# Technology and the Size and Composition of Workforce in U.S. Firms: First Evidence from the 2019 Annual Business Survey


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# Outline

- Overview of the 2019 Annual Business Survey
- Firm Adoption of Technologies
- Motivation and Adverse Factors for Adoption
- Employment Outcomes from Adoption
  - Worker Types (Production Workers (PW), Non-Production (NP), Supervisory Workers (SW) and Non-Supervisory (NSW)
  - Skills
  - Automation

# Preview of Findings

## Technology Adoption

- Specialized software and cloud computing are most adopted and Robotics and AI are least adopted
- Adoption driven by sector and skewed towards largest and oldest firms
  - Worker exposure to technology is significantly higher

## Motivations/Adverse Factors for Adoption

- Quality improvement and upgrading production are most common
- Automation is a major motivator for AI and robotics
  - Large share of manufacturing workers exposed to automation via technology
- Cost is a key adverse factor; AI and robotics often cited as "immature"

## Employment Outcomes

- Most respondents report no employment change attributable to tech
- Employment increases more likely attributed to AI
- Employment decreases more likely attributed to robotics -> production workers most impacted
- Large share of firms report skill upgrading attributed to tech

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# Overview of the Annual Business Survey (ABS)

- Background
  - Enterprise-level survey first conducted in 2018
  - Joint with NSF/National Center for Science and Engineering Statistics
  - Mailed to 300,000 nationally representative employer businesses
    - Approximately 208,000 linked responses
    - Represents 6.1M firms and 140M+ employees
  - Combines three pre-existing enterprise-level surveys: Survey of Business Owners (SBO), Annual Survey of Entrepreneurs (ASE), Business R&D and Innovation Survey for Microbusiness (BRDI-M)
- New business topic modules introduced each year, including:
    - 2019 ABS (reference year 2018) focuses on adoption and workforce impacts of AI, cloud services, specialized software, robotics, and specialized equipment
    - 2018 ABS (reference year 2017) focuses on the adoption and use of digitization, cloud services, and advanced business technologies

Weighting & Summary Stats

2018 ABS Comparison

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# Technology Adoption by Firms

- Two types of technology deployments
    1. Technology *used* in **production processes** (of goods and services)
    2. Technology *sold* in **goods and services** themselves (less common)
- Adoption is closely associated with **size** and **productivity**
- Most adopted technologies (Equipment, Cloud, and Software) are also most intensively adopted
- Nearly 60% of firms adopt zero technologies; firms adopting at least one technology are more likely to adopt a technology pair

Size/Age Heat Maps

Response & Intensity

# of Techs Used

**Technology Usage Rates (%)**

| | Weighting | AI | Cloud Comp. | Spec. Equip. | Robotics | Spec. Soft. |
|---|---|---|---|---|---|---|
| Processes & Methods | Firm | 3.2 | 34.0 | 19.5 | 2.0 | 40.1 |
| | Employment | 12.5 | 61.5 | 36.3 | 15.7 | 64.1 |
| Goods & Services | Firm | 0.5 | 3.5 | 2.5 | 0.3 | 4.3 |
| | Employment | 2.2 | 7.1 | 4.8 | 1.8 | 7.7 |

Note: Usage rates drop Missing and “Don’t Know”

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# Technology Adoption by Sector

- AI, cloud, and software most adopted in Information and Professional Services sectors
- Robotics and equipment are most adopted in Manufacturing

Firm-weighted

4-digit NAICS

| | AI (%) | Cloud (%) | Specialized Equipment (%) | Robotics (%) | Specialized Software (%) |
|---|---|---|---|---|---|
| Agriculture,..., Mining, Utilities | 21.4 | 66.0 | **49.3** | **25.6** | 68.3 |
| Construction | 4.3 | 48.6 | 34.0 | 6.7 | 51.5 |
| Manufacturing | **22.6** | 62.3 | **70.7** | **45.1** | 72.3 |
| Wholesale Trade | 16.1 | 61.1 | 47.3 | 22.0 | 65.3 |
| Retail Trade | 15.0 | 61.1 | 39.6 | 16.7 | 58.4 |
| Transportation & Warehousing | **25.7** | 69.7 | **49.7** | **22.7** | 73.6 |
| Information | **29.4** | **81.0** | **51.1** | 11.6 | **80.0** |
| Finance, Insurance, Real Estate | 17.4 | **72.2** | 13.5 | 12.0 | **74.1** |
| Professional Services | 21.0 | **72.3** | 32.1 | 17.3 | **74.2** |
| Management & Administrative | 5.6 | 58.5 | 15.7 | 2.5 | 62.5 |
| Education | 5.4 | **72.3** | 25.1 | 2.9 | 64.8 |
| Health Care | 12.9 | 66.5 | 44.4 | **23.5** | 70.2 |
| Other (Arts, Food, Other) | 4.0 | 46.0 | 25.5 | 5.4 | 52.0 |

Note: Employment-weighted. Usage rates drop Missing and "Don't Know"

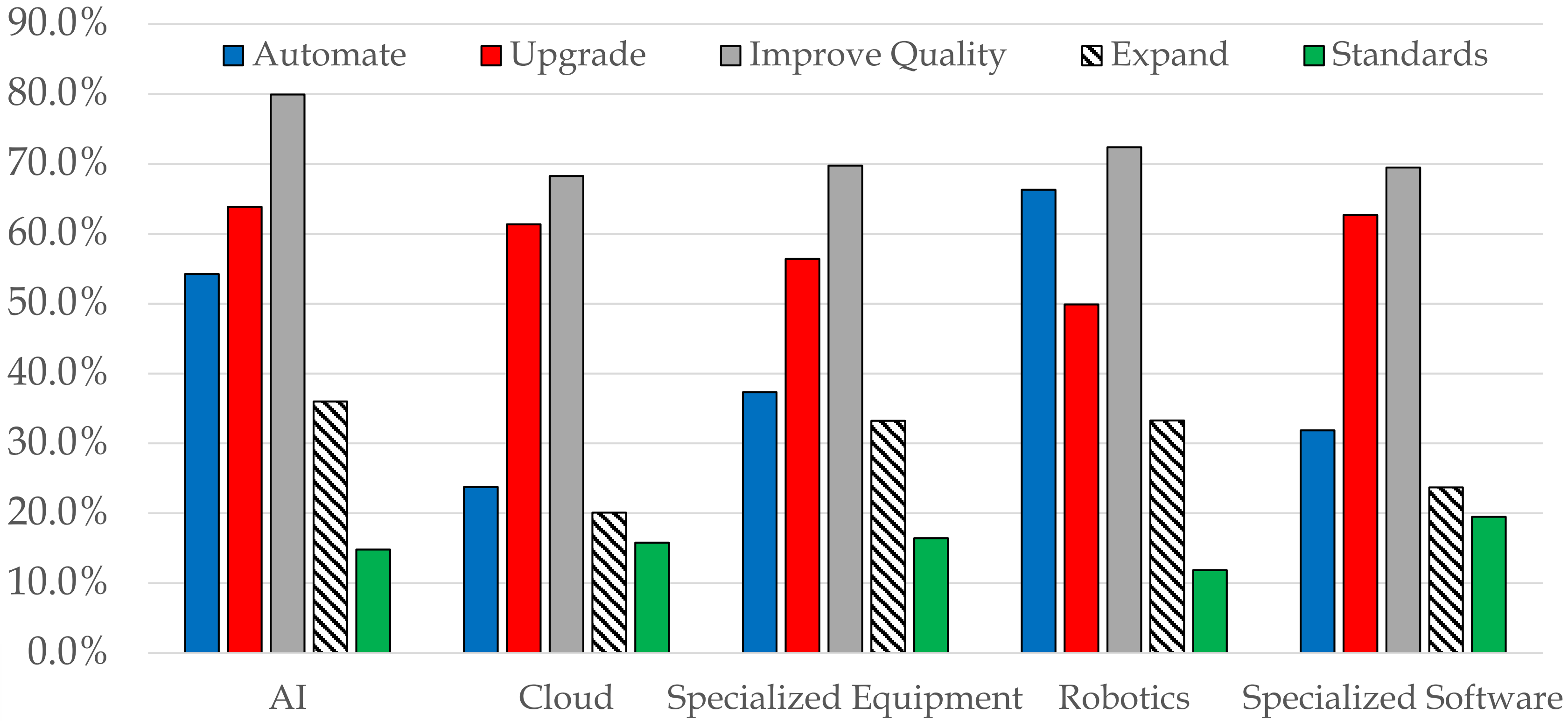
# Motivation for Technology Adoption

- Improving Quality and Upgrading* are the two leading motivators for the majority of adopting firms, except those that adopt Robotics
- AI & Robotics adoption more likely motivated by Automation
  - Firm size positively linked with automation, upgrading production and improving quality

Firm-weighted

Size and Age

Manufacturing Status




*Note: Here "upgrading" and "improving quality" refer to the upgrading or improving quality of **processes or methods**, not necessarily the upgrading or improving quality of the goods or services themselves. These are weighted by Employment.

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# Worker Exposure to Automation

- Differences in automation driven by size and sector
  - Largest differences occur in AI and Robotics
- Despite relatively small adoption rates, 10.4% of workers are exposed to automation via Robotics
  - More than 37% of manufacturing workers are exposed to automation via Robotics

**Firm-weighted**

**Worker Exposure to Automation by Technology (%)`**

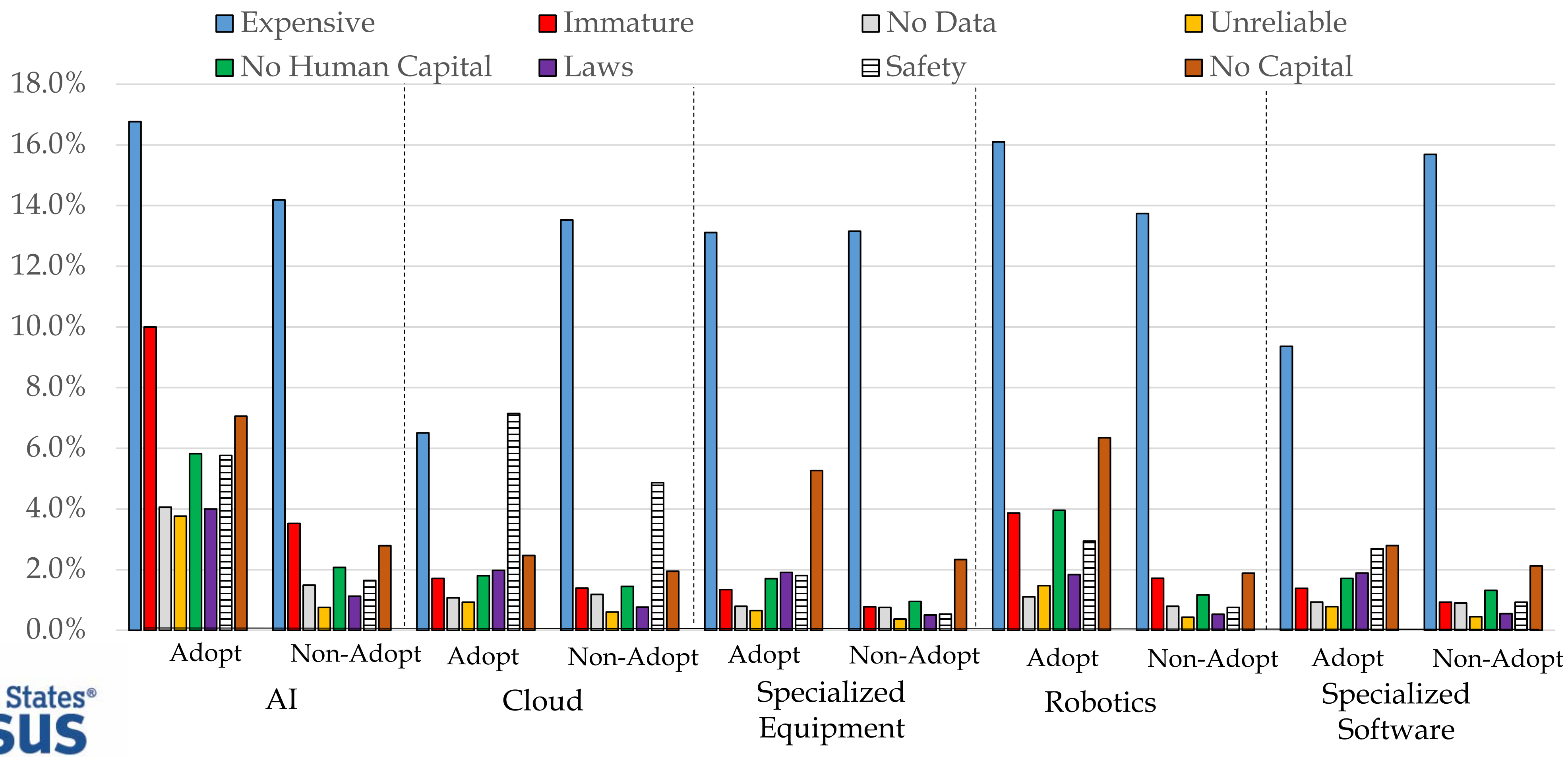
| Type | AI | Cloud Comp. | Spec. Equip. | Robotics | Spec. Soft. |
|---|---|---|---|---|---|
| All | 6.8 | 14.6 | 13.6 | **10.4** | 20.4 |
| Manufacturing | 17.6 | 18.8 | 37.8 | **37.6** | 29.8 |

# Adverse Factors for Technology Adoption

- Cost is biggest adverse factor for adoption other than inapplicability (not shown)
- AI and Robotics are still considered relatively immature
- Businesses are concerned about safety/security of cloud services

Employment -weighted

NA and No Adverse Factors

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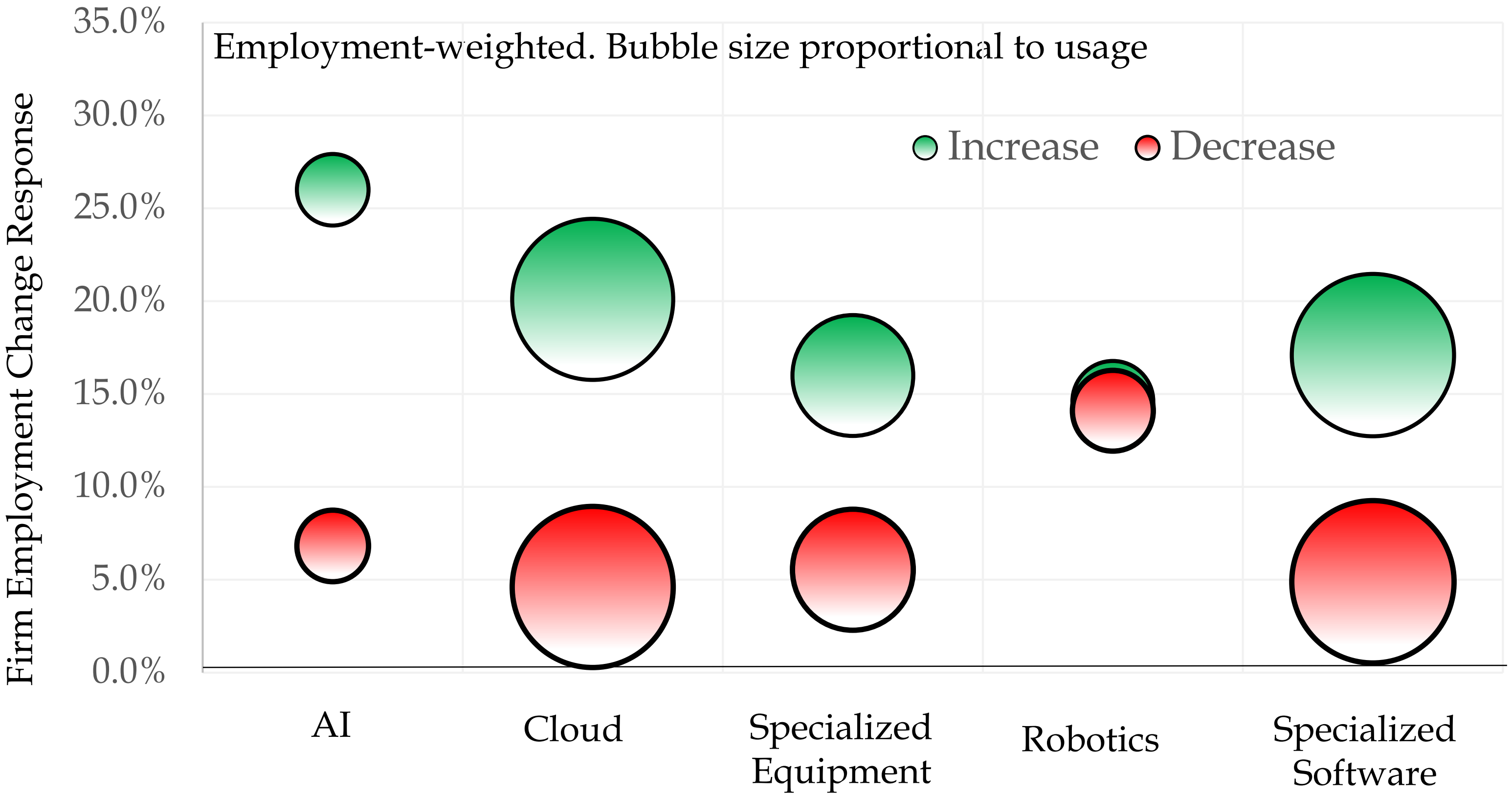
*Conditional on technology being applicable. "No adverse factors" category is dropped in figure.

# Employment Changes Attributed to Tech

- Majority of adopters do not attribute employment change to tech (~70%)
  - Self-reported - Need to validate using longitudinal Census data
- More firms attribute employment increases to tech than decreases
- More firms on net attribute employment increases to tech
  - Robotics has smallest net difference

Firm-weighted

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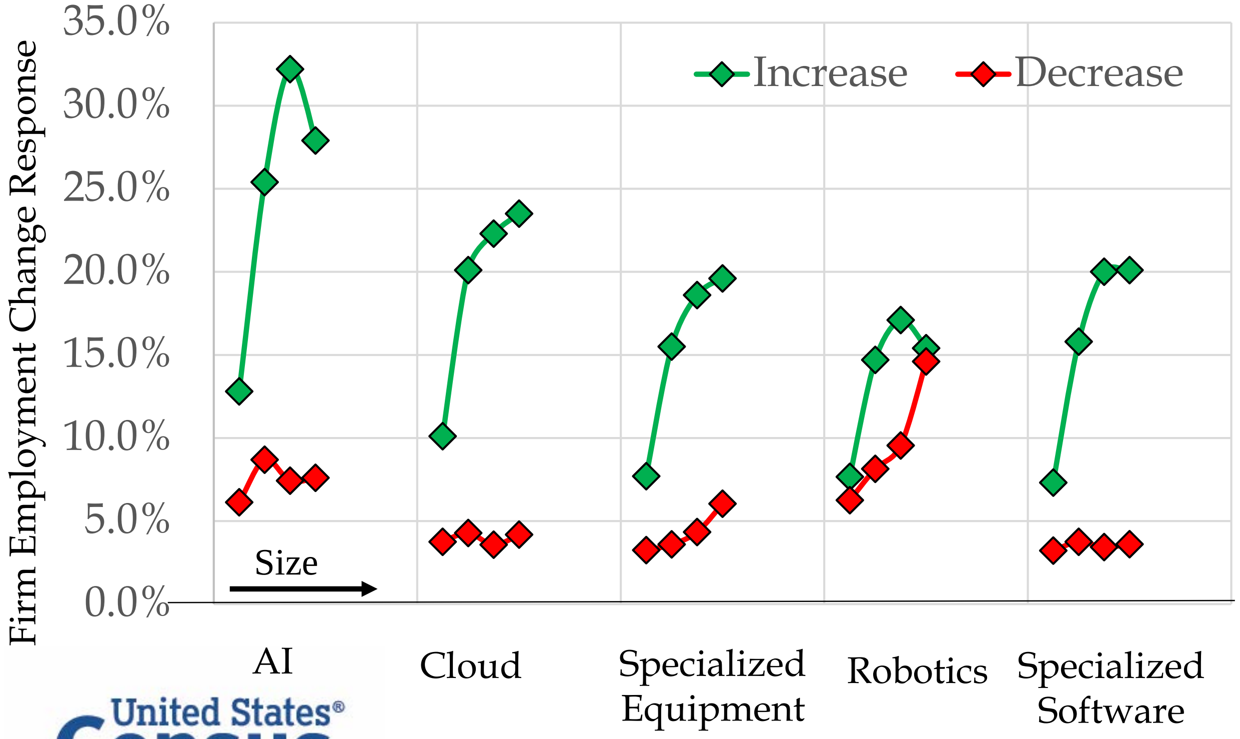
# Employment Change by Size and Age

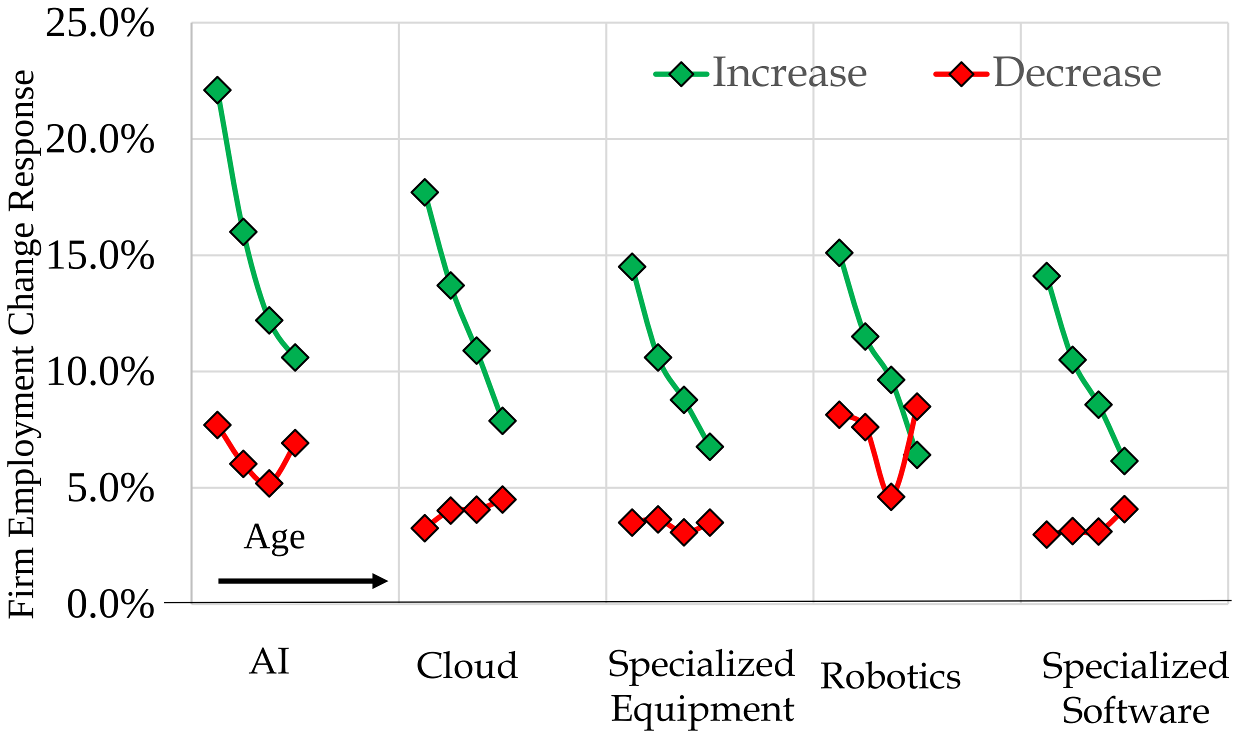
- Larger firms are ***more likely*** to report employment increases from technology adoption
- Older firms are ***less likely*** to report employment increases
- No clear pattern in reporting employment decreases, except for Robotics
- Intensity of use associated with higher share of employment increases

