Firm Investments in Artificial Intelligence Technologies and Changes in Workforce Composition

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Motivation

- Explosion in Artificial Intelligence (AI) investments in recent years
  - Due to data accumulation, drop in computational costs, and methodological advances
  - Most AI investments are in machine learning (ML), computer vision (CV), and natural language processing (NLP)

- AI can potentially disrupt the labor market and transform workforce organization
  Agrawal, Gans, and Goldfarb (2019, 2021), Acemoglu and Restrepo (2019), Webb (2020)

- How do firm workforce composition and organization change in firms investing in AI?

AI Investments and Changes in Workforce Composition and Organization

- Regarding **workforce composition**, AI could
  - Facilitate skill-biased technological change like IT (e.g., Autor, Katz, and Krueger, 1998; Machin and Van Reenen, 1998)
  - Replace high-skilled labor performing prediction tasks (e.g., Webb, 2020)
- Regarding **workforce organization**, AI could
  - Increase organizational complexity and management positions as AI increases firm size (Babina, Fedyk, He, and Hodson, 2021)
  - Increase worker autonomy and decentralization due to improved prediction and decision-making (e.g., Garicano and Rossi-Hansberg, 2006)
- How AI changes workforce composition and firm organization is empirical question

This Paper

- Key challenges:
  - Hard to measure firm-level AI investments
  - Hard to measure firm labor composition and organization
- This paper:
  - Firm-worker matched data: detailed data on worker resumes covering US firms
  - Proxy for firm-level AI investments with hiring of AI-skilled workers (Babina et al 2021)
  - Measure workforce composition: educational attainment, specialization, and skills
  - Measure workforce organization: share of junior, mid-level, and senior workers

Preview of Findings

1. Firms' AI investments are associated with a **flattening** of firms' hierarchical structure
   - Share of workers at the junior level ↑
   - Share of workers in middle-management and senior roles ↓

2. Firms' AI investments are associated with an **upskilling** of firms' workforce
   - Share of workers with bachelor and post-secondary degrees ↑
   - Share of workers with STEM majors ↑
   - Higher demand for IT and analysis skills

Overall, adoption of AI technologies is associated with significant reorganization of firms' workforces

Contribution to the Literature

- Labor market effects of AI
  Felten, Raj, and Seamans (2018), Brynjolfsson, Mitchell, and Rock (2018), Agrawal, Gans, and Goldfarb (2019, 2021), Acemoglu and Restrepo (2019, 2021), Webb (2020), Acemoglu, Hazell, Restrepo (2021), Babina, Fedyk, He, and Hodson (2021), Grennan and Michaely (2021), Alderucci, Branstetter, Hovy, Runge, and Zolas (2021), and others

- Other technologies (e.g., IT) and firm organization and workforce composition
  Brynjolfsson and Hitt (1997), Caroli and Van Reenen (2001), Bresnahan, Brynjolfsson, and Hitt (2002), Dunne, Foster, Haltiwanger, and Troske (2004), Abowd, Haltiwanger, Lane, McKinney, and Sandusky (2007), Acemolgu, Aghion, Lelarge, Van Reenen, and Zilibotti (2007), Bloom, Garicano, Sadun, and Van Reenen (2014), Dixon, Hong, and Wu (2021), Bessen, Denk, and Meng (2022), and others

- Our paper: document the relationship between the use of AI technologies and the composition and organization of the workforce at the firm level

Data

- Firm-worker matched data: Cognism, aggregator of online resumes
  - 535 million resumes; global coverage
  - Job histories, skills, education (education level and major), publications, patents, awards, references, hierarchical level
- Job postings: Burning Glass Technologies
  - 180 million US job postings
  - Comprehensive coverage of online job openings in 2007 and 2010–2018
  - Detailed taxonomy of required skills, required education and experience

