower overall complexity **drives lower bound up**
  Higher complexity differential **drives upper bound down**