Net Change

Intensity

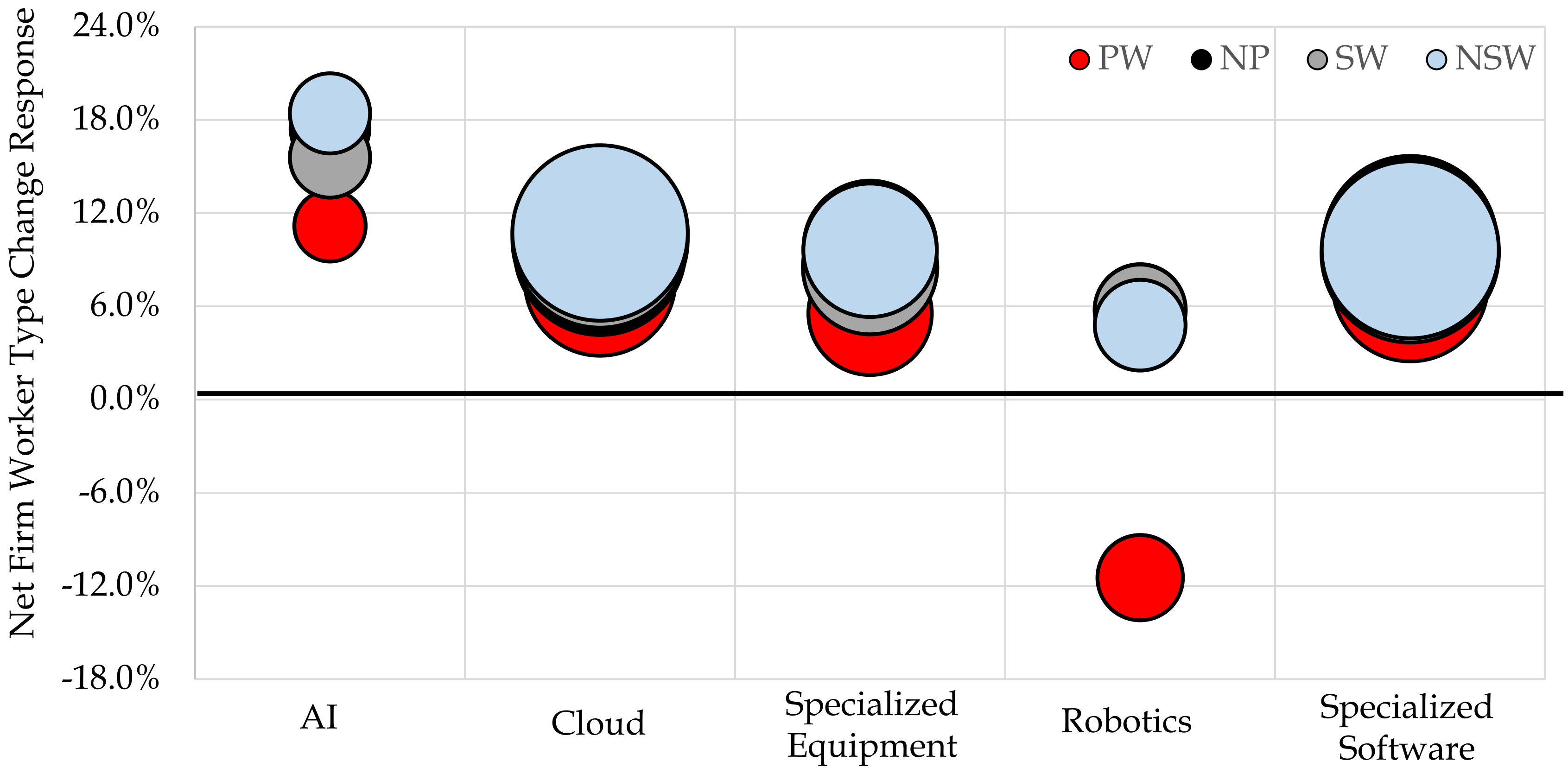



Note: Firm-weighted. Size categories include: 1-9, 10-49, 50-249 and 250+ employees




Note: Firm-weighted. Age categories include: 0-5, 6-10, 11-20 and 21+

# Net Response to Employment Change by Worker Type




Employment-weighted. Bubble size corresponds to number of adopters who employ worker type

- On average, more firms report employment increase for all worker types
- 12% more firms who adopt Robotics report decrease in employment of production workers
  - Driven by manufacturing firms

**Firm-weighted**

**Production Workers & Manufacturing**

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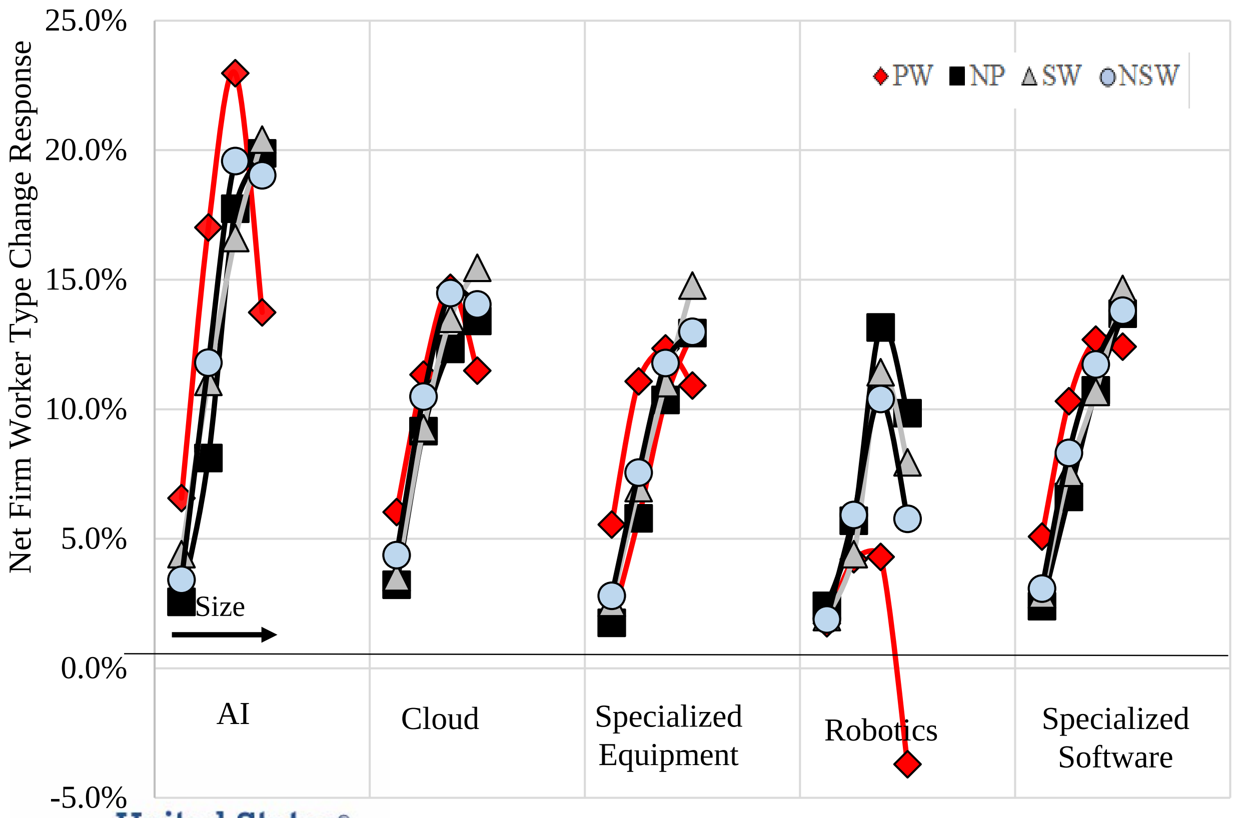
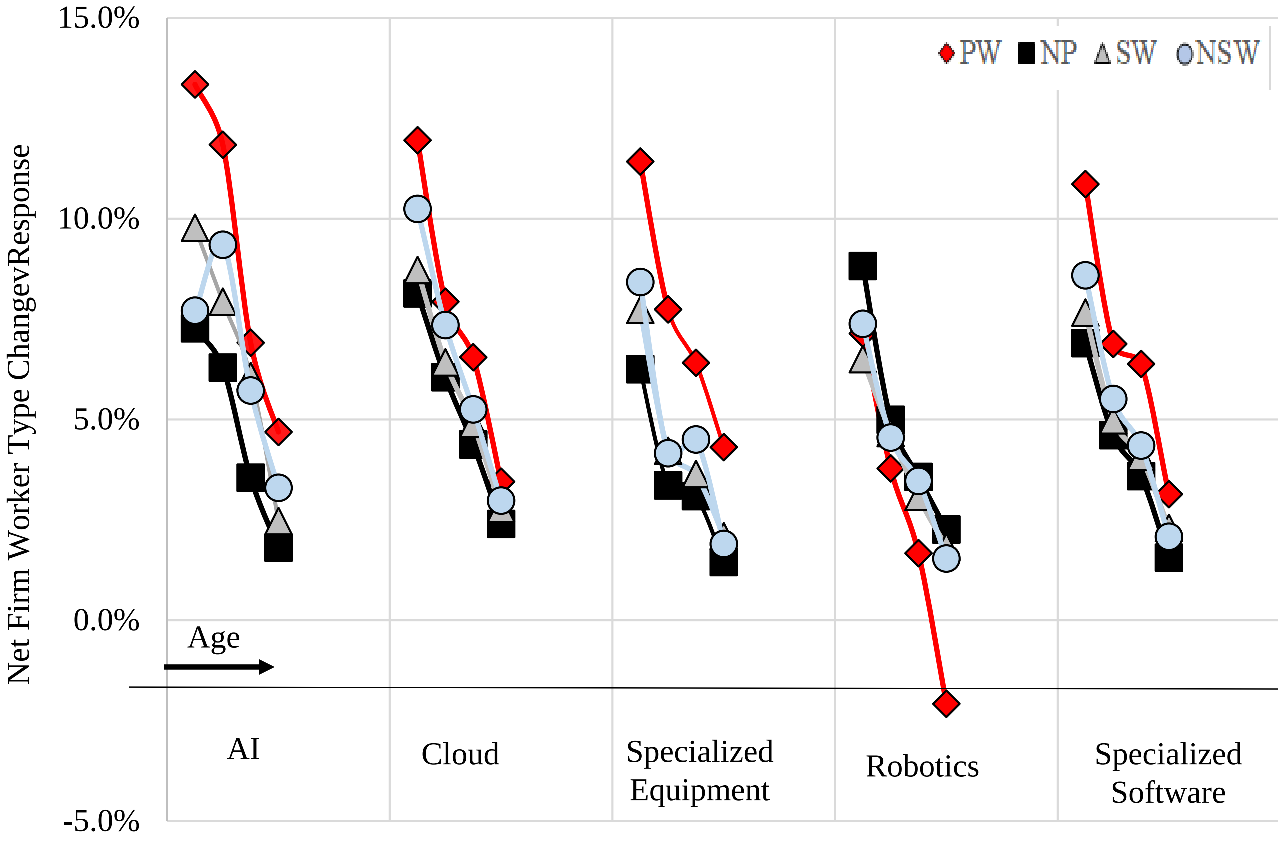
# Net Worker Type Changes by Size and Age

- Worker decomposition reveals similar patterns as Employment Change
- Production workers at largest and oldest firms more likely to decrease if firm adopts Robotics

Intensity




Note: Size categories include: 1-9, 10-49, 50-249 and 250+ employees

Note: Age categories include: 0-5, 6-10, 11-20 and 21+

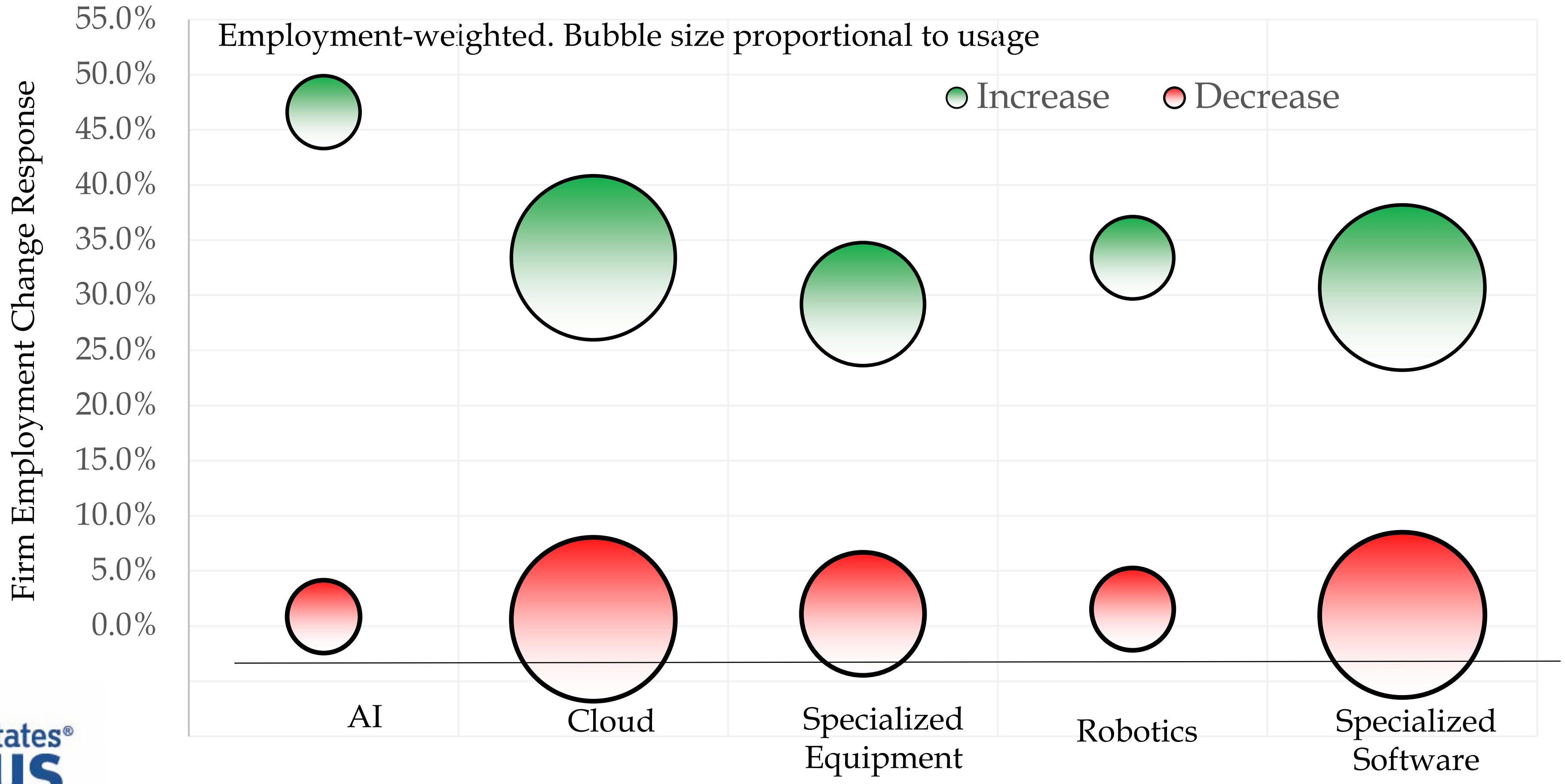
# Skill Change by Technology Adoption

- About half of firms attribute changes in skill levels to technology adoption
- Very few firms attribute declining skill levels to technology adoption

Size and Age

Intensity

Firm-weighted



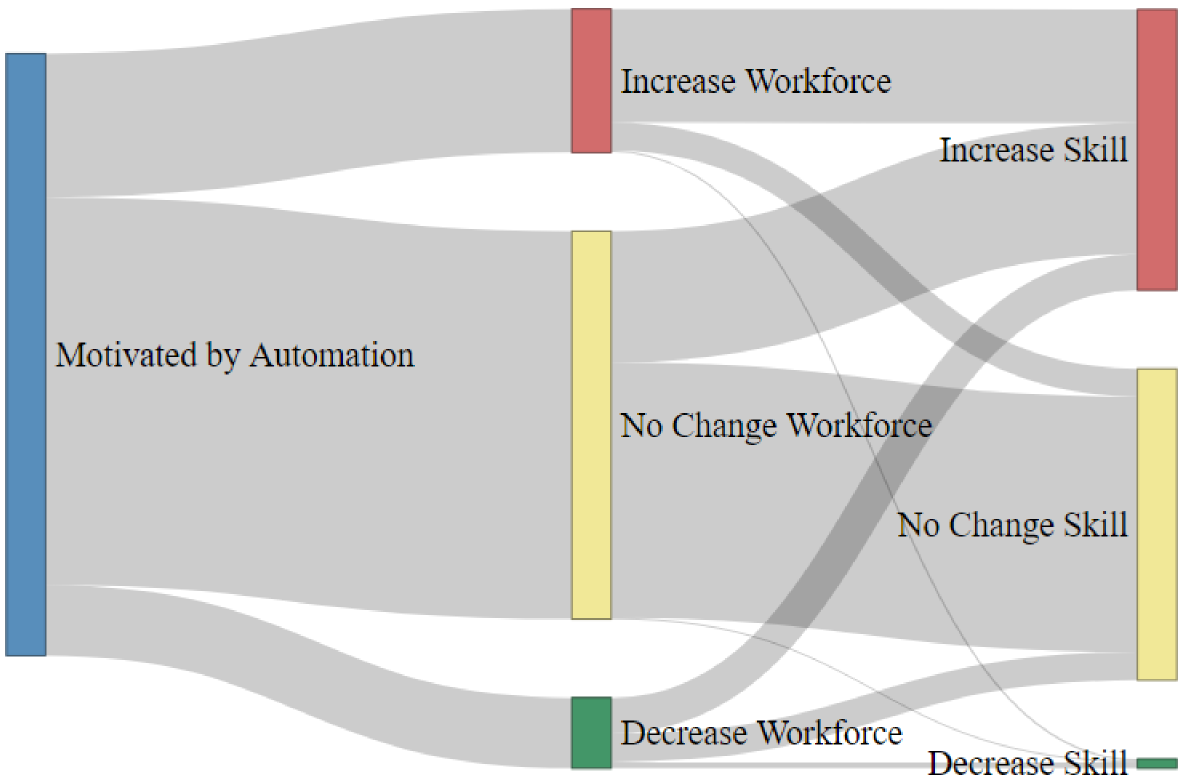
# Automation (Employment-weighted)

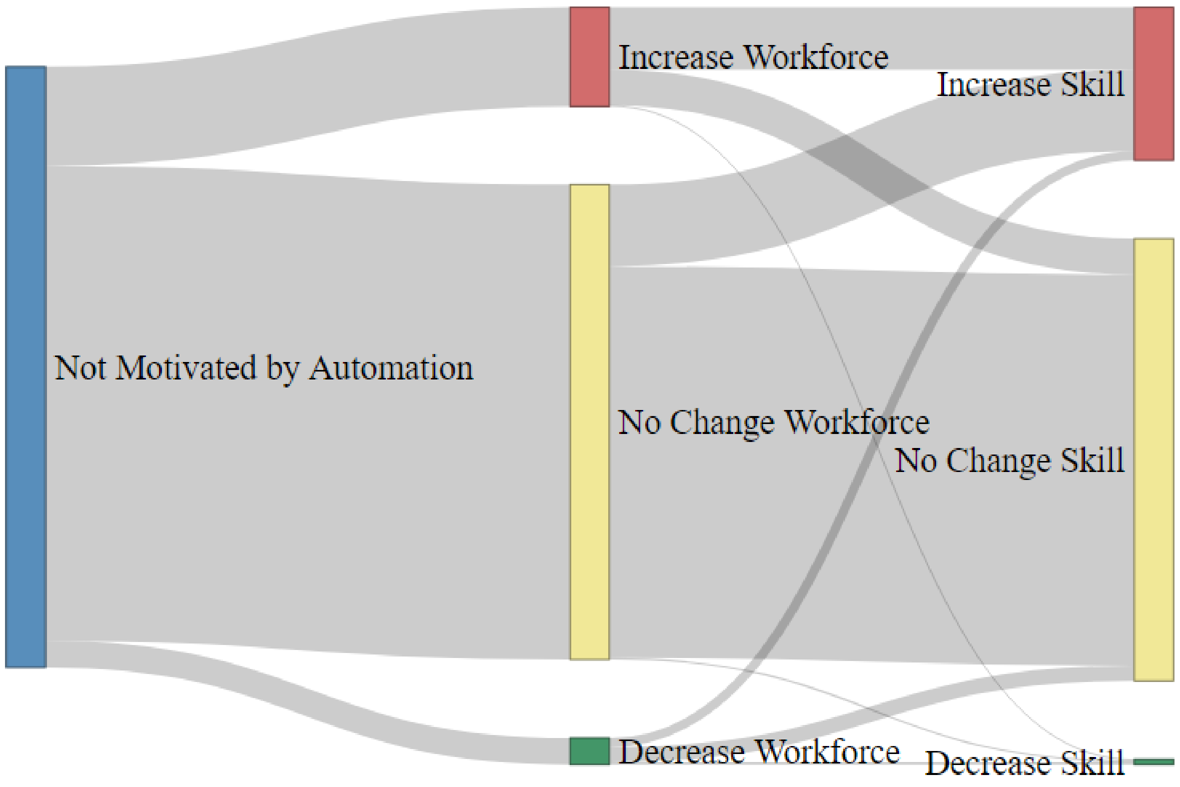
- Firms motivated by automation to adopt technologies are more likely to report increases in workforce and skill levels
- Majority of firms who automate and decrease workforce upgrade their skill

**Firm-weighted**

**AI**

**Robotics**

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# Challenges and Next Steps

- Further Validation
  - Using 2018 ABS and other Census data (ASM, LBD)
- Fix issues with non-response and "N/A" response options
  - Some inconsistencies
  - Many large, complex firms respond with "Don't Know" or missing for all technologies
- Validation of self-responses using administrative longitudinal data
  - Attempt to identify adoption dates using existing Census surveys and Census data (e.g. import data for robotics, R&D and patent data for AI)
- Causality
  - Assess how combination of firm characteristics (size, age, industry, productivity, payroll per employee, number of establishments, etc…) impact adoption rates

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# Conclusion

- New measures of technology adoption, including AI and Robotics
  - Tech adoption for AI and Robotics is very low, worker exposure is higher
  - Skewed by sector towards largest and oldest firms
- Most firms motivated by upgrading processes and improving quality of processes
  - AI and Robotics more motivated by Automation
  - Large share of manufacturing workers exposed to automation through technology (specialized equipment and robotics)
- Technology adoption more likely to lead to no change in employment levels, but increased skills
  - Production workers more likely to be negatively impacted by Robotics
- Data will be made available soon!