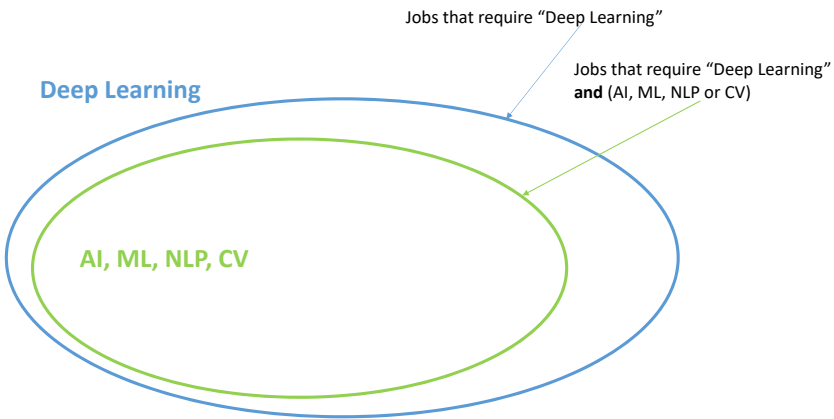
Measuring AI-skilled Human Capital

- AI = algorithms that learn (make predictions) from data
  - Main areas of commercial interest: machine learning, computer vision, natural language processing \item Commercial applications picked up around 2012
- AI versus previous automation technologies:
  - Tech such as robotics automated low-skill, manual, repetitive tasks
  - AI automates high-skilled tasks such as prediction, detection, classification
- AI versus other data analysis methods:
  - Modeling complex, non-linear relationships
  - Processing larger datasets, unstructured data (visual, language)
- Key inputs into AI: data, computing power, **human capital** to implement AI algorithms
- Use measure of firms' AI investments based on AI-skilled human capital from Babina, Fedyk, He, and Hodson (2021)

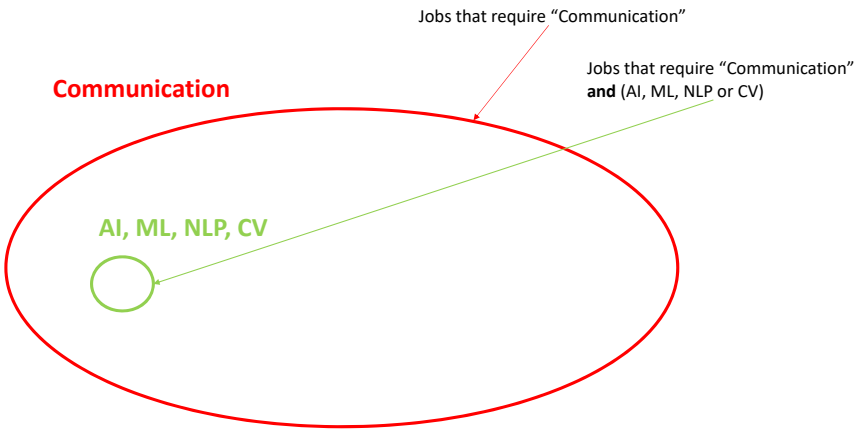
Measuring AI-skilled Human Capital

- Step 1: Identify relevant skills from Burning Glass job postings
  - Main idea: if a skill is related to AI, then jobs requiring that skill should also require some of the core AI skills
  - Four core AI skills: Artificial Intelligence, Machine Learning, Natural Language Processing, Computer Vision
  - AI-relatedness score of skill s =
    % of jobs requiring skill s that also require at least one core AI skill
  - Skills with score>0.7 are highly related to AI: Tensorflow (0.90), Unsupervised Learning (0.89), Deep Learning (0.86)

Some Skills **Have High Overlap** with AI-specific Skills



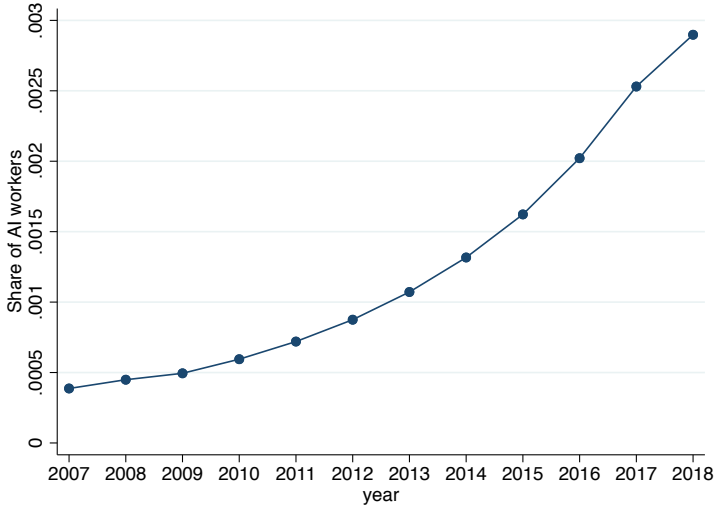
Some Skills **Do Not Have High Overlap** with AI-specific Skills