Challenges and Next Steps

# Thank you!

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# Appendix

# A.1 Overview of the 2019 Annual Business Survey

This section provides:

- An overview of the sampling for 2019 ABS
- How the LBD weights were developed
- Overview of 2018 ABS
    - Technology responses
- Comparison with 2018 Annual Business Survey

# Annual Business Survey (ABS) Sampling

- The 2019 ABS sampling is stratified by ownership status, industry, and state from the 2018 Business Register
- Uses administrative data to estimate probability that firm is minority- or women-owned with each firm placed in one of 9 ownership frames for sampling (listed alphabetically)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| American Indian | Asian | Black (or African American | Hispanic | Native Hawaiian and Other Pacific Islands | Non-Hispanic White Men | Other (different race as write-in) | Publicly Owned | Women |

- Large companies are selected with certainty based on volume of sales, payroll, or number of paid employees
- Certain R&D industries are selected with certainty (e.g. NAICS 5417)
- R&D module (BRDIS-M) only asked of businesses with fewer than 10 employees

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# Constructing Tabulation Weights using LBD

- Motivation for Constructing New Weights
  - ABS sample frames based on business owner characteristics (e.g., race, ethnicity, sex)
  - Survey-weighted aggregation of employment, firm counts, etc. inconsistent with LBD
  - Latest extract does not include "corrections" for non-response
- Longitudinal Business Database (LBD)
  - Based on administrative records of employer firms—represents universe of employers
  - Includes firm age information (not available in ABS data)
  - More reliable employment data than ABS (some firms likely reporting payroll in the ABS)
- Methodology
  - Stratify based on size, age, and sector characteristics
  - 12 size and 12 age groups (as defined in BDS); and 19 sectors (two-digit NAICS)
  - Weight for firm in stratum *s*:

$$\frac{\text{Number of LBD firms in } s}{\text{Number of ABS firms in } s}$$

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# Comparing ABS and LBD weights

- Approximately 208,000 respondents linked with LBD (out of 300,000 possible)
- Self-constructed "LBD weights" match universe better than using survey weights, which were not updated to reflect the response rate
- Sectoral distributions also match more closely than using survey weights
- **Use LBD weights (firm-weighted) for all subsequent analysis, unless otherwise specified**

| | 2018 LBD (universe) | ABS (survey weights) | ABS (LBD weights) |
|---|---|---|---|
| Total Firms | 6.1 million | 3.8 million | 6.1 million |
| Total Employment | 141.7 million | 82.5 million | 143.0 million |
| Mean Employment | 23.1 | 22.0 | 23.3 |
| Mean Firm Age | 14.2 years | 14.9 years | 14.2 years |

# Size and Age Distribution of ABS Sample

- LBD weights more closely reflect Business Dynamic Statistics
- More than ¾ of weighted firms have fewer than 10 employees
- 95 percent of weighted firms have fewer than 50 employees

Size Distribution

| Employment | Unweighted | Weighted | BDS* |
|---|---|---|---|
| 1 to 9 | 67 | 78 | 76 |
| 10 to 49 | 20 | 18 | 20 |
| 50 to 249 | 7 | 3 | 4 |
| 250 or more | 6 | 1 | 1 |

Age Distribution

| Age (Years) | Unweighted | Weighted | BDS* |
|---|---|---|---|
| 0 to 5 | 28 | 34 | 33 |
| 6 to 10 | 15 | 16 | 17 |
| 11 to 20 | 24 | 22 | 23 |
| 21 or more | 33 | 28 | 27 |

*BDS Statistics come from 2016 BDS as 2018 BDS statistics have different size/age categories

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# Sectoral Distribution of ABS Sample

All sectors represented. Survey skews more towards Manufacturing and Professional services, but is corrected

| | Unweighted | Weighted | 2018 LBD |
|---|---|---|---|
| NAICS 11,21-22 - Agriculture,..., Mining, Utilities | 2 | 1 | 1 |
| NAICS 23 - Construction | 7 | 12 | 12 |
| NAICS 31-33 - Manufacturing | 18 | 4 | 4 |
| NAICS 42 - Wholesale Trade | 7 | 5 | 5 |
| NAICS 44-45 - Retail Trade | 7 | 11 | 10 |
| NAICS 48-49 - Transportation & Warehousing | 4 | 3 | 3 |
| NAICS 51 - Information | 5 | 1 | 1 |
| NAICS 52-53 - Finance, Insurance, Real Estate | 6 | 9 | 9 |
| NAICS 54 - Professional Services | 21 | 13 | 13 |
| NAICS 55-56 - Management & Administrative | 4 | 6 | 6 |
| NAICS 61 - Education | 1 | 2 | 2 |
| NAICS 62 - Health Care | 7 | 11 | 11 |
| NAICS 71-72,81 - Other (Arts, Food, Other) | 11 | 23 | 23 |

# 2018 Annual Business Survey (Overview)

- Significantly larger sample size (mailout was 850,000 potential respondents) than 2019 ABS (300,000)
- 2018 Annual Business Survey module included questions on adoption of "Digitization of Information", "Cloud Purchases" and "Business Technologies"
- Some overlap with 2019 Annual Business Survey, including Cloud Purchases, AI and Robotics
- Similar aggregate adoption rates and size/age decomposition of adoption rates in overlapping technologies
- https://www.census.gov/library/working-papers/2020/adrm/CES-WP-20-40.html

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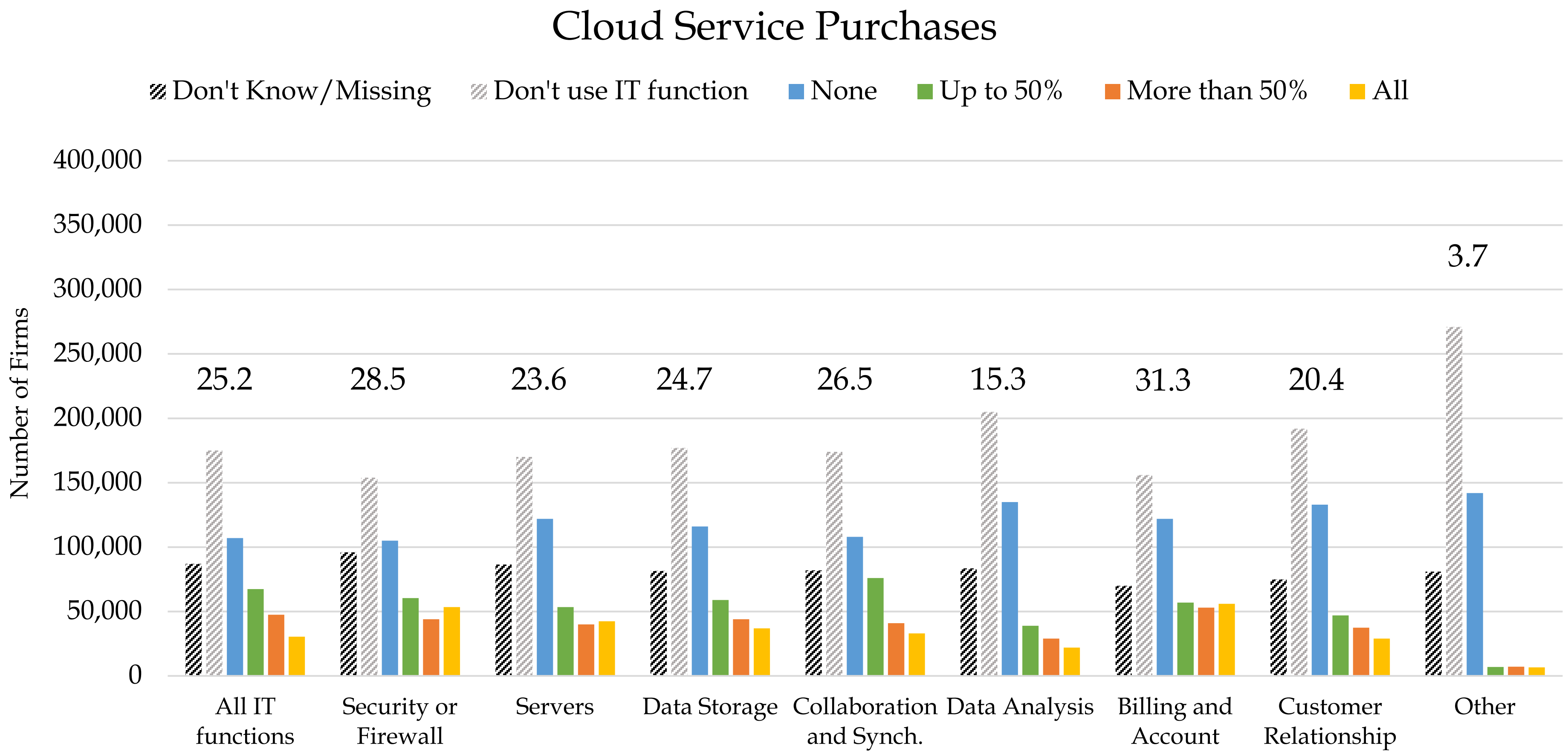
# 2018 Annual Business Survey – Cloud Service Purchases (Question 2)

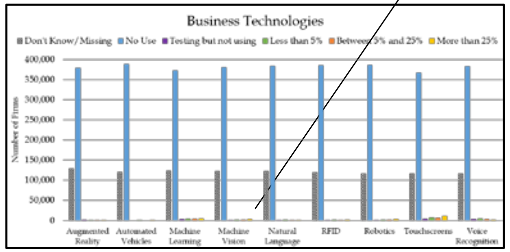
Considering the amount spent on each of these IT functions, how much was spent on cloud services?

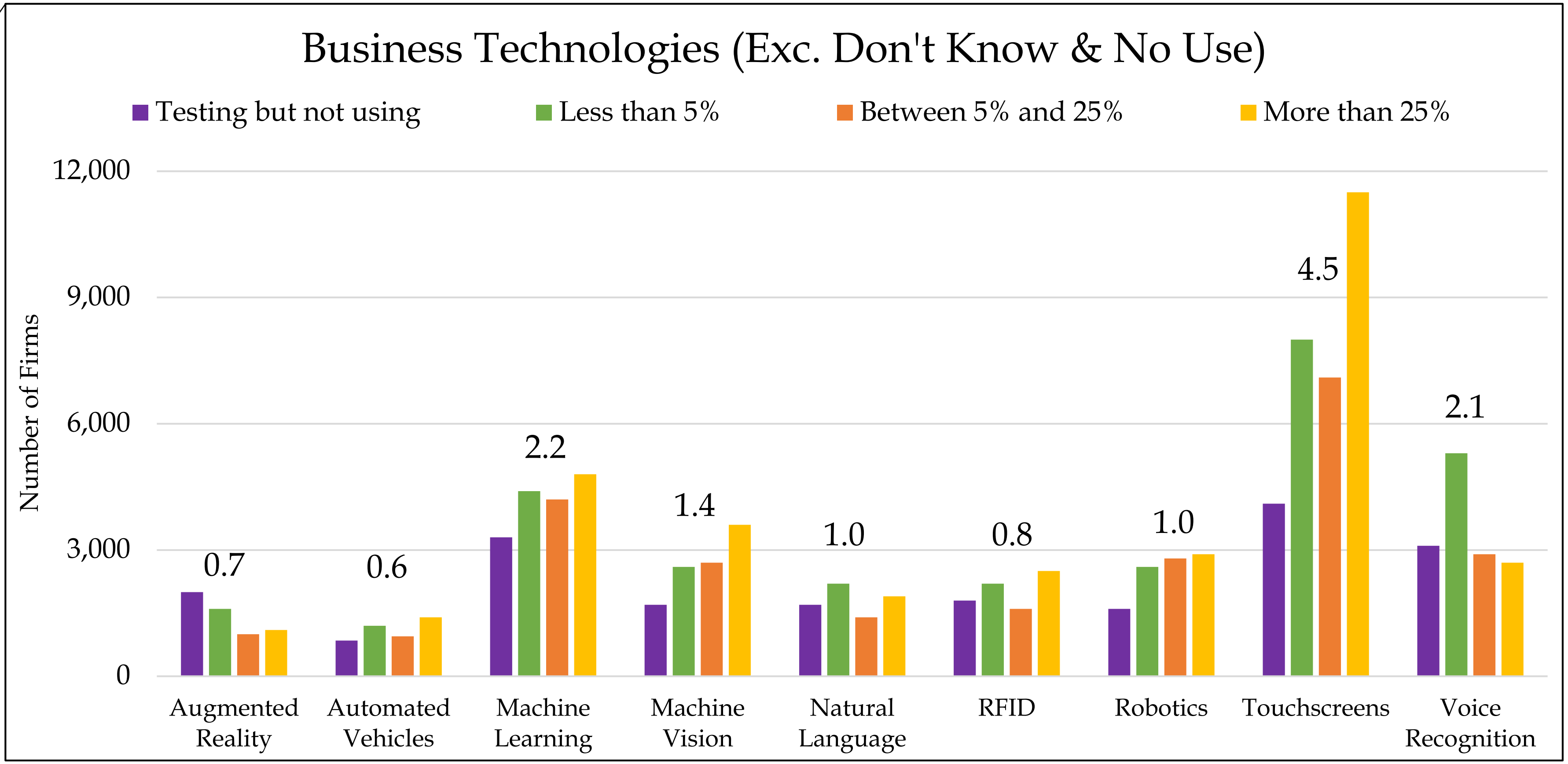



*Number on top is total imputed usage rate

# 2018 Annual Business Survey – Business Technologies (Question 3)

In 2017, to what extent did this business use the following technologies in producing goods or services?




*Number on top is total imputed usage rate

# Technology Comparison with 2018 ABS

## Construct transition matrices between adoption of AI and Robotics from 2018 to 2019

| **AI** | No Use in 2019 | Testing in 2019 | Use in 2019 |
|---|---|---|---|
| No Use in 2018 | 0.97 (0.95) | 0.00 (0.01) | 0.03 (0.04) |
| Testing in 2018 | 0.78 (0.73) | 0.09 (0.10) | 0.13 (0.17) |
| Use in 2018 | 0.82 (0.78) | 0.02 (0.04) | 0.15 (0.19) |

| **Robotics** | No Use in 2019 | Testing in 2019 | Use in 2019 |
|---|---|---|---|
| No Use in 2018 | 0.98 (0.95) | 0 (0) | 0.02 (0.04) |
| Testing in 2018 | 0.64 (0.57) | 0.11 (0.14) | 0.25 (0.29) |
| Use in 2018 | 0.46 (0.33) | 0.02 (0.01) | 0.53 (0.66) |

*Employment-weighted in parentheses

- 2018 AI definition includes Machine Learning, Machine Vision, Natural Language Processing, Voice Recognition and Automated Guided Vehicles
- Large differences in AI response may be due to definitional differences or cognitive error
- Vast majority of "testers" decide to not adopt

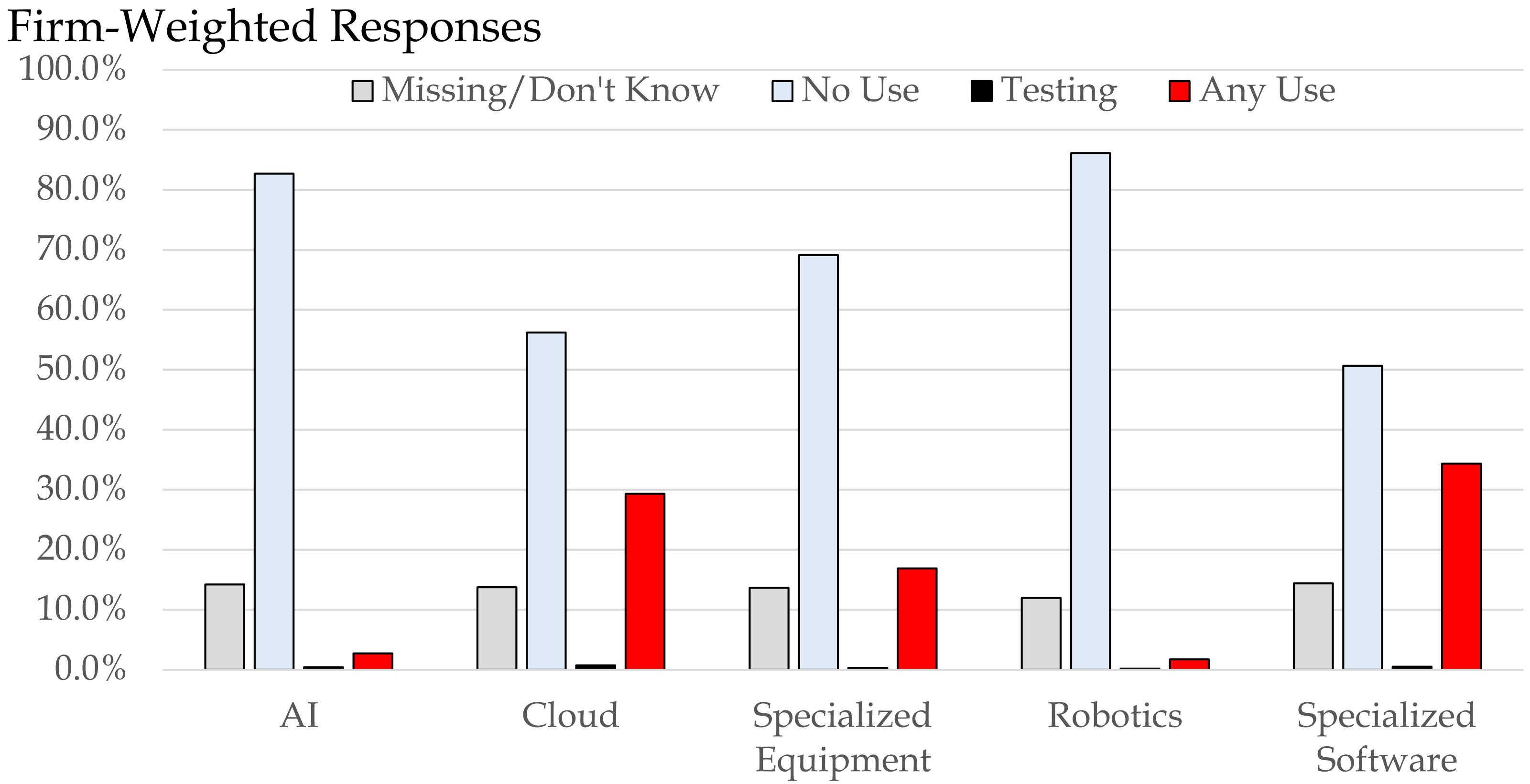
# A.2 - Firm Adoption of Technologies

This section provides:

- Breakdown of firm response to each technology question
- Size/age heat maps of technology
- Industry employment-weighted breakdown of technology
- Top manufacturing industries (4-digit NAICS) that adopt AI or Robotics
- Number of technologies adopted by firm

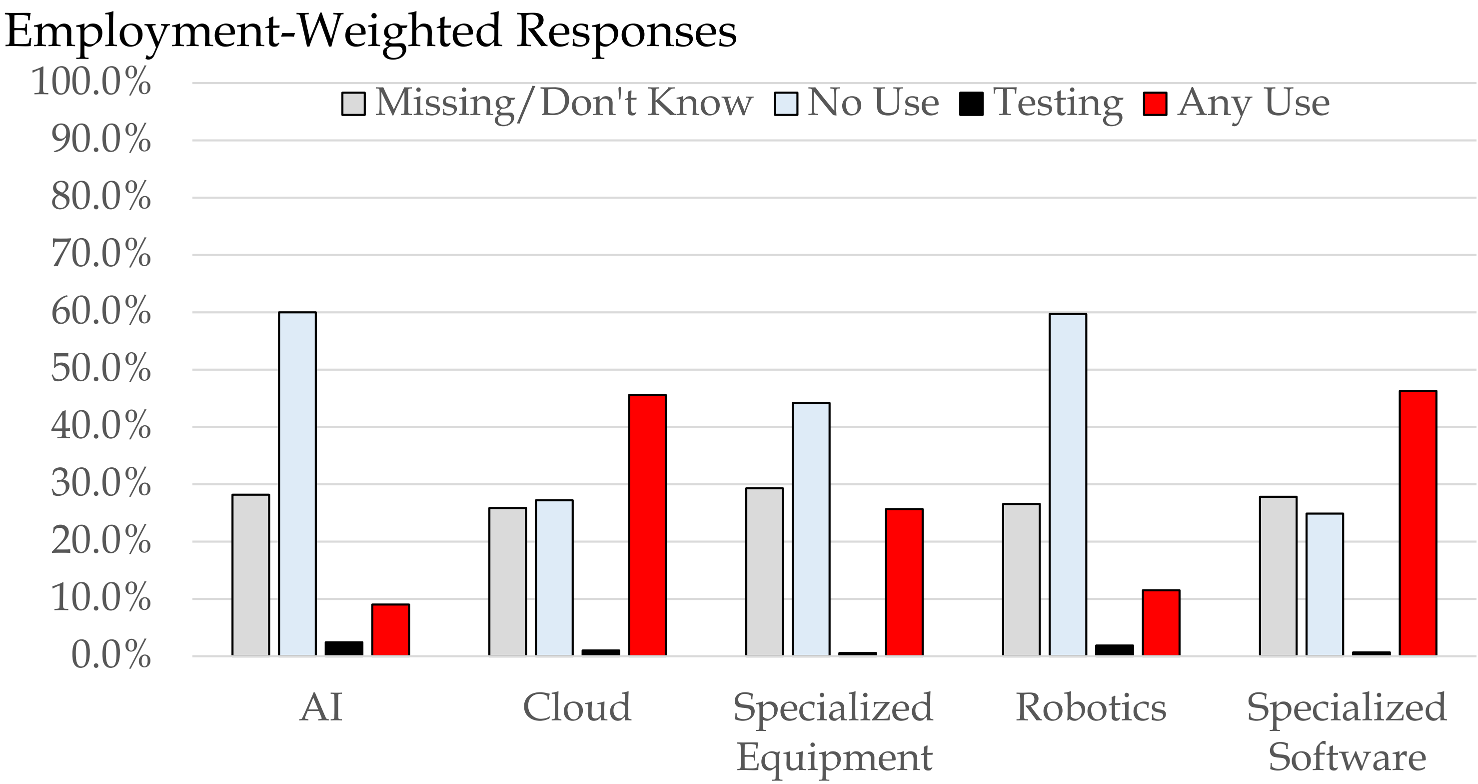
# Technology Use (Firm-weighted)

- "Not in use" is most common response for all technologies
- Specialized software and cloud computing are most common technologies,
- Robotics and AI are least common technologies
- Technology users make up a larger share of *employment* than they do of *firms*



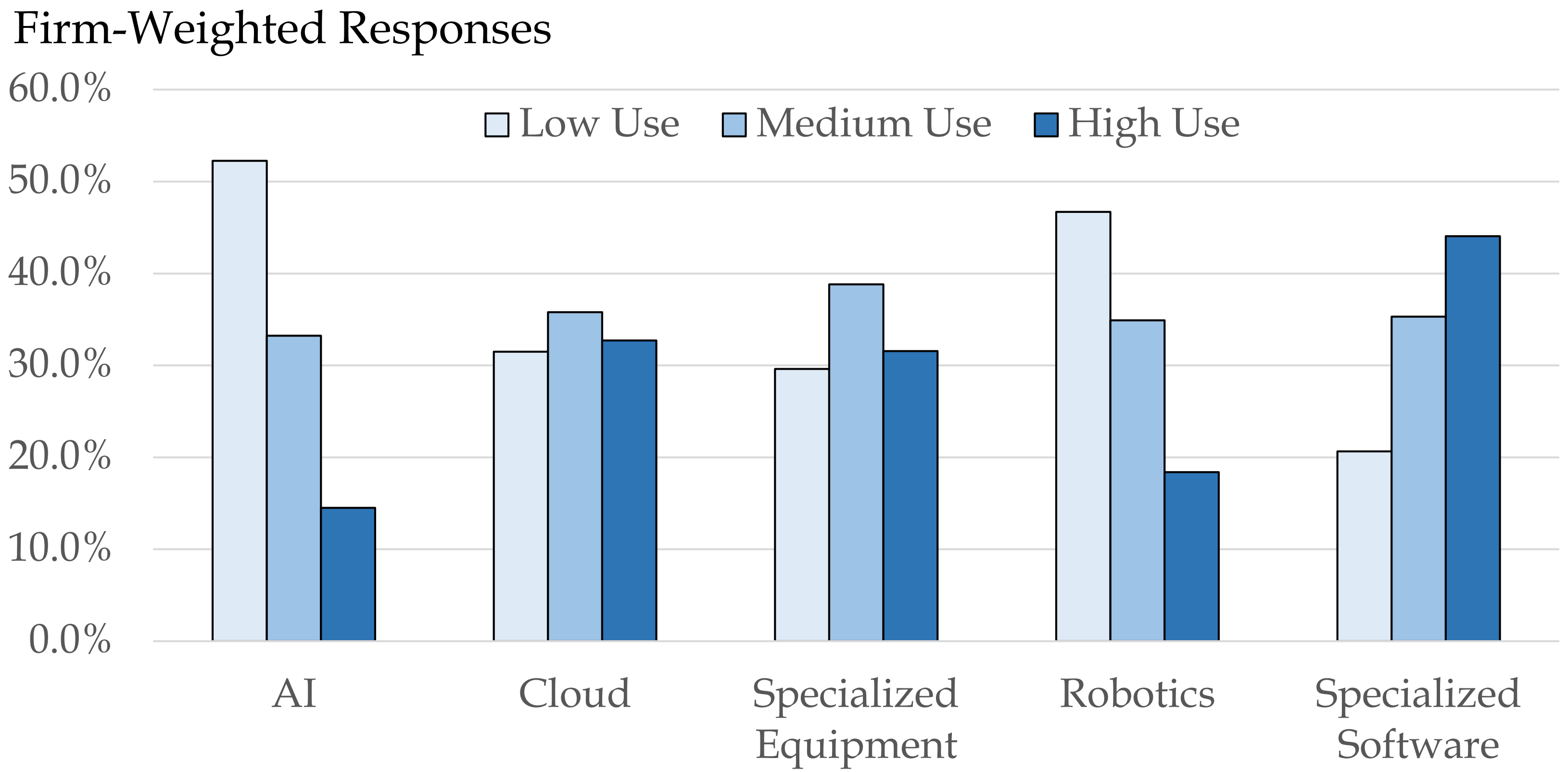
# Technology Use (Employment-weighted)

- Employment-weighted responses reflect worker-level exposure to different technologies
- Usage rates are significantly higher for AI (+6pp), Cloud (+16pp), SE (+9pp), Robotics (+10pp) and SS (+12pp)
- Missing and Don't Know also significantly higher (2x higher on average)
  - Reflects item non-response by largest firms (see 2018 ABS Paper for discussion on imputation and dealing with item non-response)



# Technology Intensity (Firm-weighted, Cond. on Use)

- Most commonly adopted technology (i.e., specialized software) is also used the most intensively
- Employment-weighted intensive margins follow closely with firm-weighted
- Least commonly adopted technologies (i.e., robotics and AI) are also used the least intensively
  - Adverse factors preventing more adoption?

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# Technology Adoption by Size and Age

- Largest and oldest firms are most likely to adopt a technology
- Size and technology adoption association is monotonic… Age is more nuanced (younger firms adopt more when small, but older firms adopt more when large)

| AI | | | | |
|---|---|---|---|---|
| Age/Size | 0-9 Emp | 10-49 Emp | 50-249 Emp | 250+ Emp |
| 0-5 Years | 0.04 (0.04) | 0.04 (0.05) | 0.06 (0.06) | 0.06 (0.06) |
| 6-10 Years | 0.03 (0.03) | 0.04 (0.04) | 0.05 (0.06) | 0.07 (0.09) |
| 11-20 Years | 0.03 (0.03) | 0.04 (0.04) | 0.06 (0.06) | 0.10 (0.13) |
| 21+ Years | 0.02 (0.02) | 0.03 (0.03) | 0.04 (0.04) | 0.07 (0.21) |

| Cloud | | | | |
|---|---|---|---|---|
| Age/Size | 0-9 Emp | 10-49 Emp | 50-249 Emp | 250+ Emp |
| 0-5 Years | 0.36 (0.39) | 0.46 (0.47) | 0.58 (0.59) | 0.68 (0.69) |
| 6-10 Years | 0.32 (0.35) | 0.46 (0.48) | 0.62 (0.63) | 0.66 (0.67) |
| 11-20 Years | 0.29 (0.32) | 0.43 (0.44) | 0.57 (0.58) | 0.69 (0.71) |
| 21+ Years | 0.23 (0.27) | 0.38 (0.41) | 0.53 (0.55) | 0.69 (0.75) |

| Specialized Equipment | | | | |
|---|---|---|---|---|
| Age/Size | 0-9 Emp | 10-49 Emp | 50-249 Emp | 250+ Emp |
| 0-5 Years | 0.18 (0.21) | 0.25 (0.25) | 0.27 (0.28) | 0.30 (0.23) |
| 6-10 Years | 0.17 (0.2) | 0.25 (0.25) | 0.29 (0.29) | 0.20 (0.24) |
| 11-20 Years | 0.17 (0.2) | 0.27 (0.27) | 0.30 (0.31) | 0.31 (0.29) |
| 21+ Years | 0.18 (0.22) | 0.27 (0.28) | 0.34 (0.36) | 0.34 (0.47) |

| Robotics | | | | |
|---|---|---|---|---|
| Age/Size | 0-9 Emp | 10-49 Emp | 50-249 Emp | 250+ Emp |
| 0-5 Years | 0.02 (0.02) | 0.03 (0.03) | 0.04 (0.04) | 0.06 (0.05) |
| 6-10 Years | 0.02 (0.02) | 0.03 (0.03) | 0.05 (0.05) | 0.06 (0.08) |
| 11-20 Years | 0.01 (0.02) | 0.03 (0.03) | 0.05 (0.06) | 0.10 (0.12) |
| 21+ Years | 0.01 (0.01) | 0.03 (0.03) | 0.06 (0.07) | 0.13 (0.28) |

| Specialized Software | | | | |
|---|---|---|---|---|
| Age/Size | 0-9 Emp | 10-49 Emp | 50-249 Emp | 250+ Emp |
| 0-5 Years | 0.38 (0.42) | 0.5 (0.51) | 0.57 (0.58) | 0.71 (0.69) |
| 6-10 Years | 0.37 (0.41) | 0.52 (0.53) | 0.60 (0.61) | 0.65 (0.69) |
| 11-20 Years | 0.36 (0.40) | 0.51 (0.52) | 0.63 (0.64) | 0.70 (0.70) |
| 21+ Years | 0.34 (0.40) | 0.5 (0.52) | 0.61 (0.63) | 0.71 (0.75) |

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Note: All table values are the estimated coefficients on size-age interactions in a linear probability model (LPM) regression with technology use as the dependent variable. No other controls were included in the regression. Employment-weighted numbers are included in parentheses.

# Technology Adoption by Sector (Firm-weighted)

- Some big sectoral differences in employment-weighted technology adoption rates – "Transportation and warehousing" and "Agriculture" are major users of AI and Robotics

| | AI (%) | Cloud (%) | Specialized Equipment (%) | Robotics (%) | Specialized Software (%) |
|---|---|---|---|---|---|
| Agriculture,…, Mining, Utilities | 1.1 | 18.5 | **23.1** | 1.3 | 26.1 |
| Construction | 1.9 | 24.2 | 18.2 | 1.2 | 26.5 |
| Manufacturing | 3.1 | 31.0 | **39.9** | **8.7** | 42.1 |
| Wholesale Trade | 2.2 | 31.5 | 16.0 | 2.3 | 33.7 |
| Retail Trade | 2.6 | 25.6 | 15.6 | 2.0 | 32.7 |
| Transportation & Warehousing | 2.6 | 24.7 | 14.5 | 0.8 | 30.1 |
| Information | **8.2** | **60.4** | 22.6 | **2.5** | **62.6** |
| Finance, Insurance, Real Estate | **4.0** | 46.0 | 6.9 | 0.7 | 49.6 |
| Professional Services | **6.3** | **54.6** | 19.2 | **3.4** | **60.3** |
| Management & Administrative | 2.6 | 31.1 | 16.4 | 0.9 | 33.8 |
| Education | 2.4 | **47.8** | 12.9 | 1.0 | 46.8 |
| Health Care | 3.5 | 42.9 | **32.4** | **2.5** | **53.3** |
| Other (Arts, Food, Other) | 2.0 | 23.0 | 19.9 | 1.0 | 31.7 |

# Top Manufacturing Industries for Automation Technologies (AI & Robotics)

| Top NAICS for AI Adoption | Firm-Weighted | Employment-Weighted |
|---|---|---|
| 3341 - Computer and Peripheral Manufacturing | 6.1% | 20.0% |
| 3251 - Basic Chemicals | 6.0% | 5.9% |
| 3345 - Navigation and Control Instrument | 5.6% | 31.3% |
| 3334 - HVAC Manufacturing | 4.4% | 31.3% |
| 3115 - Dairy Product Manufacturing | 4.2% | 32.1% |

| Top NAICS for Robotics Adoption | Firm-Weighted | Employment-Weighted |
|---|---|---|
| 3221 - Forging | 20.6% | 81.8% |
| 3363 - Motor Vehicle | 19.7% | 67.2% |
| 3325 - Hardware | 19.4% | 87.4% |
| 3311 - Iron & Steel Mills | 16.4% | 34.9% |
| 3115 - Dairy Product Manufacturing | 14.0% | 75.4% |

- AI is most commonly found in Computer and Electronic Manufacturing (NAICS 334)
- Robotics most commonly found in heavy machinery manufacturing

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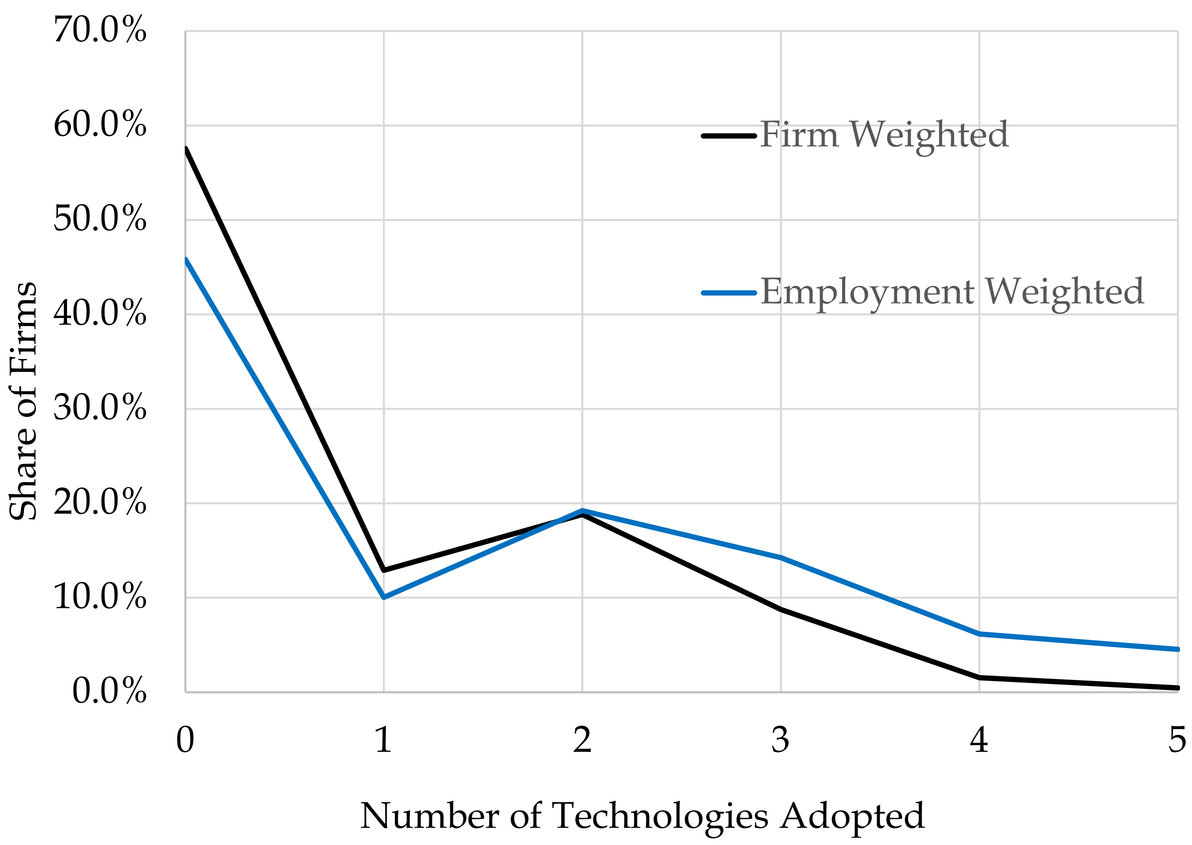
# Number of Technologies Adopted




- 58 of Firms do not adopt *any* technology
- Largest firms adopt multiple technologies
- Firms who adopt a technology are more likely to adopt 2 technologies
- Most common technology pairings include:
  1. Cloud and Specialized Software
  2. Cloud, Specialized Software and Equipment
  3. Specialized Software and Equipment

# A.3 - Motivation and Adverse Factors for Adoption

This section provides:

- Summary of Motivation Responses (Firm-weighted)
- Summary of Motivation Responses by Size and Age
- Summary of Motivation Responses by Manufacturing Status
- Firm exposure to Automation
- Employment-weighted adverse factors
- NA and No adverse factors (Firm-weighted)
- NA and No adverse factors (Employment-weighted)

# Motivation for Technology Adoption (Firm-weighted)

For employees of firms that use AI or Robotics, more than half are employed by firms that adopted AI or Robotics for the purpose of Automation*

| Technology | Automate | Upgrade | Improve Quality | Expand | Standards | Other | # of Firms (000s) | # of Workers |
|---|---|---|---|---|---|---|---|---|
| **AI** | **29.0%** | 36.6% | 49.8% | 24.8% | 11.8% | 18.7% | 166 | 12.9M |
| **Cloud** | 16.0% | 42.9% | 49.8% | 14.5% | 10.7% | 16.0% | 1,794 | 65.2M |
| **Specialized Equipment** | 20.4% | 37.9% | 51.3% | 25.5% | 11.0% | 17.7% | 1,033 | 36.7M |
| **Robotics** | **39.6%** | 31.1% | 45.8% | 24.1% | 8.2% | 20.8% | 106 | 16.4M |
| **Specialized Software** | 20.3% | 43.2% | 51.4% | 15.8% | 12.2% | 19.2% | 2,102 | 66.2M |

*Note: Here "automation" specifically means the automation of tasks performed by labor.

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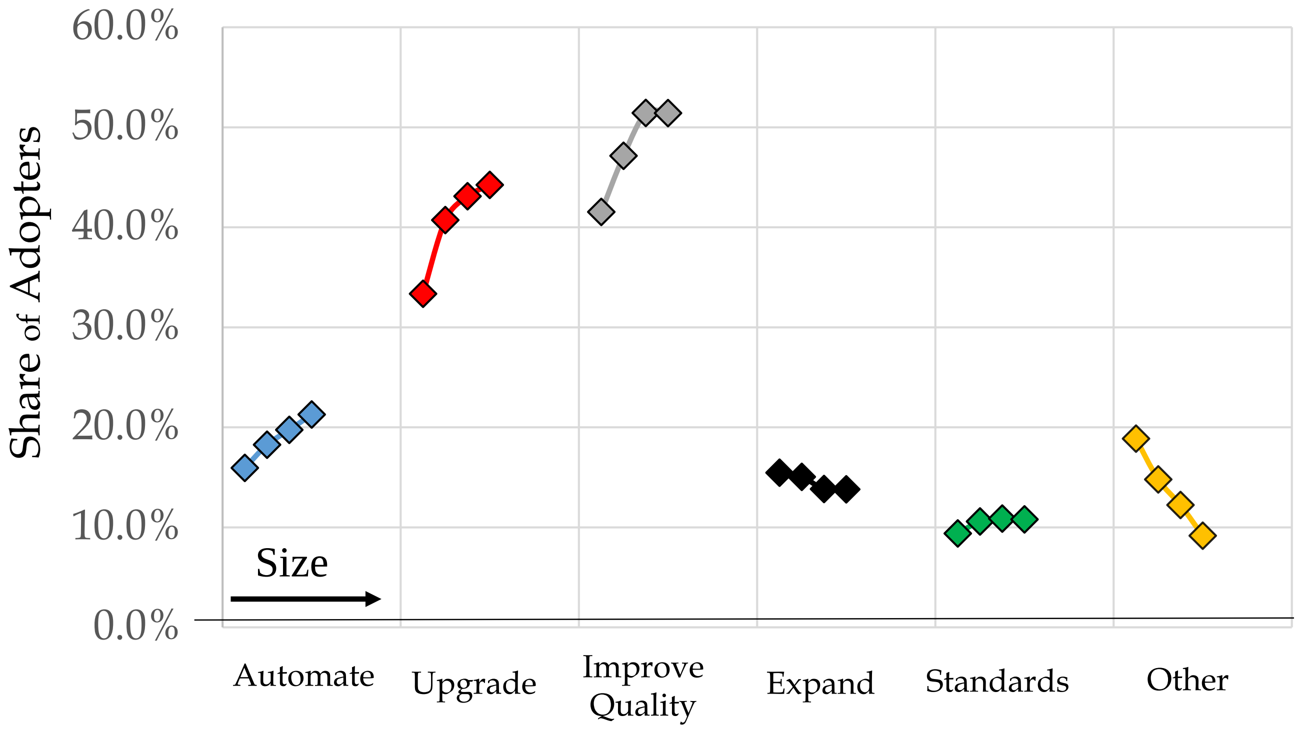
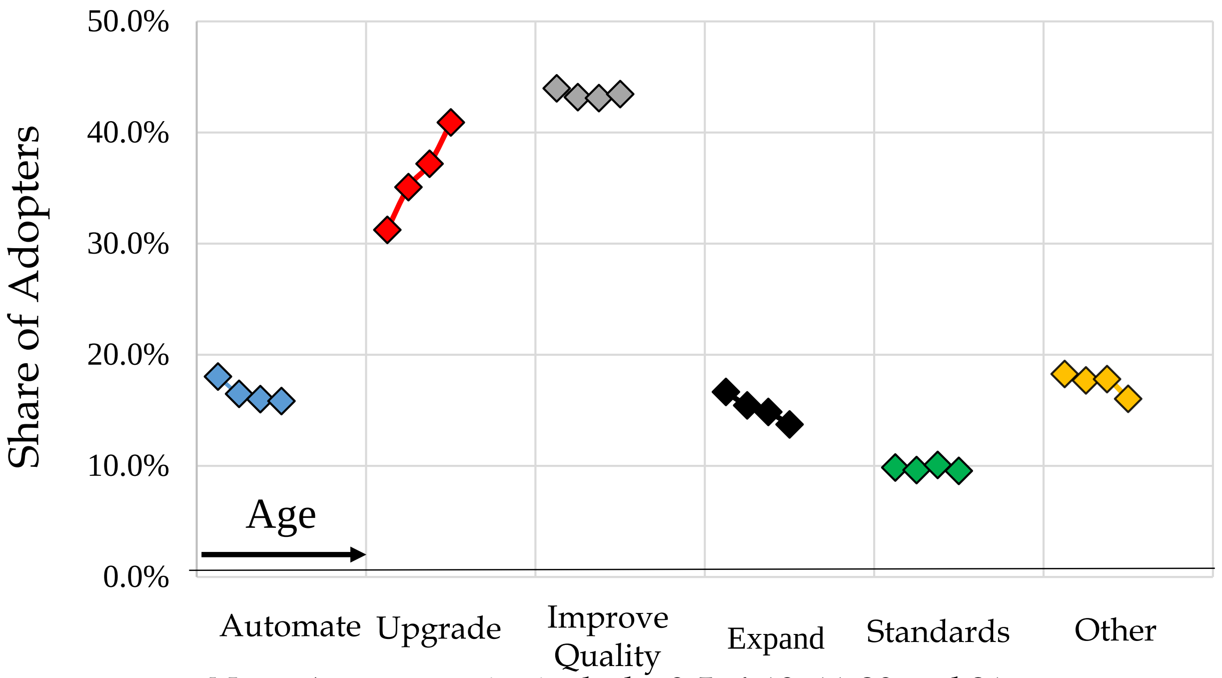
# Motivation by Size and Age