Measuring AI-skilled Human Capital

- Step 2: Identify AI jobs in Cognism online resumes
  - A job in a resume is AI-skilled if it contains a highly related AI skill (score>0.7 in job postings data) in resume (job title, job description, publications, patents)
  - Examples:
    - Job title: “Senior Machine Learning Developer”
    - Job description: “develop Chatbots using Python with Scikit Learn, Tensorflow and Deep Learning models...”
    - Publications: “A New Cluster-Aware Regularization of Neural Networks”
    - Patents: “Systems and methods for prime design using Machine Learning”
- Step 3: At firm-year level, calculate share of workers who are AI-skilled

Explosion in Artificial Intelligence (AI) Investments over Past 10 Years



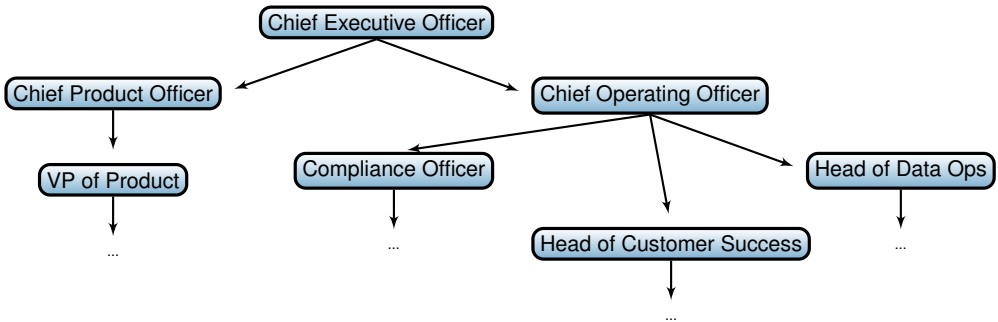
Babina, Fedyk, He, and Hodson (2021)

Cognism Resume Data: Strengths

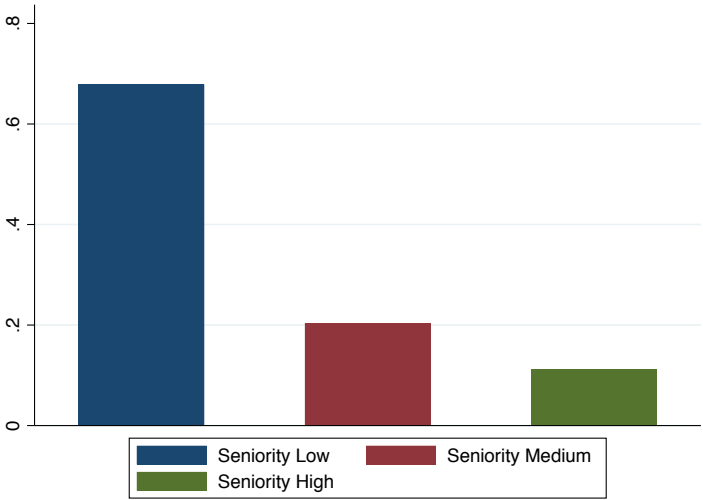
1. Resume data provides good coverage
   1.1 US resumes cover 64% of 2018 employees
2. Resume data captures actual hiring, not just demand
   2.1 Babina, Fedyk, He, and Hodson (2021) find similar results of AI on firm growth and product innovation using job posting data, validating use of job postings for AI
3. Independent variable: AI Investments
   3.1 Resume data captures AI-skilled labor onboarded via acquisitions
   3.2 Able to incorporate external AI software into internal AI-investments
4. Dependent variables: Workforce composition and organization
   4.1 Able to measure workforce organization, educational level, skills, etc.