- Motivation for Automation, Process Upgrade and Quality Improvements increases as firms get bigger
- Motivation for Process Upgrading increases as firms get older




Note: Size categories include: 0-9, 10-49, 50-249 and 250+ employees




Note: Age categories include: 0-5, 6-10, 11-20 and 21+

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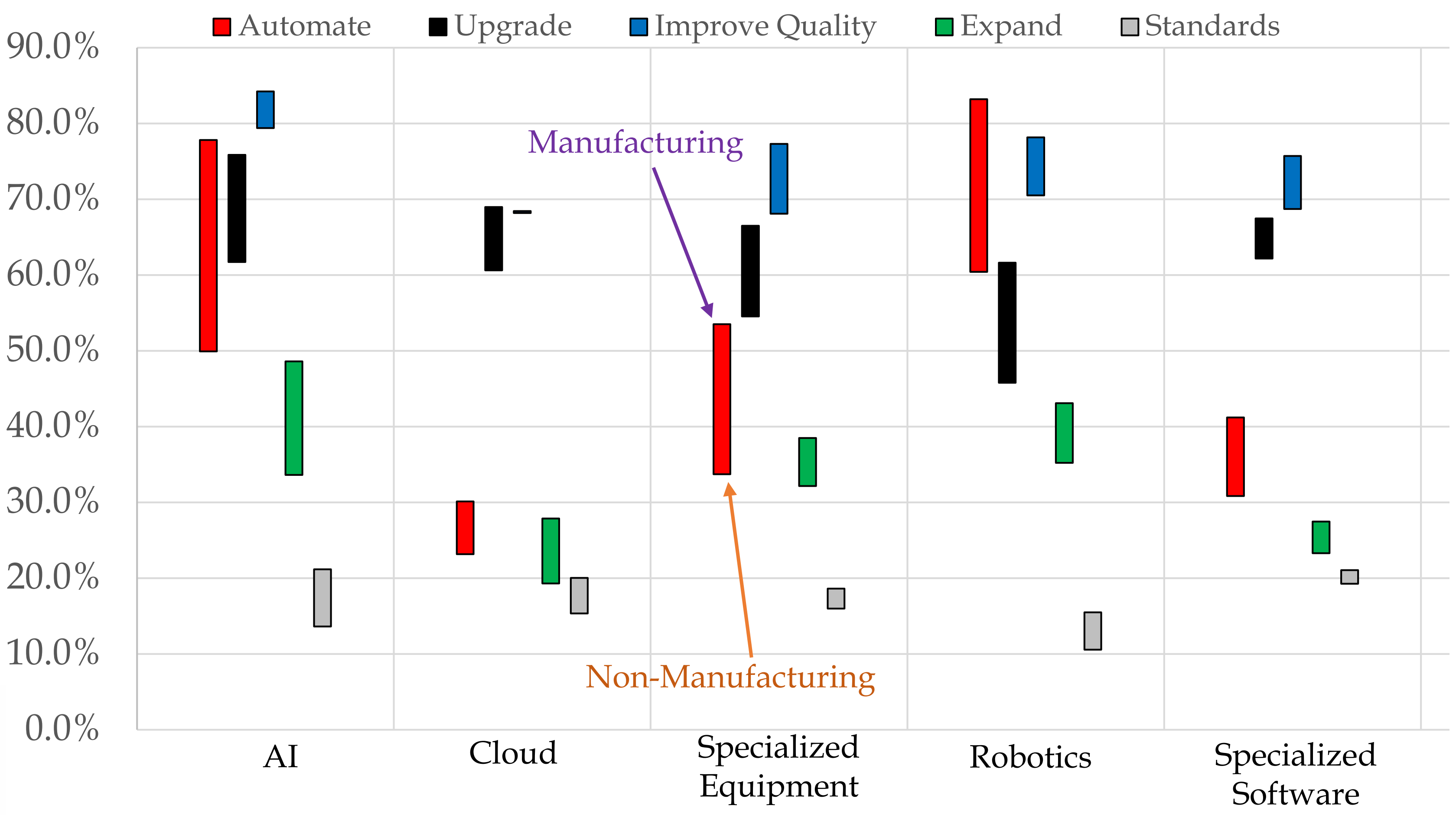
# Net Difference in Motivation by Manufacturing Status

Manufacturing firms adopting AI, Robotics, and Specialized Equipment much more likely to be motivated by Automation




*Bars reflect difference in Motivation responses by Technology type between Manufacturing and non-Manufacturing Firms

**Robotics-Expand and Cloud-Improve Quality have more non-manufacturing firms than manufacturing

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# Firm Exposure to Automation

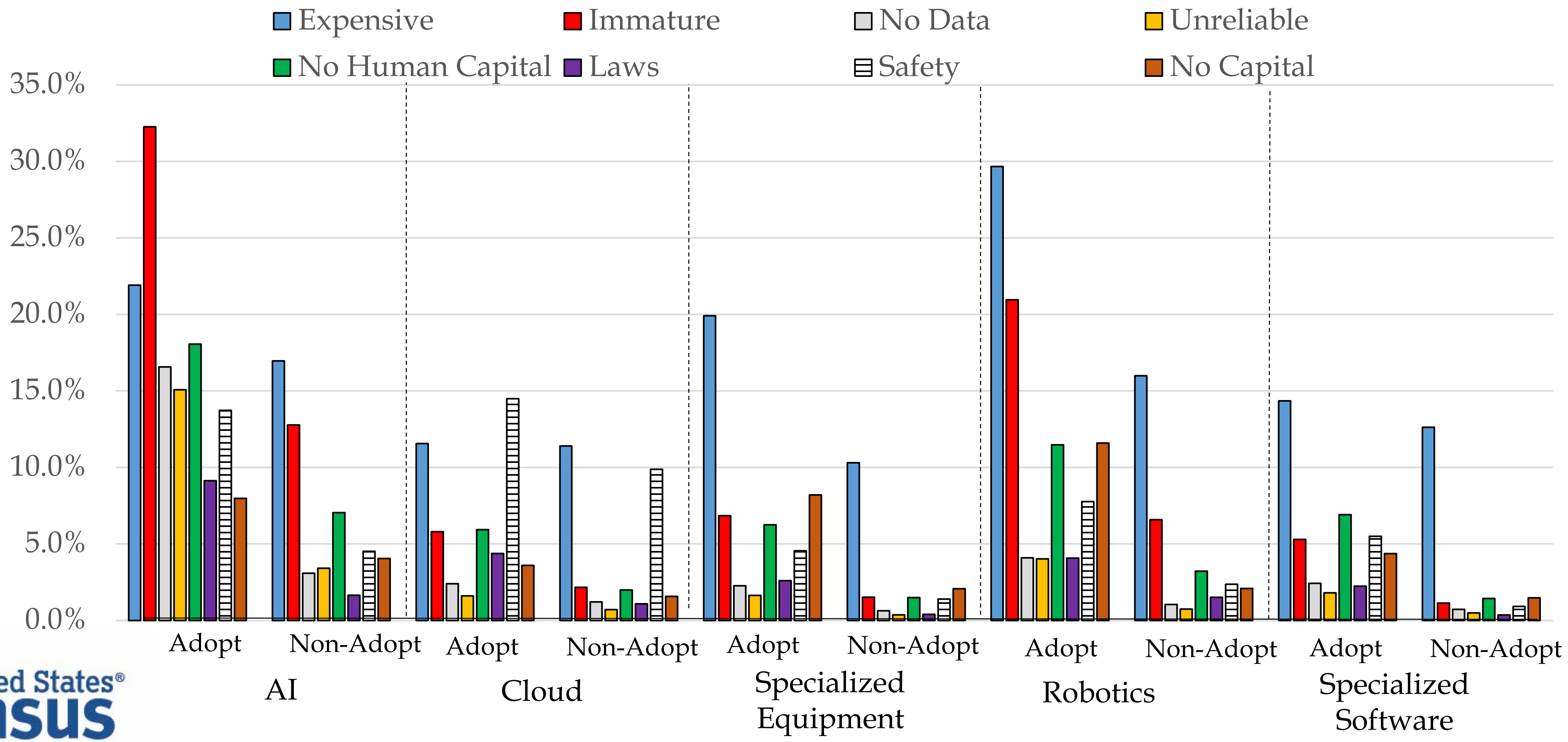
- Small share of firms motivated to adopt a technology by automation
- Size and sector are key determinants of automation usage by firm

**Firm Exposure to Automation by Technology (%)`**

| Type | AI | Cloud Comp. | Spec. Soft. | Robotics | Spec. Equip. |
|---|---|---|---|---|---|
| All | 0.9 | 5.4 | 4.0 | **0.8** | 8.1 |
| Manufacturing | 1.2 | 4.4 | 13.4 | **5.3** | 10.2 |

# Adverse Factors for Technology Adoption (Employment-weighted)

- Employment-weighted adverse factors highlight immaturity and cost of technology for adopters
- Lack of human capital is major factor preventing adoption of AI and Robotics
- AI has several factors, including Unreliability, lack of data and security




*Conditional on technology being applicable. “No adverse factors” category is dropped in figure.

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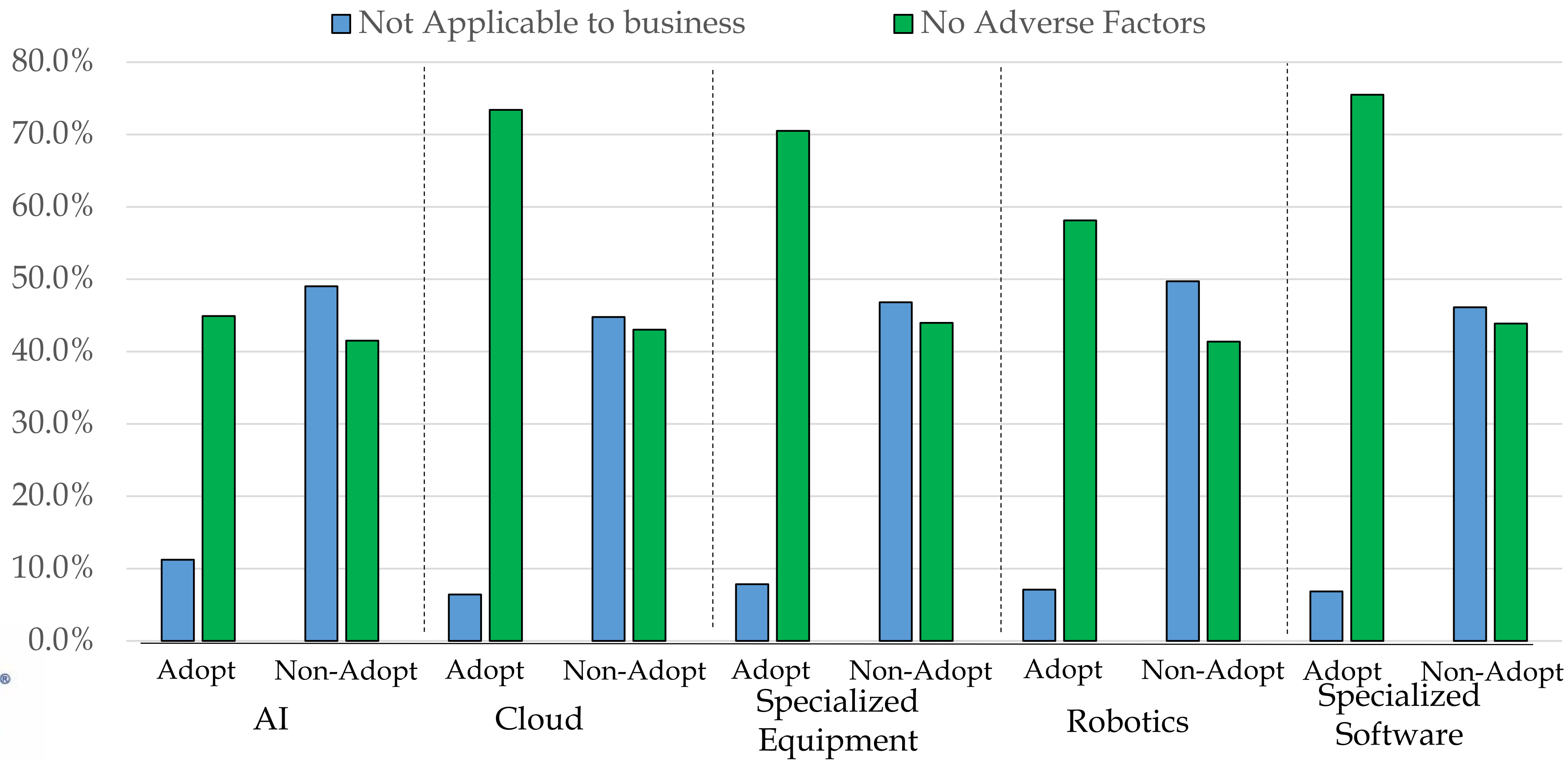
# NA and Adverse Factors for Technology Adoption (Firm-weighted)

- Majority of non-adopters report "Not Applicable" or "No Adverse Factors" preventing adoption (80-90% of respondents)




*Unconditional shares. Firm-weighted.

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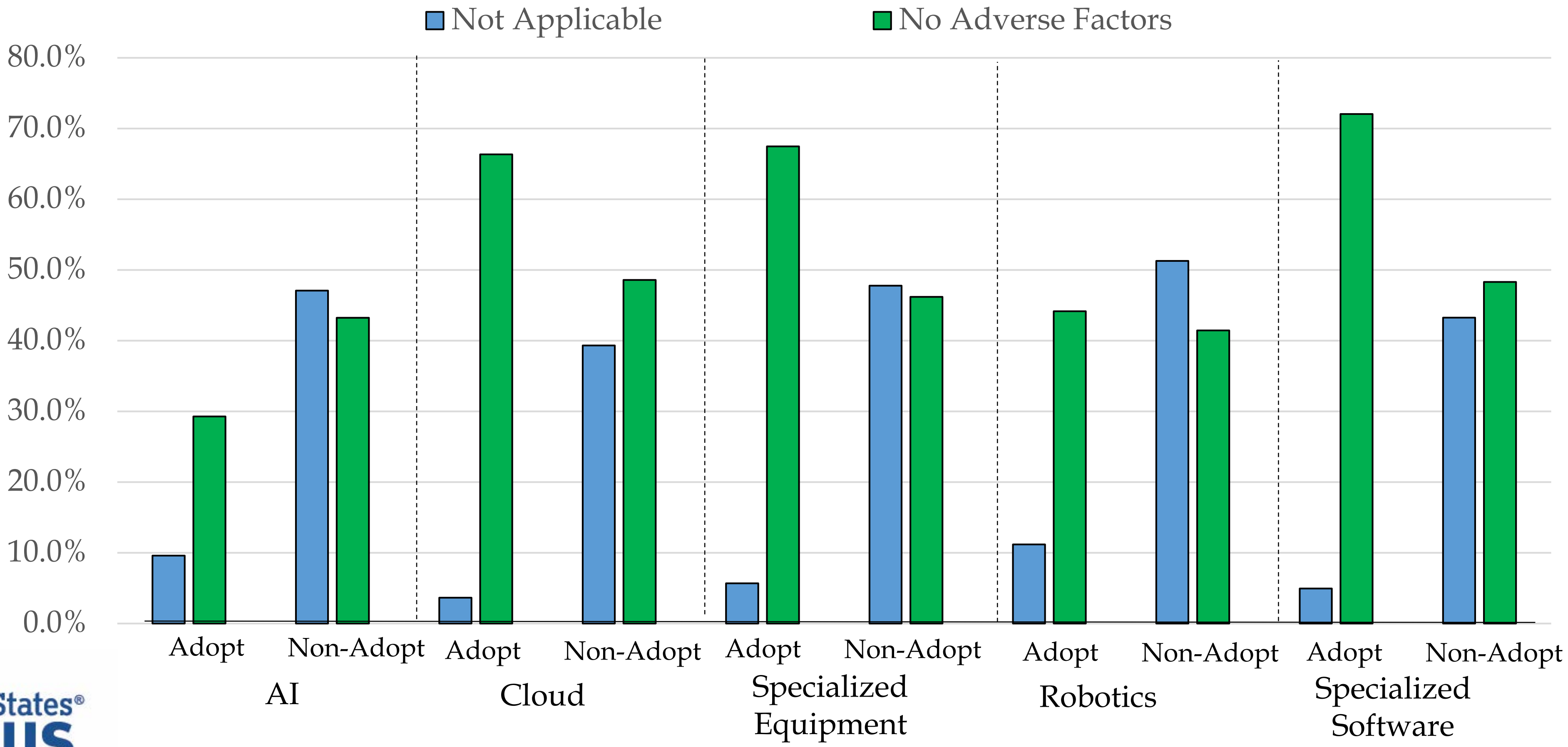
# NA and Adverse Factors for Technology Adoption (Employment-weighted)

- Majority of non-adopters report “Not Applicable” or “No Adverse Factors” preventing adoption (80-90% of respondents)




*Unconditional shares. Employment-weighted.

# A.4 - Employment Outcomes from Adoption

This section provides:

- Generalized Ordered Logit framework
- Employment changes from tech (firm-weighted)
- Net Difference in Firm Responses to changes in worker type (firm-weighted)
- Production Worker Changes by Manufacturing status (employment-weighted)
- Skill changes from tech (firm-weighted)
- Net Difference in Firm Responses to Employment Changes by Size, Age and intensity (firm-weighted)
- Net difference in Firm Responses to changes in worker types by intensity (firm-weighted)
- Net Difference in Firm Responses to Skill Changes by Size, Age and intensity (firm-weighted)
- Sankey diagram on employment and skill change by automation (firm-weighted)
- Sankey diagram on employment and skill change by AI and Robotics (firm-weighted)
- Sankey diagram on production worker change from Robotics (employment-weighted)
- Challenges and Next Steps

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# Generalized Ordered Logit Specification (Tech Use)

- Estimate the following two equations for each technology $tech$:

$$\ln\left(\frac{p_j^{dec}}{p_j^{nc}+p_j^{inc}}\right)^{tech} = \alpha_{tech}^{dec} + X_j{}'\gamma_{tech}^{dec} \qquad (1)$$

$$\ln\left(\frac{p_j^{dec}+p_j^{nc}}{p_j^{inc}}\right)^{tech} = \alpha_{tech}^{nc} + X_j{}'\gamma_{tech}^{nc} \qquad (2)$$

- Firm level (conditional on adoption of $tech$): firm $j$
- $X_j$: vector of firm characteristics including two-digit NAICS sectors, 4 size bins, and 4 age bins
- $\gamma_{tech}^{dec}, \gamma_{tech}^{nc}$: effect of firm characteristics on log odds ratio of the event ($\Delta emp_{tech} \leq -1$) or ($\Delta emp_{tech} \leq 0$), respectively
  - For worker types (PW, NP, SW and NSW), we drop observations who do not employ specific worker type
- *Proportional odds/parallel lines* assumption: $\gamma_{tech}^{dec} = \gamma_{tech}^{nc}$
  - Wald test $\Longrightarrow$ reject proportional odds model in favor of **partial proportional odds** model

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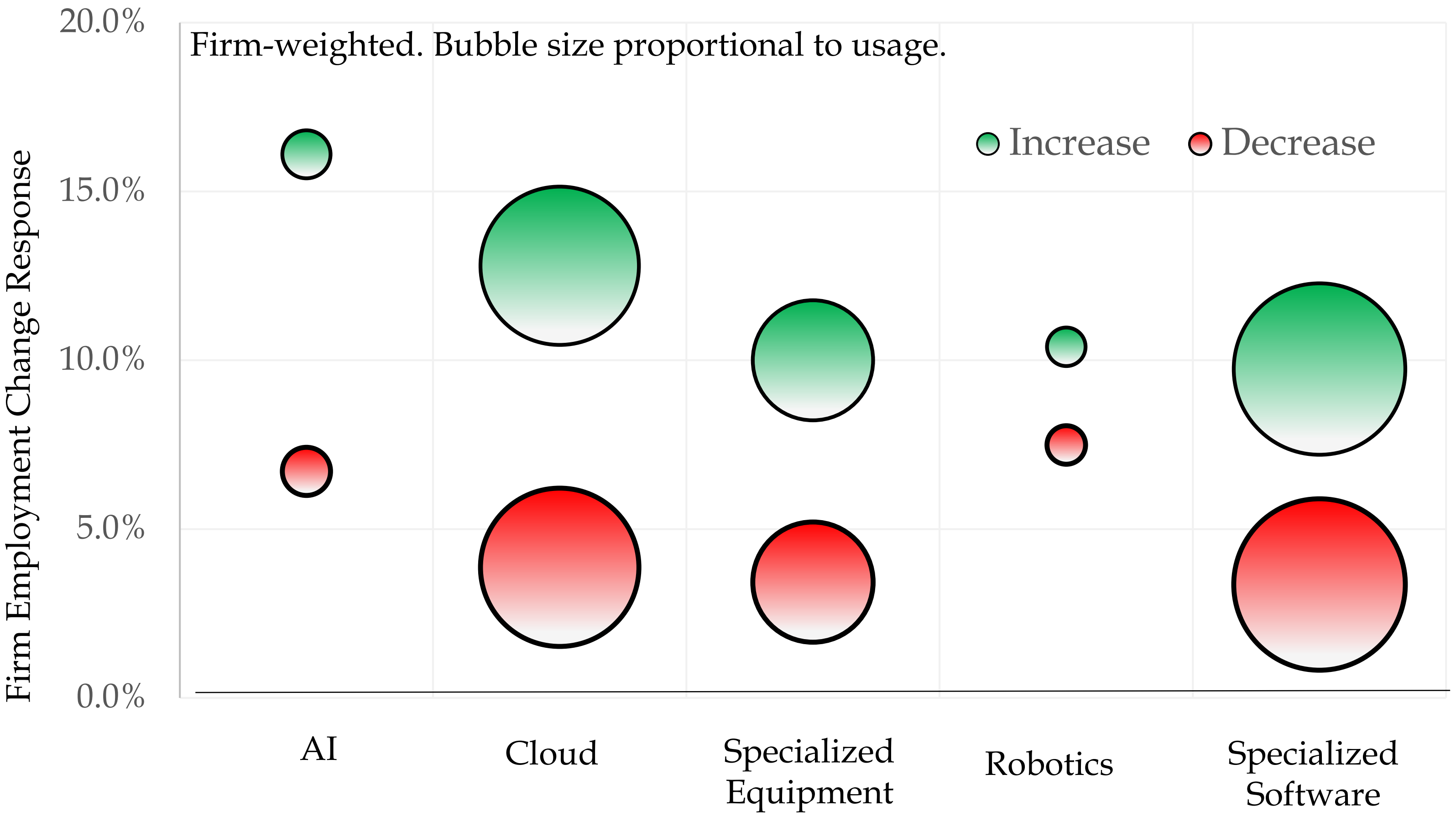
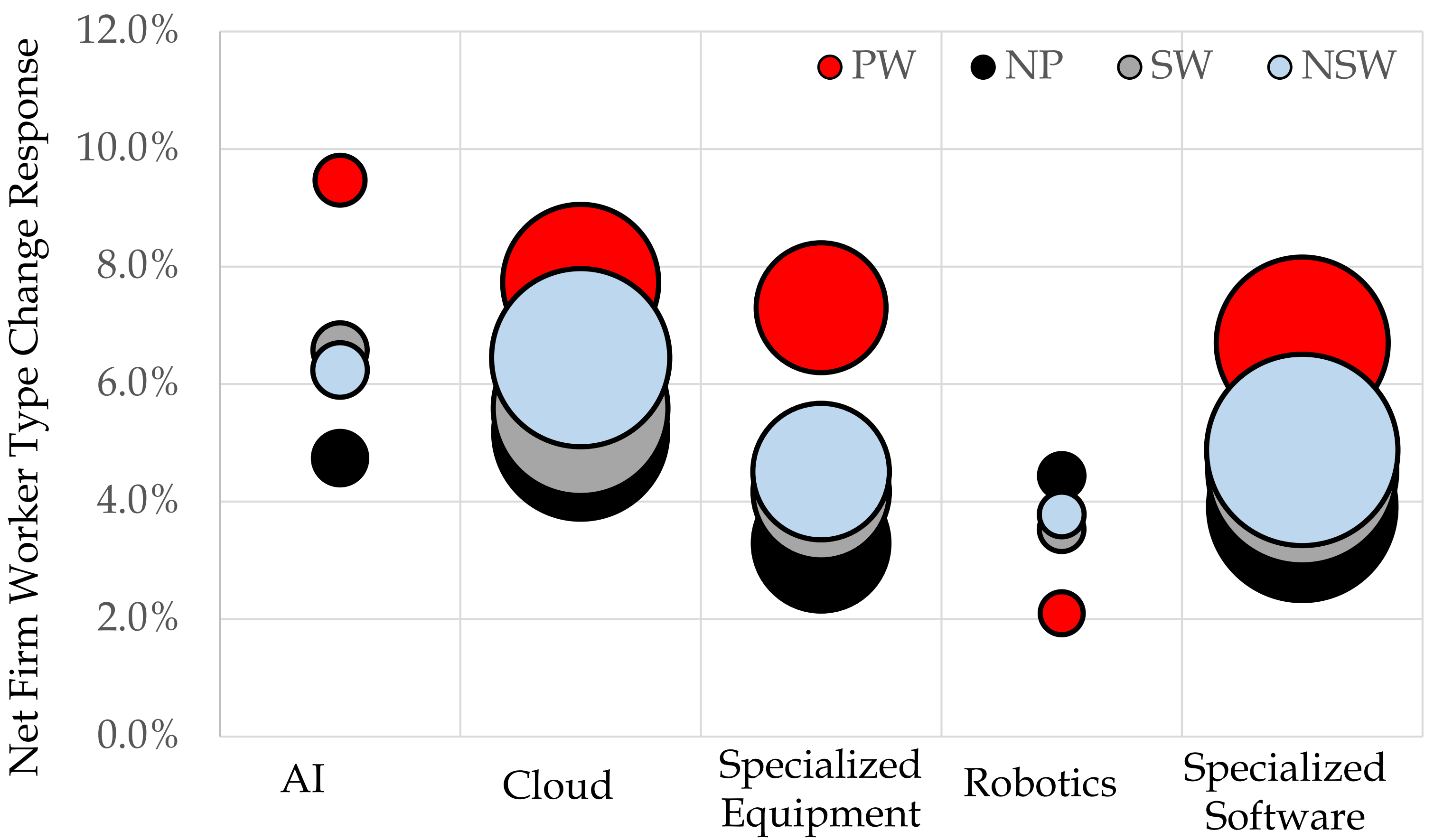
# Employment Changes Attributed to Tech

- Majority of adopters do not attribute employment change to tech (~75%)
- More firms attribute employment increases to tech than decreases
- More firms on net attribute employment increases to tech
  - Robotics has smallest net difference



# Worker Type Changes (Firm-weighted)

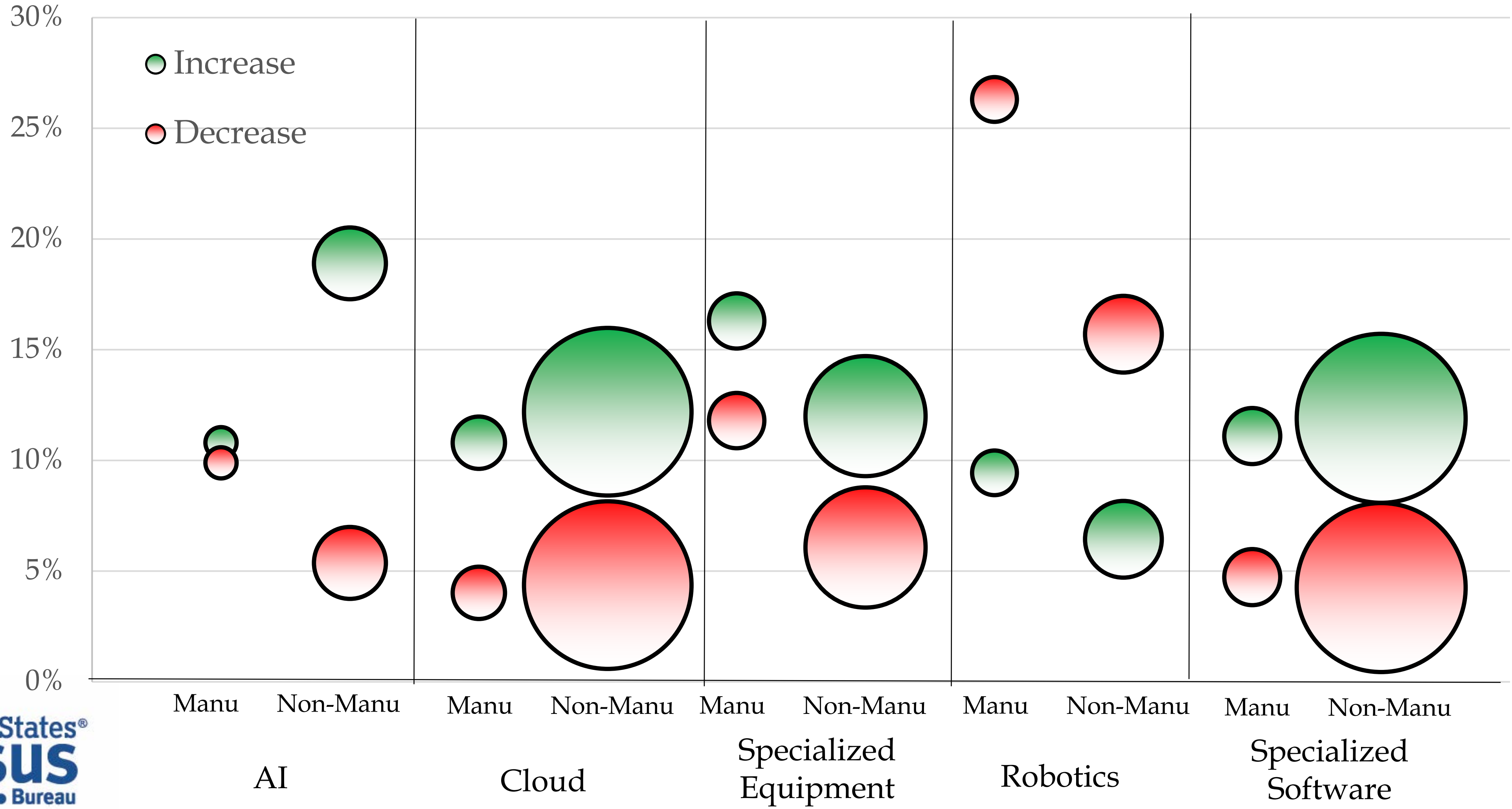
- Firm-weighted changes to worker type show similar patterns but no net negative for production workers




Bubble size corresponds to number of adopters who employ worker type

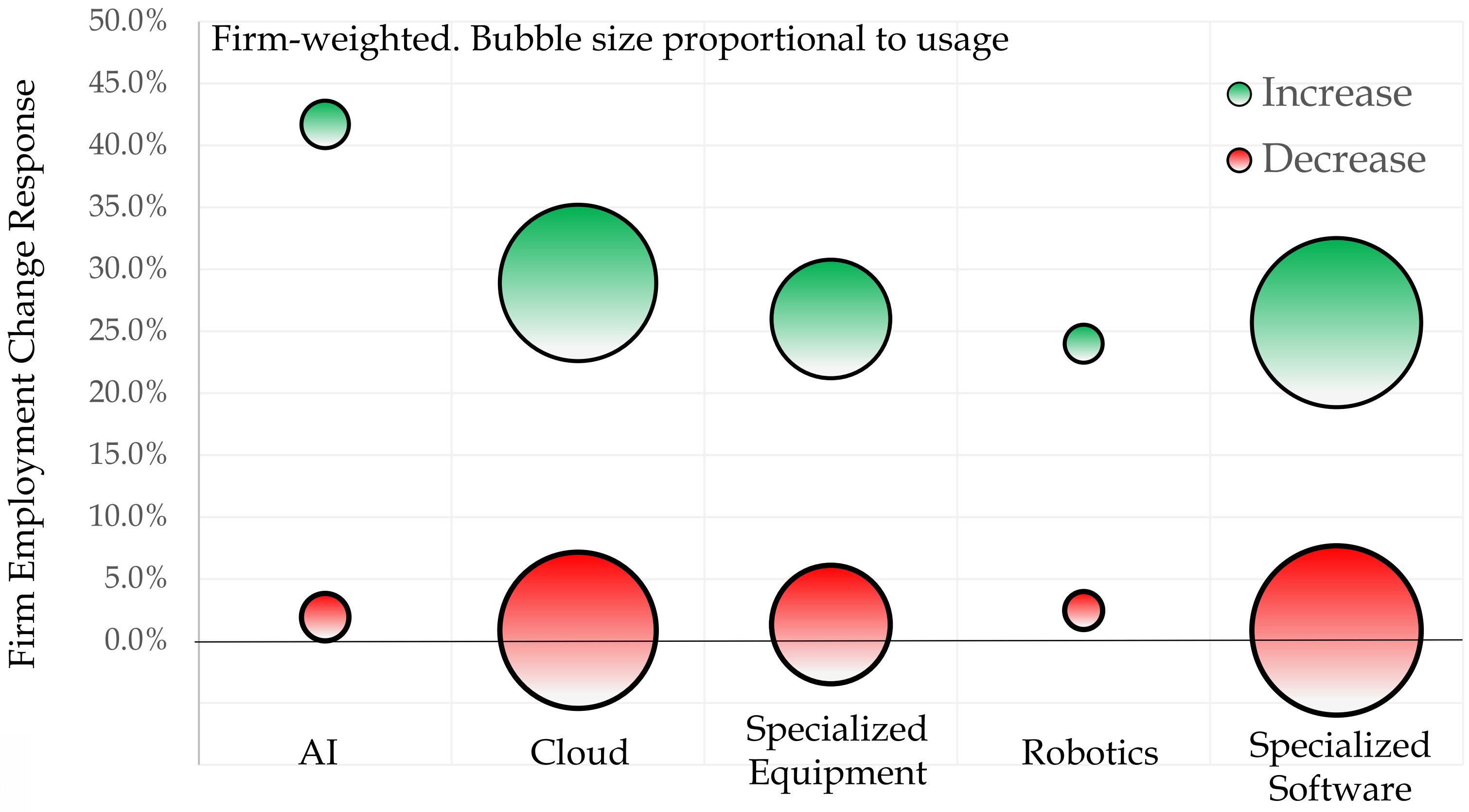
# Production Worker Changes by Manufacturing Status

## Decline in Production Workers driven by Manufacturing Sector



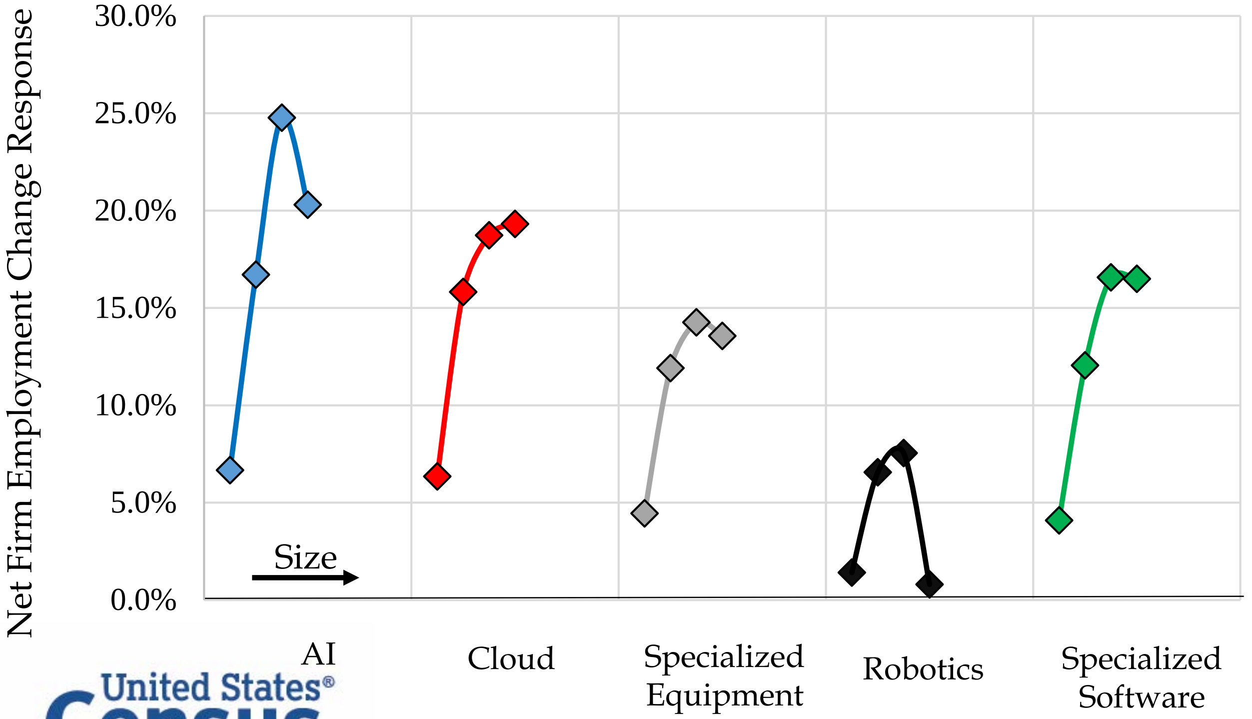
# Skill Change by Technology Adoption (Firm-weighted)

- About half of firms attribute changes in skill levels to technology adoption
- Very few firms attribute declining skill levels to technology adoption

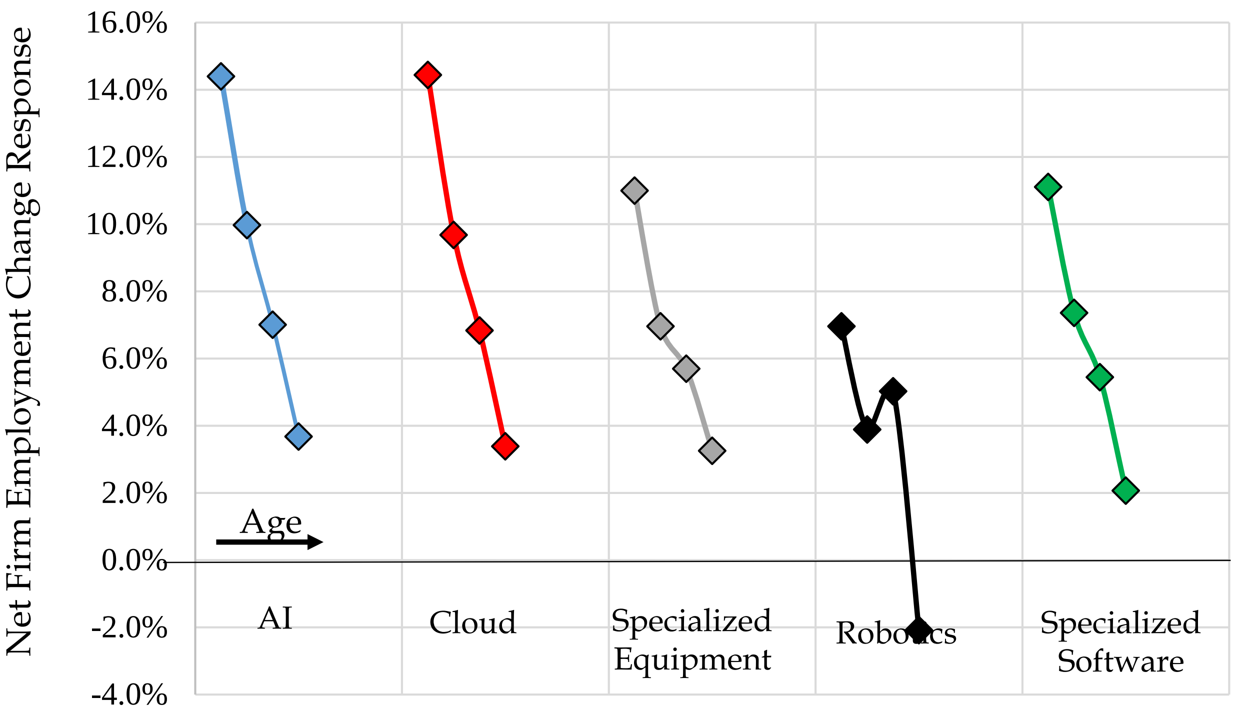


# Net Employment Change by Size and Age

- Net difference in employment change is positive across all size categories, with lowest difference in Robotics
- Net difference in employment change is declining by age, with oldest firms reporting more employment decreases than increases in Robotics



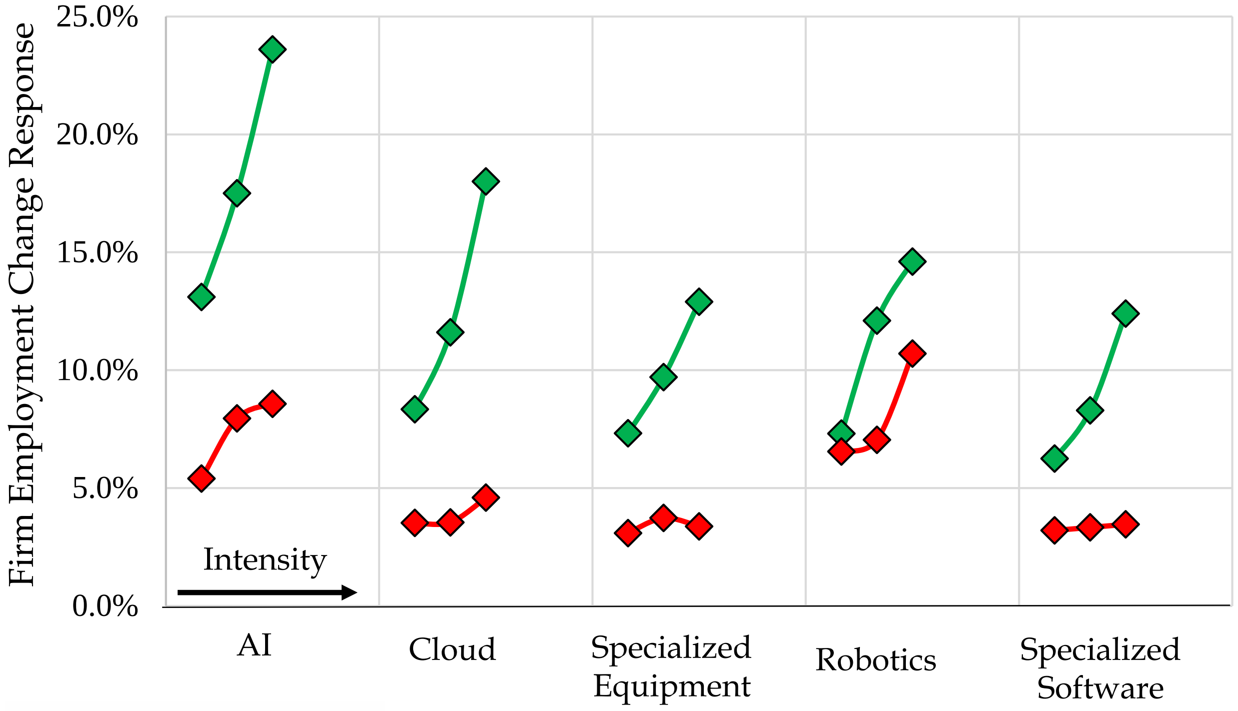

Note: Size categories include: 0-9, 10-49, 50-249 and 250+ employees

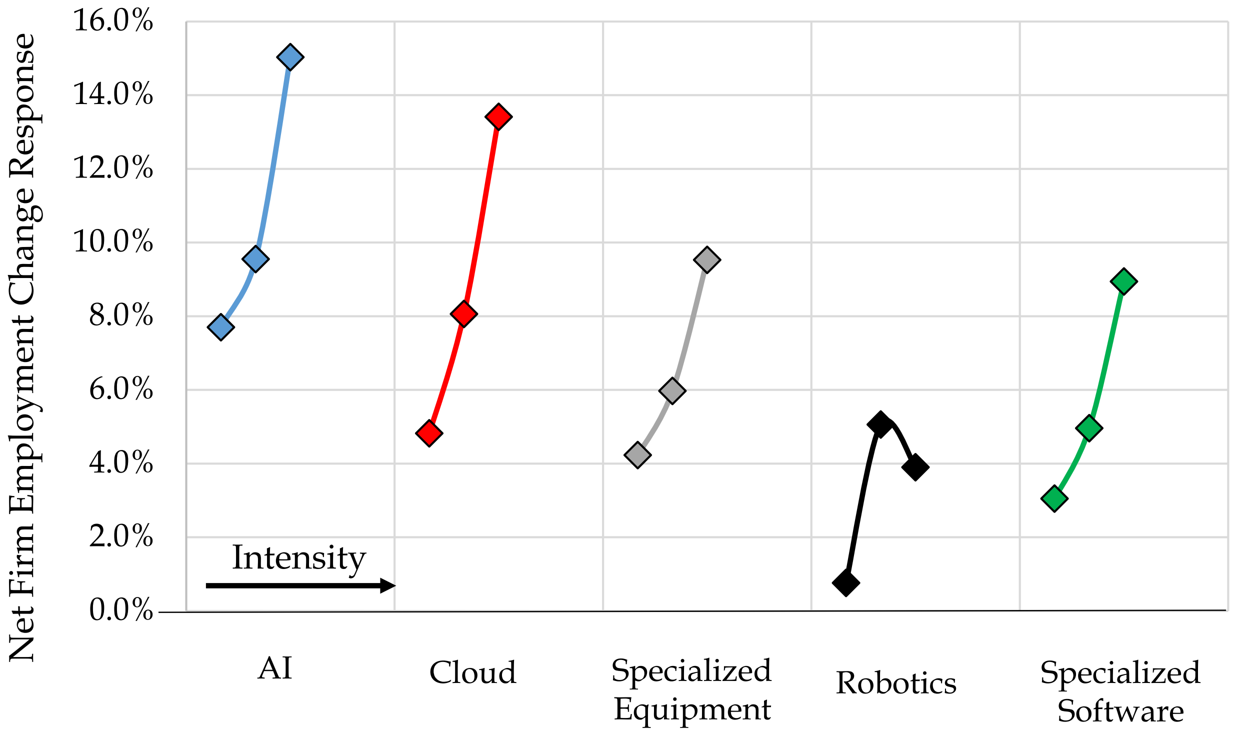



Note: Age categories include: 0-5, 6-10, 11-20 and 21+

# Employment Changes by Intensity of Adoption

- Higher technology adoption intensity is associated with higher shares of firms reporting employment increases