Workforce Organization: Hierarchical Levels in Worker Resumes

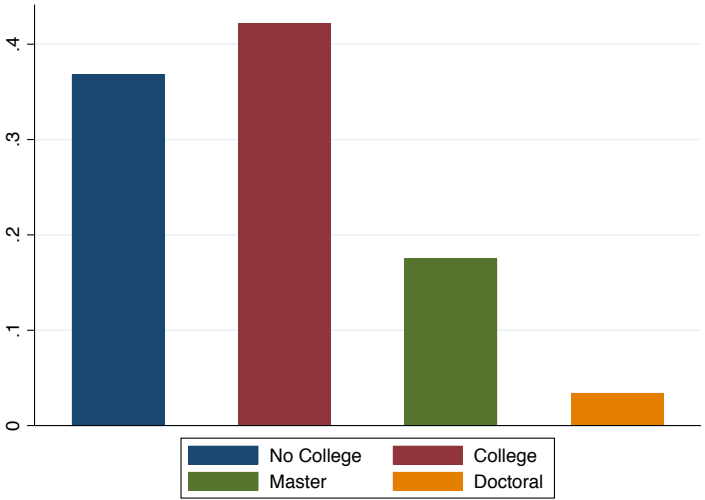
- Over 20,000 individual job titles are classified manually, and the remaining job titles are classified into seniority levels using machine learning and graph theory
- Seniority levels are grouped into three levels: **low** (entry level and staff), **medium** (team leads and middle management), and **high** (executives and department heads)



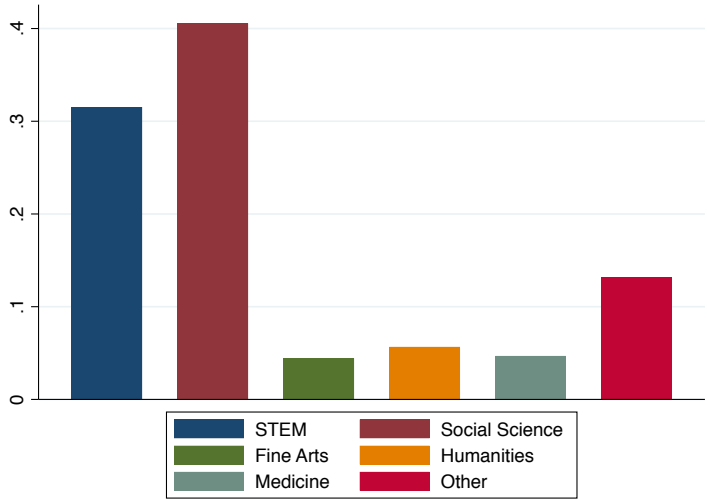
Hierarchical Levels in Worker Resumes



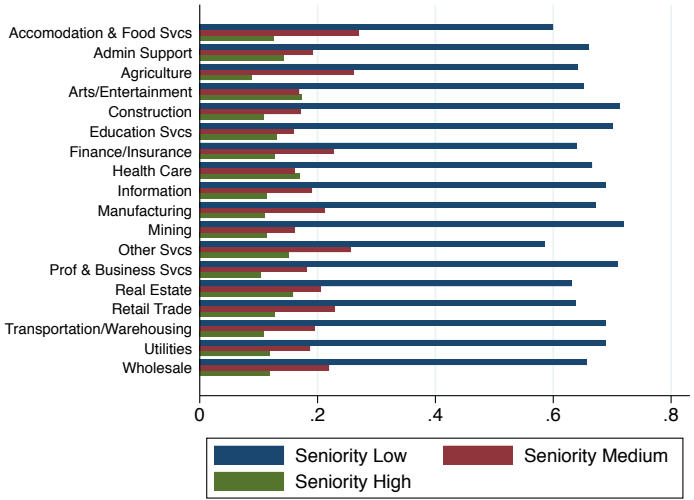
Education Levels in Worker Resumes



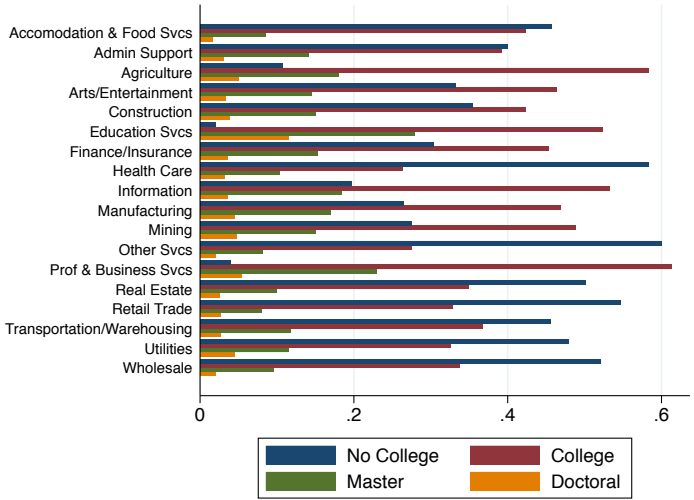
Majors (of the Most Recent Degree) in Worker Resumes