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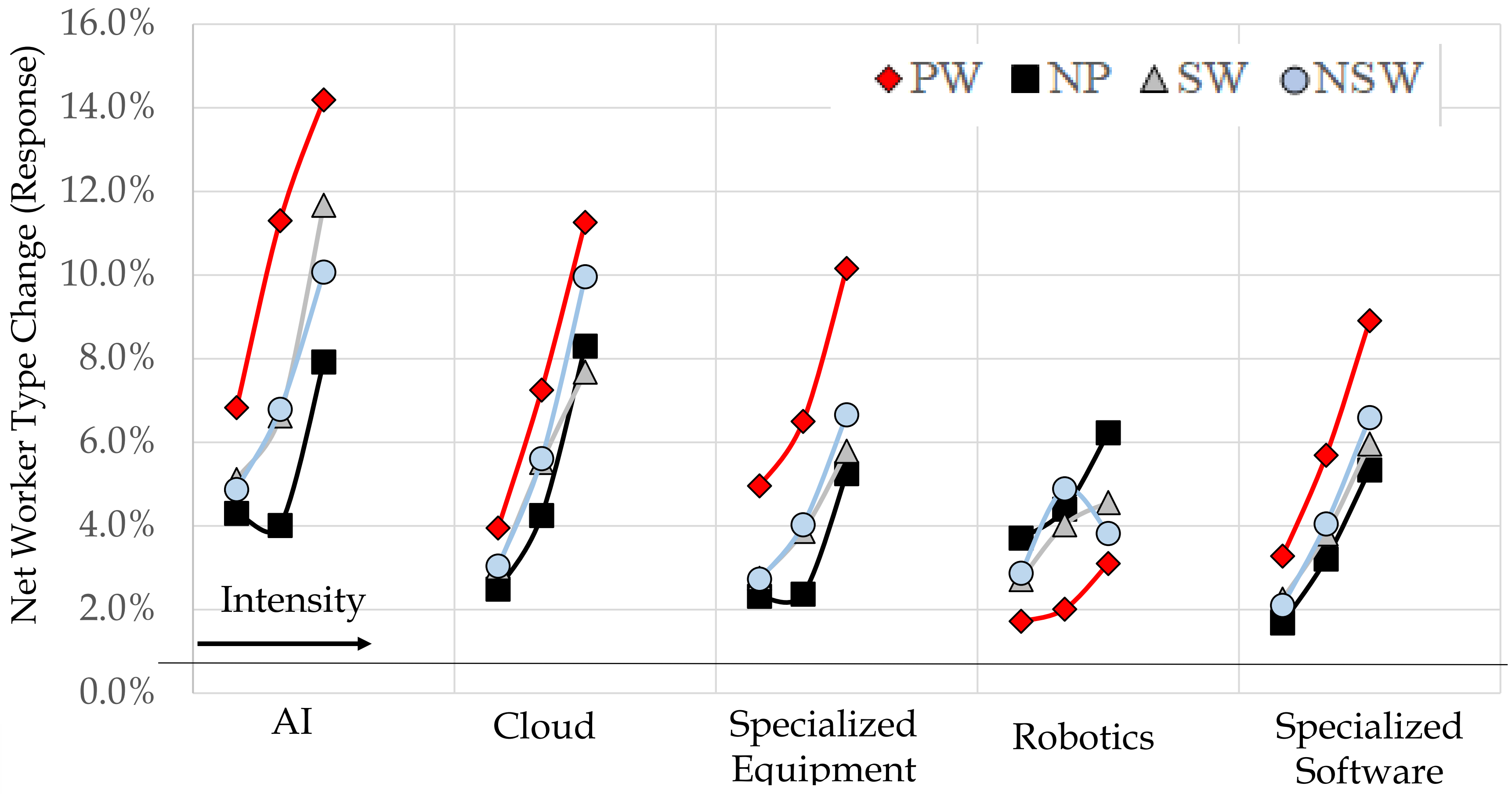
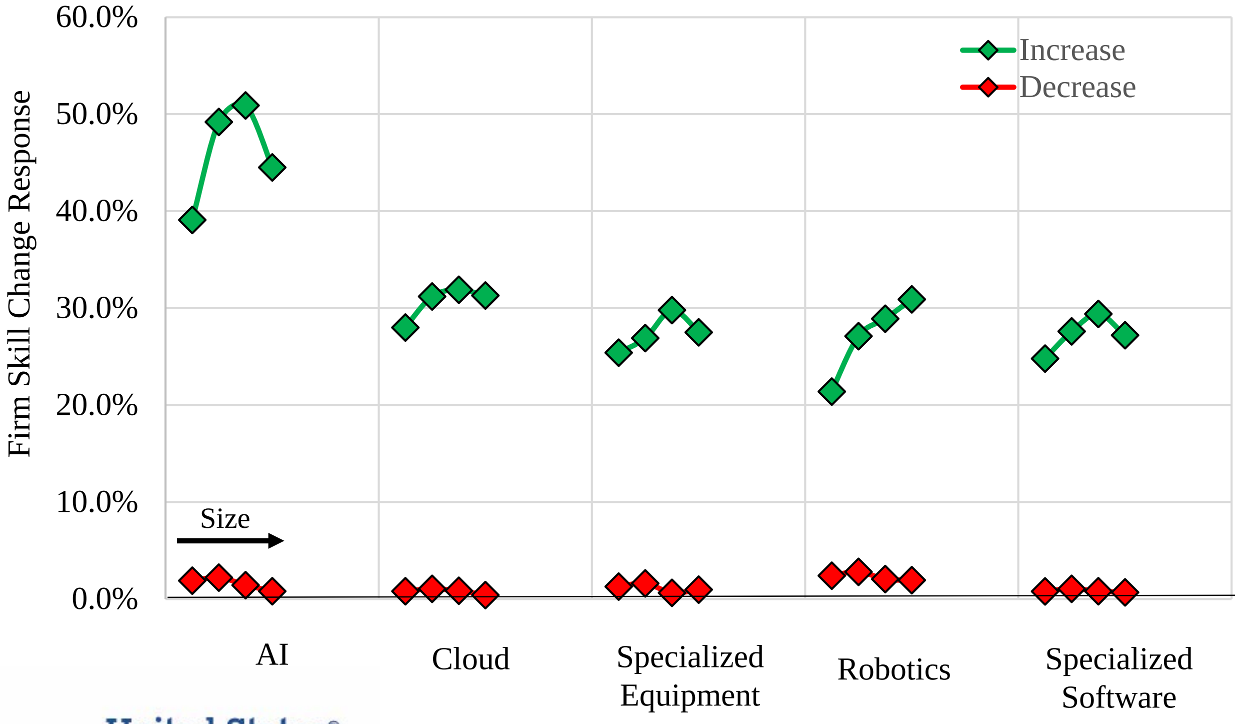
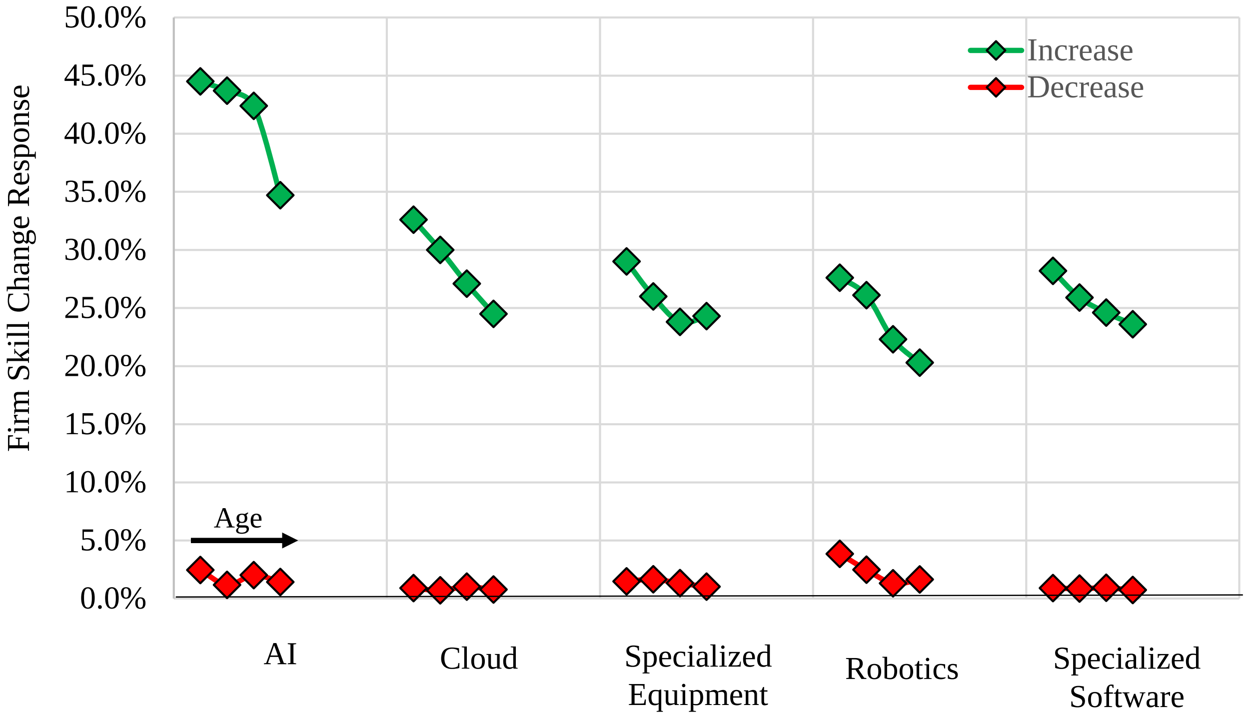
# Net Worker Type Change by Intensity of Adoption



# Skill Change by Size and Age

- Larger share of firms report some change to skill
- Size is positively associated with likelihood of reporting Skill increase
- Age is negatively associated with likelihood of reporting Skill increase
- More intense adoption is associated with higher reported Skill increase

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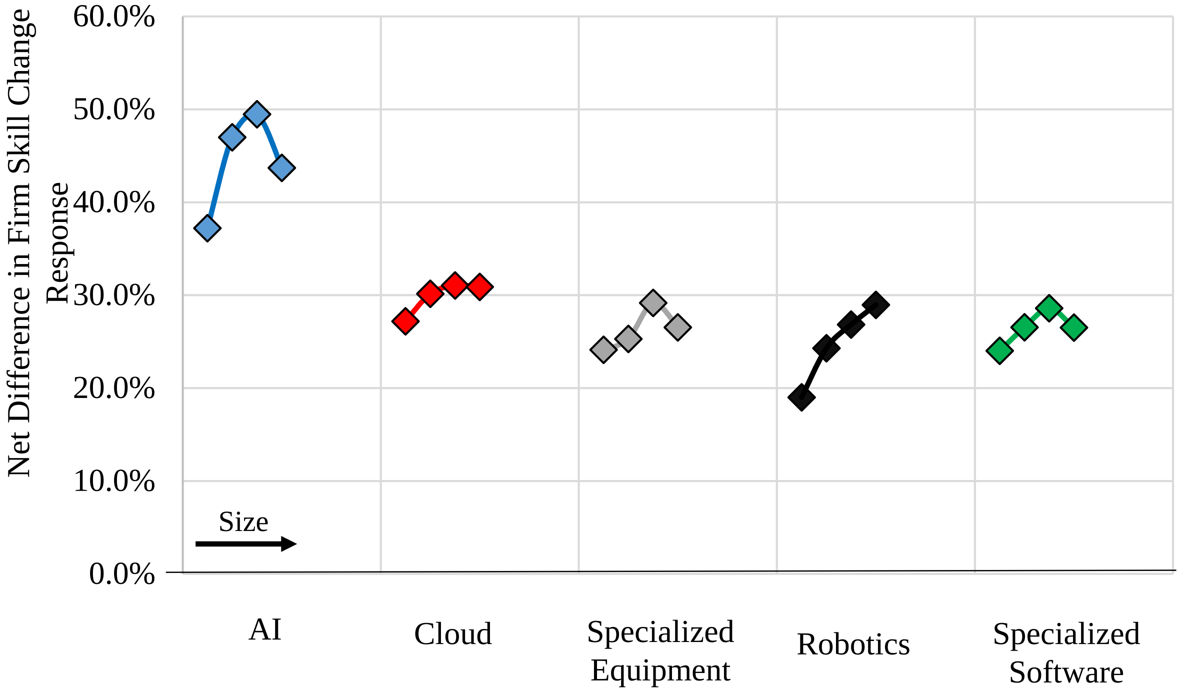
Note: Size categories include: 0-9, 10-49, 50-249 and 250+ employees

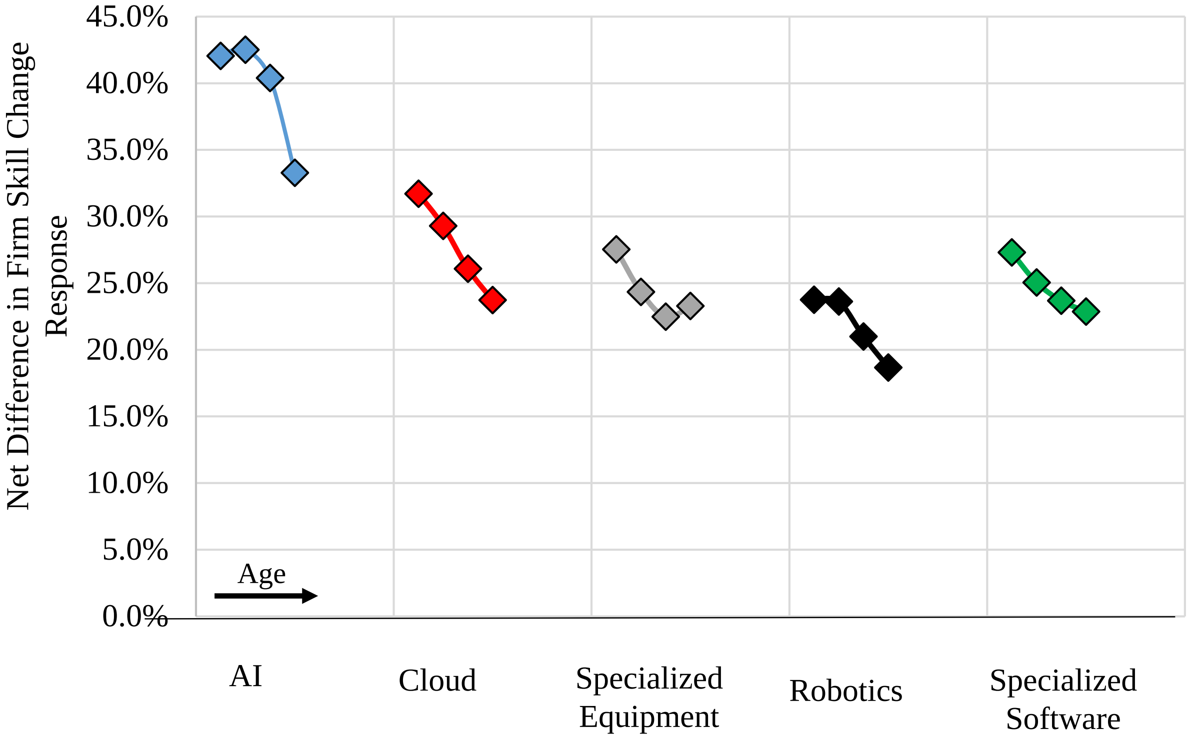
Note: Age categories include: 0-5, 6-10, 11-20 and 21+

# Net Skill Change by Size and Age

- Share of firms responding with increased skill increases slightly with size
- Share of firms responding with increased skill decreases with age




Note: Size categories include: 0-9, 10-49, 50-249 and 250+ employees




Note: Age categories include: 0-5, 6-10, 11-20 and 21+

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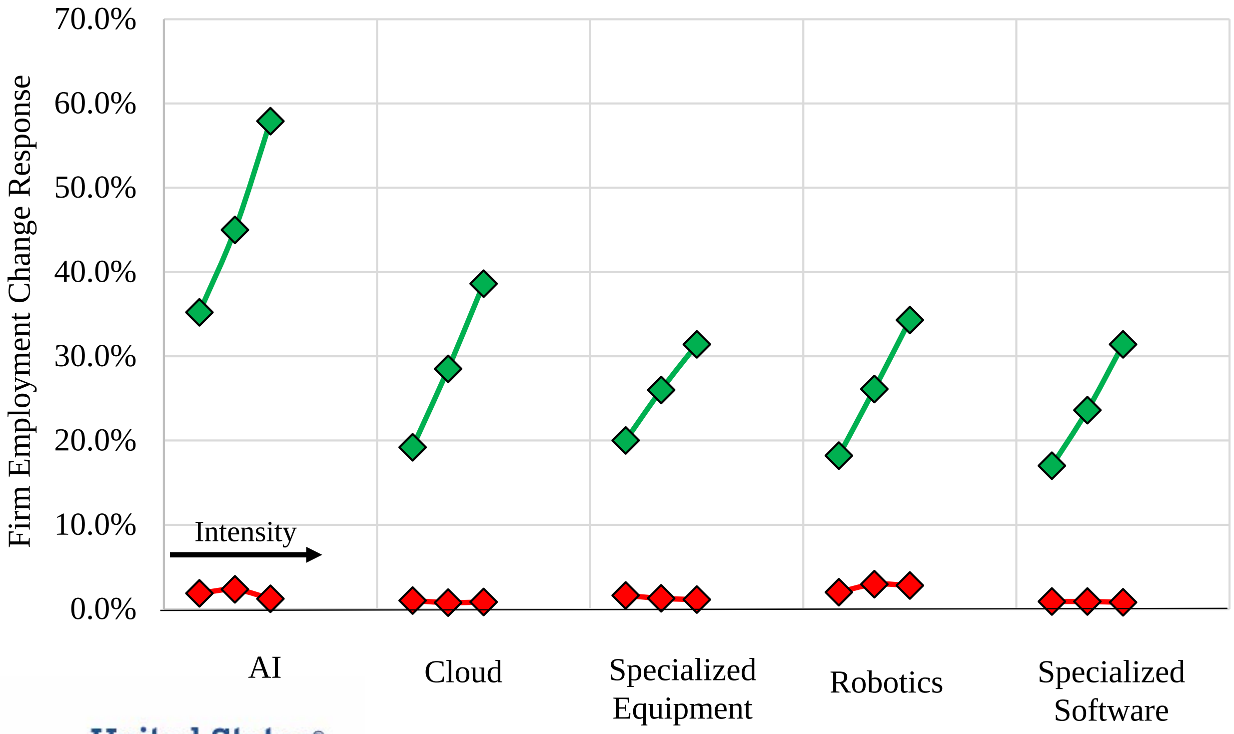
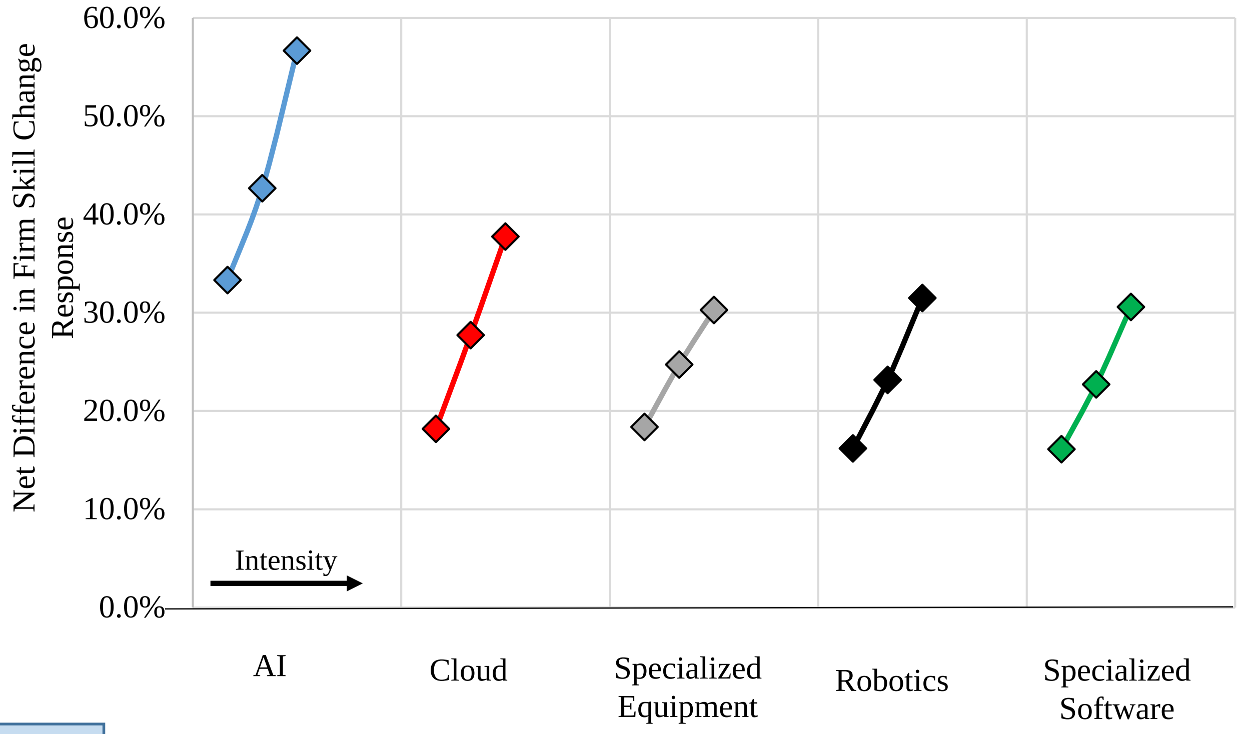
# Skill Change by Intensity of Adoption

- As intensity of adoption rises, higher share of firms respond with increasing Skill

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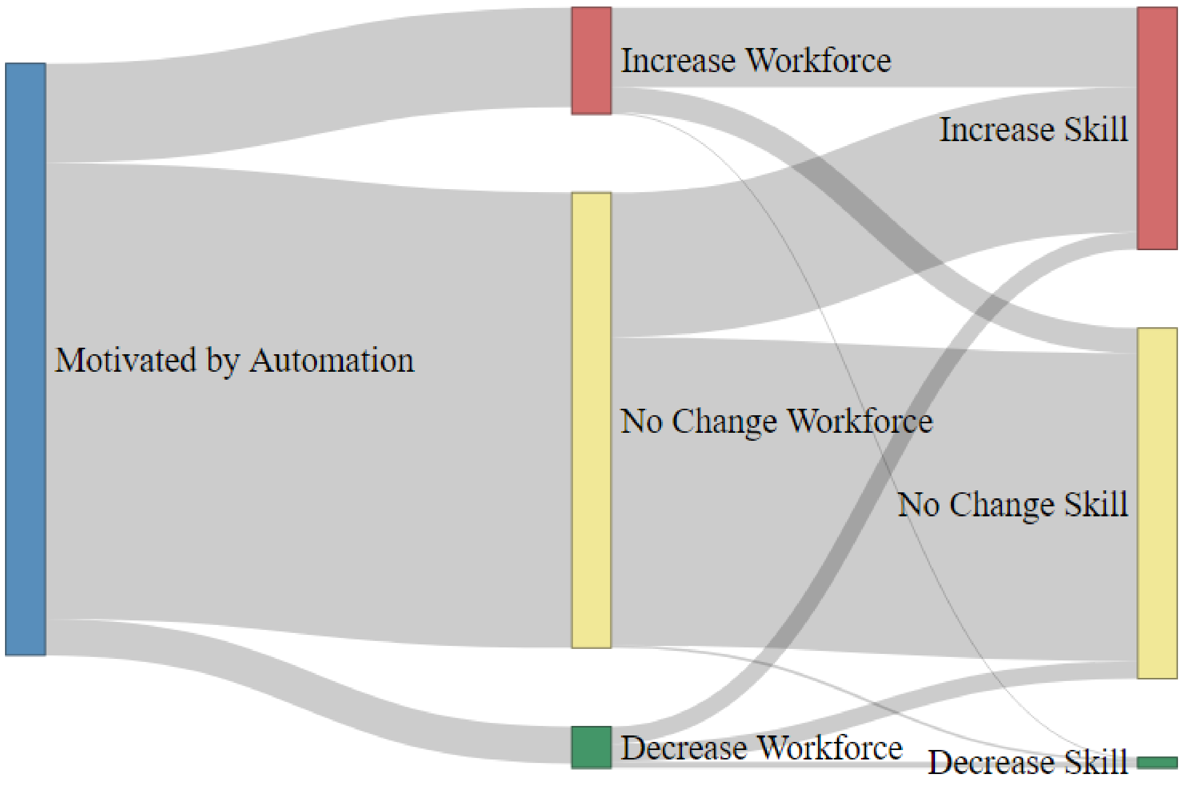
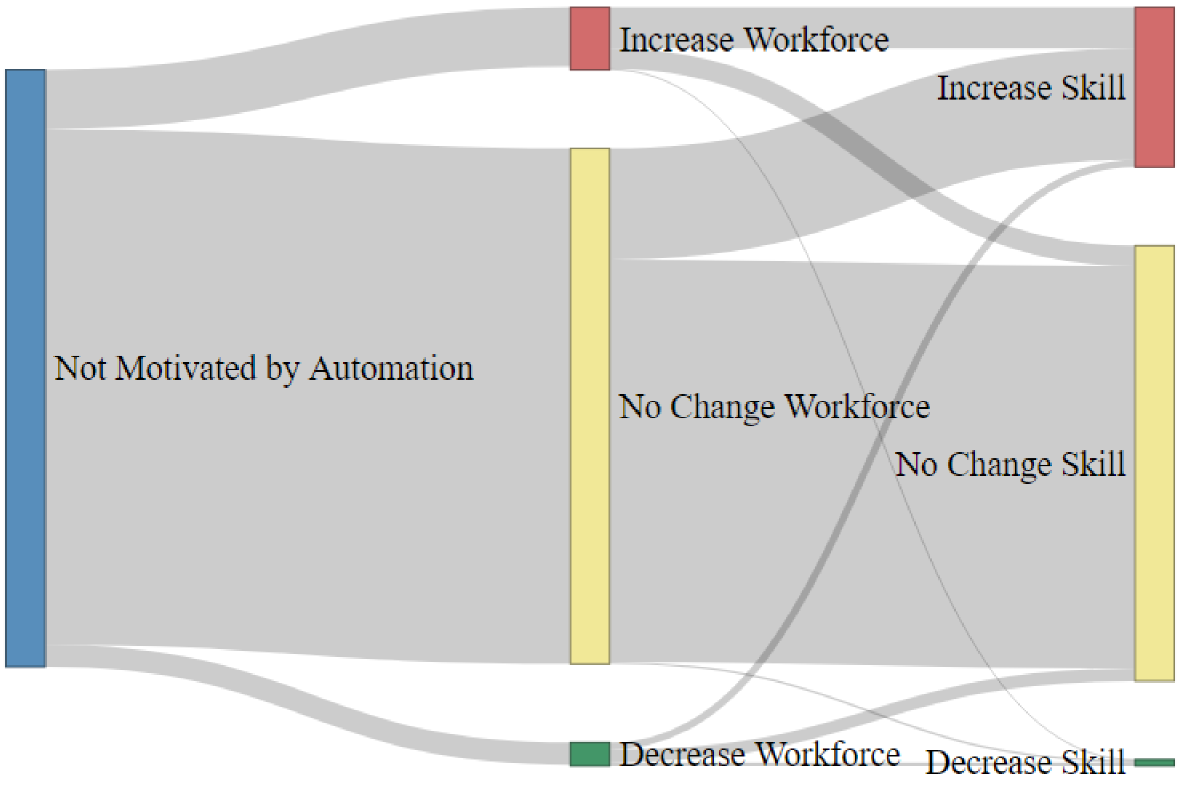
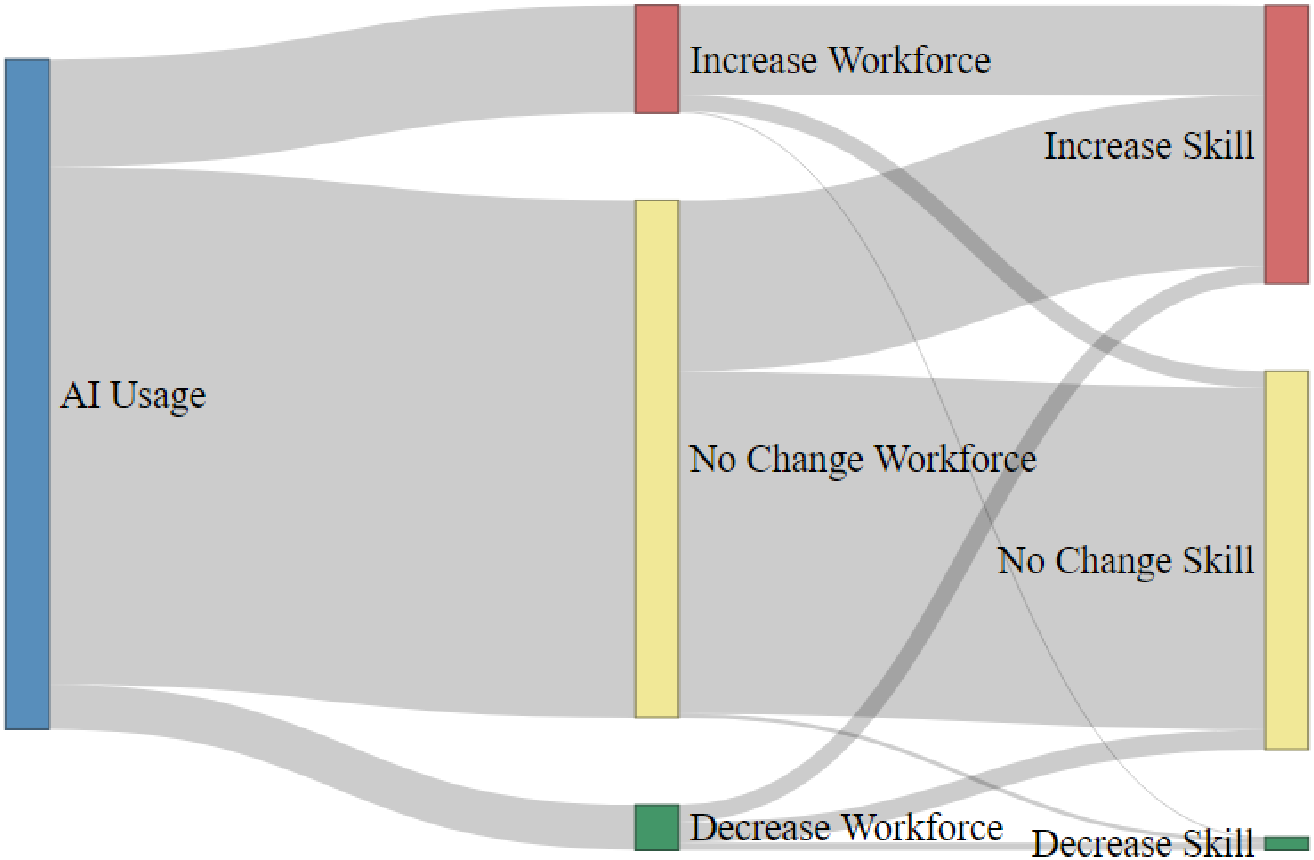
# Automation (Firm-weighted)

Similar patterns persist when weighted by firm: Firms motivated by Automation are more likely to report Increase Workforce and Increase Skill



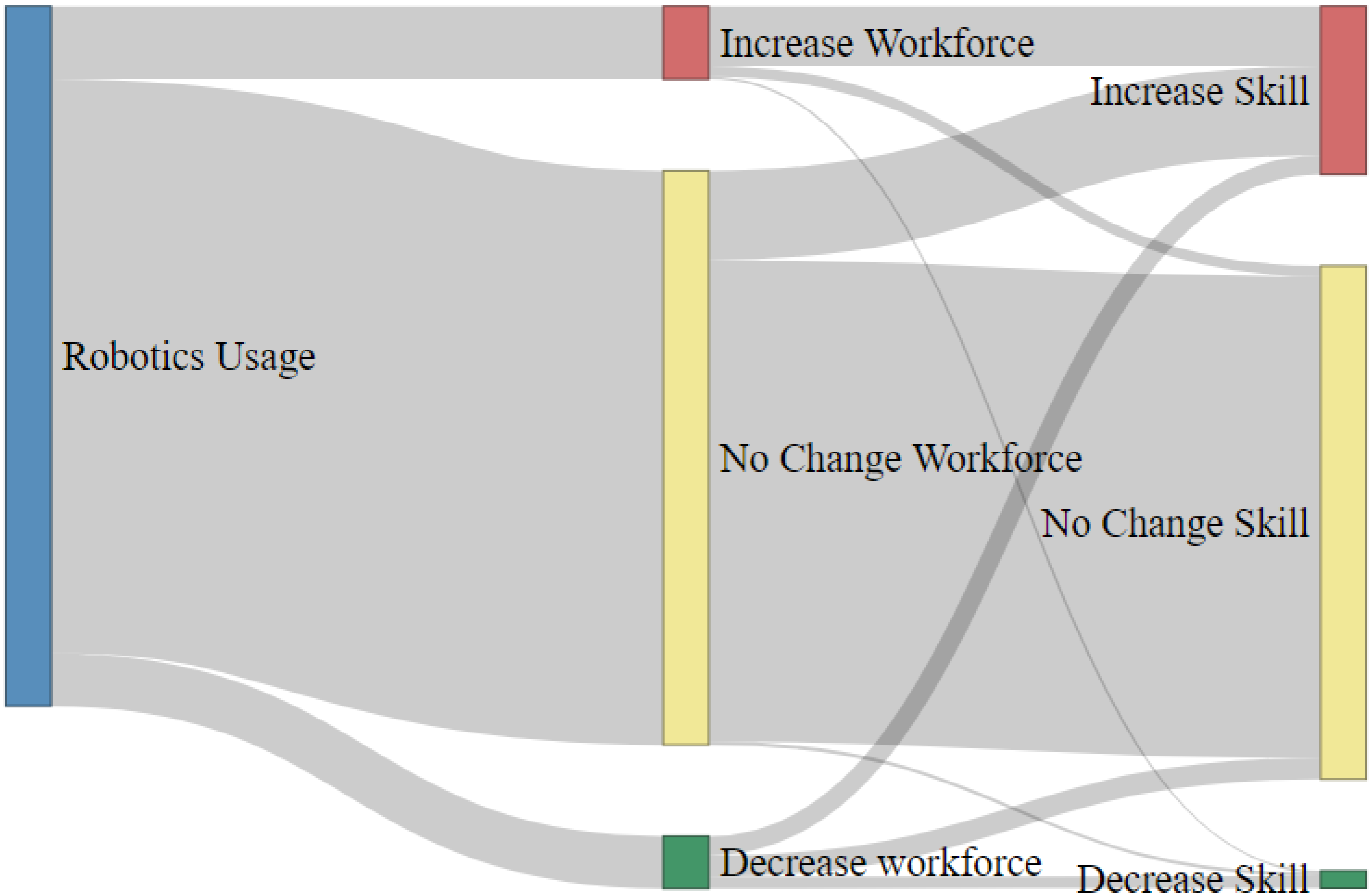



# AI Adoption on Employment and Skill Changes (Firm-weighted)




Adoption of AI has mostly led to No Change in Employment, but increase in Skill

# Robotics on Employment and Skill (Firm-weighted)

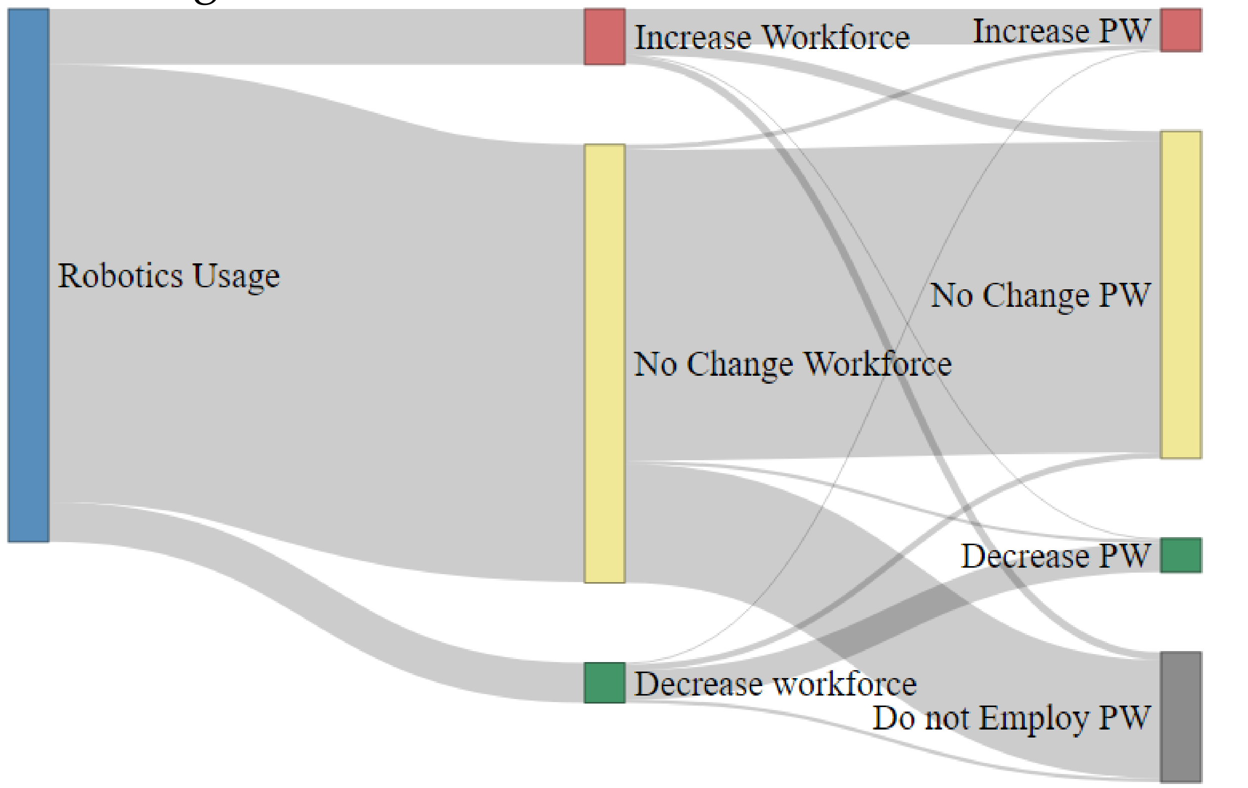



Robotics use is associated with little change in employment and not much change in Skill

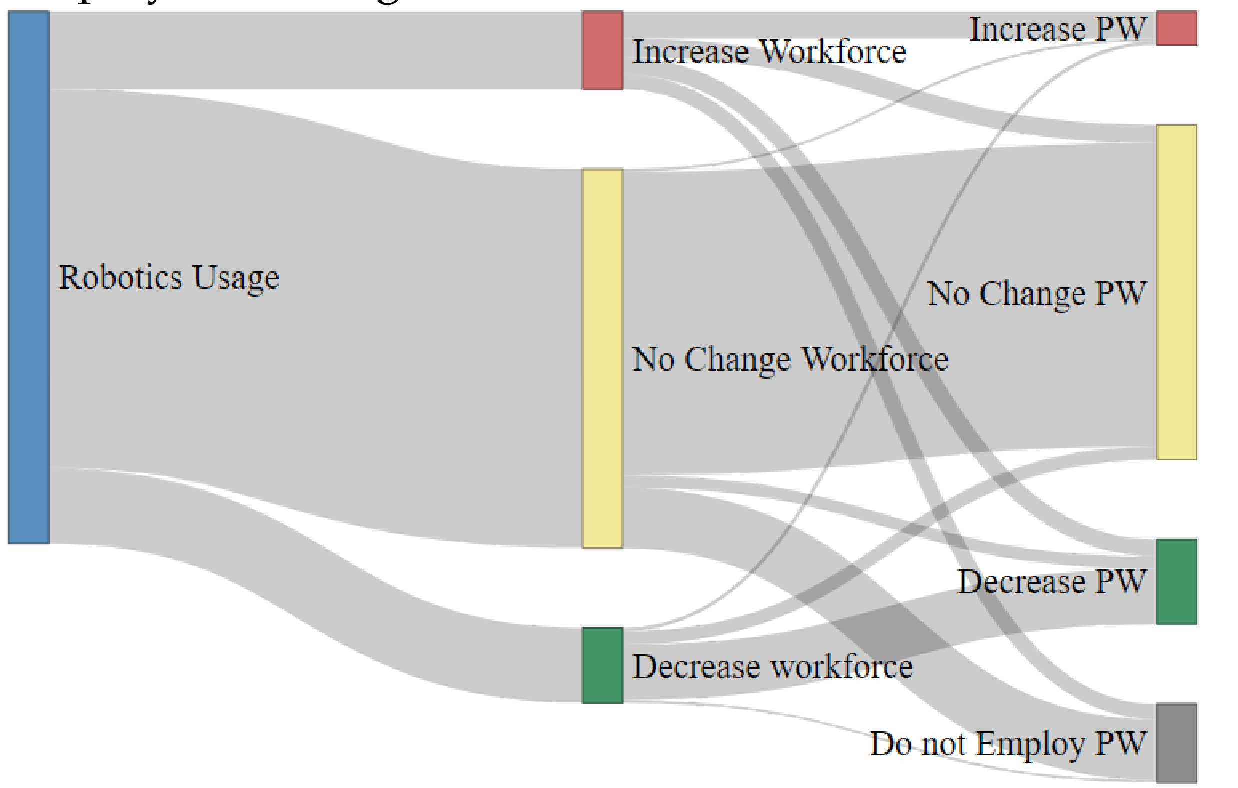
# Robotics and Employment and Production Workers

Employment-weighted Robotics employment change highlights how employment decreases are driven by reduction in production workers. Even firms that increase workforce, less than a majority also increase their PW

Firm-weighted




Employment-weighted

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# Challenges and Next Steps

- "N/A" response option used inappropriately
  - Response option reads "Not applicable, we did not employ [worker type]"
  - Firms respond "N/A" for both production and non-production workers (or both supervisory and non-supervisory workers)
  - Firms respond "N/A" for one technology but not the other
  - *Robustness*: Focus on manufacturing sector for analysis based on worker types
- Non-response
  - Many large, complex firms respond "Don't Know" or missing for all technologies
  - Individuals responding to survey commonly hold positions such as "financial analyst"
  - *Robustness 1*: Limited telephone follow-up for those with Census account managers
  - *Robustness 2*: Repeat analysis and focus on smaller, less complex firms
- Current weights unfit for longitudinal analysis
  - Much larger sample in Year 1 means longitudinally matched firms received larger weights in Year 2 than in Year 1 (particularly smaller firms)
  - *Solution*: Create our own weights for longitudinally matched sample based on 2017 and 2018 LBD

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# Challenges and Next Steps (Cont.)

- Causality
  - Assess how combination of firm characteristics (size, age, industry, productivity, payroll per employee, number of establishments, etc…) impact adoption rates
- Validation Exercises
  - Validate robotics usage with firm-level import data
  - Further validation with 2018 ABS