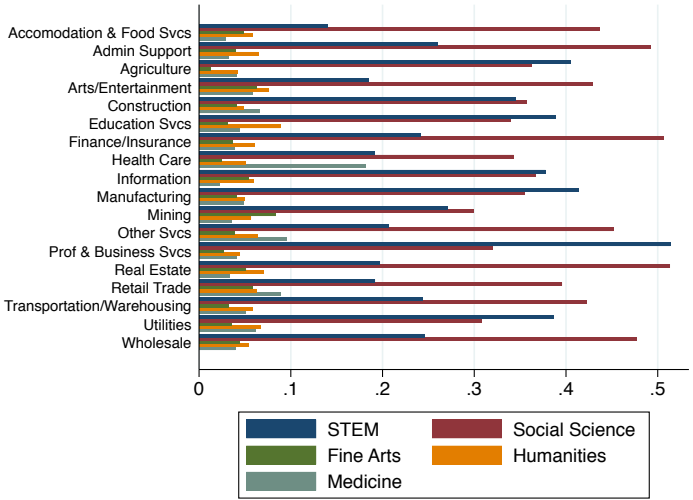
Distribution of Hierarchical Levels by Industry Sector



Distribution of Workers' Education Levels by Industry Sector



Distribution of Workers' Majors by Industry Sector



Firms' AI Investments and Changes in Workforce Composition and Organization

- Long-differences regression at firm-level:

$$\Delta Y_i^{2010-2018} = \beta \Delta ShareAIWorkers_i^{2010-2018} + \gamma X_i^{2010} + IndustryFE + \varepsilon_i$$

  - $\Delta ShareAIWorkers_i^{2010-2018}$ measures AI investments
  - Control for: industry fixed effects, firm-level and commuting-zone-level controls in 2010

Firms' AI Investments and Changes in Firm Organization

	Δ Share Seniority Low		Δ Share Seniority Middle		Δ Share Seniority High	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Share AI Workers	0.015***	0.016***	-0.007***	-0.008***	-0.007**	-0.008**
	(0.004)	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)
Industry Sector FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y
Adj R-Squared	0.175	0.335	0.170	0.233	0.170	0.314
Observations	1,218	1,218	1,218	1,218	1,218	1,218

Consistent with AI increasing worker autonomy and leading to more decentralization

Firms' AI Investments and Changes in Worker Education Levels

	Δ Share College		Δ Share Master		Δ Share Doctoral		Δ Share No College	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Share AI Workers	0.033***	0.037***	0.027***	0.029***	0.007***	0.006***	-0.068***	-0.073***
	(0.012)	(0.010)	(0.004)	(0.004)	(0.001)	(0.001)	(0.014)	(0.014)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.099	0.198	0.107	0.217	0.155	0.210	0.115	0.214
Observations	1,218	1,218	1,218	1,218	1,218	1,218	1,218	1,218

We find similar results using required education level in job postings: a one-standard-deviation increase in the share of AI workers is associated with a 0.5 additional year of required education in new job openings

Firms' AI Investments and Changes in Worker Majors

	Δ Share STEM		Δ Share Social Science		Δ Share Fine Arts		Δ Share Humanities		Δ Share Medicine	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δ Share AI Workers	0.030***	0.029***	-0.011***	-0.007**	-0.003	-0.002	0.001	0.000	-0.002**	-0.003**
	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.179	0.225	0.111	0.186	0.140	0.192	0.219	0.242	0.161	0.217
Observations	1,216	1,216	1,216	1,216	1,216	1,216	1,216	1,216	1,216	1,216

Firms' AI Investments and Changes in Required Skills

- Use Burning Glass job postings data: Groups all skills into one of 28 skill clusters
  - For example, the skill "Python" belongs to the "Information Technology" skill cluster, and the skill "Machine Learning" belongs to the "Analysis" skill cluster
- Steps to calculate required skills at firm-year level
  - Calculate the share of required skills that fall within each skill cluster for each job posting
  - Average these shares across all job postings of a given firm to get a weighted share of job postings requiring skills in each skill cluster
- Main findings: Firms that invest more in AI
  - Increase in IT and analysis skills
  - Decrease in finance, supply chain, and maintenance skills
  - No changes in HR or legal skills!

Firms' AI Investments and Changes in Required Skills

	Δ Share of Jobs w/ Administration Skill		Δ Share of Jobs w/ Analysis Skill		Δ Share of Jobs w/ Business Skill		Δ Share of Jobs w/ Customer Service Skill		Δ Share of Jobs w/ Engineering Skill		Δ Share of Jobs w/ Finance Skill		Δ Share of Jobs w/ Healthcare Skill	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Δ Share AI Workers	-0.001	-0.000	0.005***	0.004***	0.001	-0.003	-0.006	0.004	-0.000	-0.002	-0.007	-0.011**	-0.003	-0.002
	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.004)	(0.005)	(0.006)	(0.002)	(0.002)	(0.005)	(0.005)	(0.003)	(0.004)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.062	0.094	0.264	0.306	0.094	0.146	0.222	0.349	0.038	0.123	0.059	0.178	0.046	0.100
Observations	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099

	Δ Share of Jobs w/ HR Skill		Δ Share of Jobs w/ IT Skill		Δ Share of Jobs w/ Legal Skill		Δ Share of Jobs w/ Marketing Skill		Δ Share of Jobs w/ Sales Skill		Δ Share of Jobs w/ Science Skill		Δ Share of Jobs w/ Supply Chain Skill	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Δ Share AI Workers	0.001	-0.000	0.016**	0.012*	-0.001	-0.000	0.003*	0.001	0.004	0.008	-0.000	-0.001	-0.006***	-0.002
	(0.001)	(0.002)	(0.007)	(0.007)	(0.001)	(0.001)	(0.002)	(0.003)	(0.005)	(0.006)	(0.001)	(0.001)	(0.002)	(0.003)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.057	0.105	0.227	0.271	0.034	0.119	0.016	0.066	0.332	0.386	0.107	0.141	0.069	0.145
Observations	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099

Increase in IT and analysis skills, decrease in finance, supply chain, and maintenance skills

Firms' AI Investments and Changes in Required Skills

	Δ Share of Jobs w/ Agriculture Skill		Δ Share of Jobs w/ Construction Skill		Δ Share of Jobs w/ Design Skill		Δ Share of Jobs w/ Economics Skill		Δ Share of Jobs w/ Education Skill		Δ Share of Jobs w/ Utilities Skill		Δ Share of Jobs w/ Environment Skill	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Δ Share AI Workers	-0.000	-0.000*	-0.001	-0.000	-0.001	-0.002	0.000	0.000	-0.001	-0.002*	-0.001	-0.000	0.001	0.001
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.074	0.107	0.055	0.083	0.169	0.352	0.081	0.176	0.068	0.103	0.023	0.081	0.181	0.192
Observations	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099

	Δ Share of Jobs w/ Industry Knowledge Skill		Δ Share of Jobs w/ Maintenance Skill		Δ Share of Jobs w/ Manufacturing Skill		Δ Share of Jobs w/ Media Skill		Δ Share of Jobs w/ Personal Care Skill		Δ Share of Jobs w/ Public Safety Skill	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Δ Share AI Workers	-0.001	0.002	-0.007***	-0.006***	-0.002*	-0.002	0.001	0.001*	0.001	-0.000	-0.000	0.000
	(0.003)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.000)	(0.001)
Industry Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Adj R-Squared	0.117	0.166	0.121	0.168	-0.002	0.028	0.099	0.108	0.161	0.239	0.154	0.248
Observations	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099	1,099

Increase in IT and analysis skills, decrease in finance, supply chain, and maintenance skills

Firms' AI Investments and Changes in Workforce Composition

- Babina, Fedyk, He, and Hodson (2021) document that AI increases firm-level employment
  - This paper shows that the additional workers are mostly **high-skilled** and **technical**
- This is consistent with the **product innovation** channel driving AI-driven firm growth documented in Babina, Fedyk, He, and Hodson (2021)
  - Product innovation can require complementary investments and more educated workforces

Conclusion

- Use a novel resume dataset to measure: Firm-level AI technology use and **workforce composition** and **organization for a large sample of firms**
- Main Contribution: **Firms' AI investments** are associated with **flattening** of **firm's hierarchical structure** and **upskilling** of firm workforce