Artificial Intelligence, Firm Growth, and Industry Concentration

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Motivation

- Explosion in Artificial Intelligence (AI) investment in recent years
  - From $7.6 billion in 2010 to $48 billion in 2018 in the US + $24 billion targeted by EU, $150 billion by China
- How does AI affect firms and industries?
  - Huge potential to transform production, yet sluggish productivity growth recently

Motivation

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- How does AI affect firms and industries?
  - Huge potential to transform production, yet sluggish productivity growth recently
- Potential channels:
  - Productivity growth (Brynjolfsson, Hitt, Kim 2011; Tanaka, Bloom, David, Koga 2019)
  - Monopoly power (Varian 2018; Mihet and Philippon 2019)
  - Economies of scale (Autor, Dorn, Katz, Patterson, Van Reenen, 2020; Aghion, Bergeaud, Boppart, Klenow, Li 2019; Farboodi, Mihet, Philippon, Veldkamp 2019)

This paper

- Goals:
  - Which firms invest in AI?
  - How do AI investments affect firm growth?
  - Which firms benefit most, and how does AI affect industry concentration?

- Our approach:
  - **Data:** detailed, firm-level information on demand for AI talent (job postings) + hiring of AI talent (resumes) of US public firms
  - **Measure:** data-driven measure of AI-relatedness of each skill and job, without pre-specifying AI-related words
  - **Identification:** instrument AI investments with:
    a) industry-level AI investments in Europe
    b) shift-share instrument relying in differences in local exposure to AI

Preview of findings

1. Rapid growth in AI technologies across a wide range of industries
2. Large firms are more likely to invest in AI
3. Firm-level: AI increases sales, employment, market share
   - No effect on productivity or markups
   - Growth is concentrated in ex-ante largest and most productive firms
4. Industry-level: AI increases aggregate sales, employment and industry concentration

Overall, AI leads to the expansion of ex-ante most efficient firms and contributes to the rise of “superstar” firms

Data

- Job postings: Burning Glass Technologies
  - 180 million job postings, comprehensive coverage of online job openings in 2007 and 2010–2018
  - Detailed taxonomy of required skills
- Employment profiles (resumes): Cognism, aggregator of public profile information
  - 145 million full profiles; global coverage
  - Job histories, skills, education, publications, patents, awards, references
  - Captures actual hiring, not just demand

Measuring AI

- Identify relevant skills: Burning Glass
  - 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

Highly related (score>0.7) (N=68)	**Less related (0.05<score<0.7)** (N=533)	**Not related (score<0.05)** (N=13,577)
Tensorflow (0.90)	Information retrieval (0.37)	Communication skills (0.003)
Unsupervised learning (0.89)	Logistic regression (0.26)	Microsoft Office (0.001)
Deep learning (0.86)	Speech recognition (0.22)	Lawn mowing (0.000)
Random forests (0.84)	Python (0.12)	

Measuring AI

Burning Glass job postings

A job posting is AI-related if average score of all required skills > 0.1

Example:
Required skills: Machine learning (1), Text mining (0.63), MapReduce (0.29), Apache Hadoop (0.21), Data mining (0.16), Software engineering (0.04), Research (0.01), Communication skills (0.00)
Average score: **0.29**

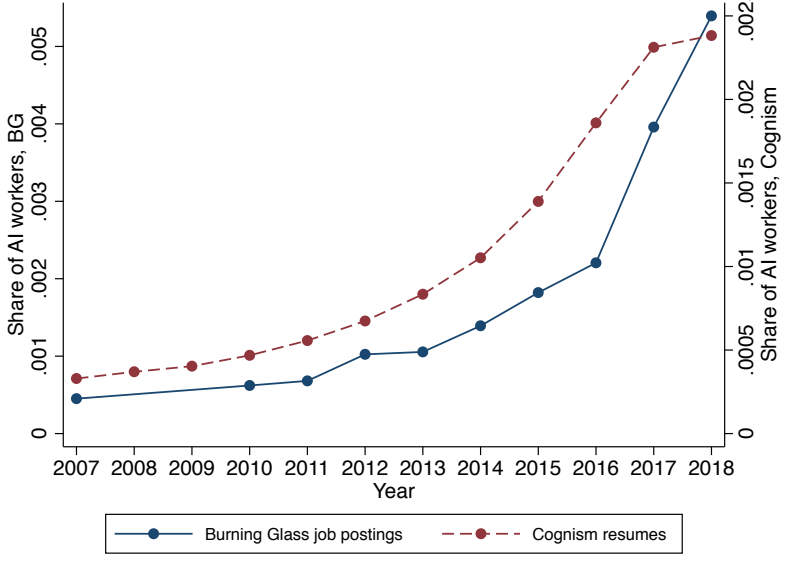
Cognism online resumes

A job in a resume is AI-related if it contains a highly related skill (score$>$0.7) in profile

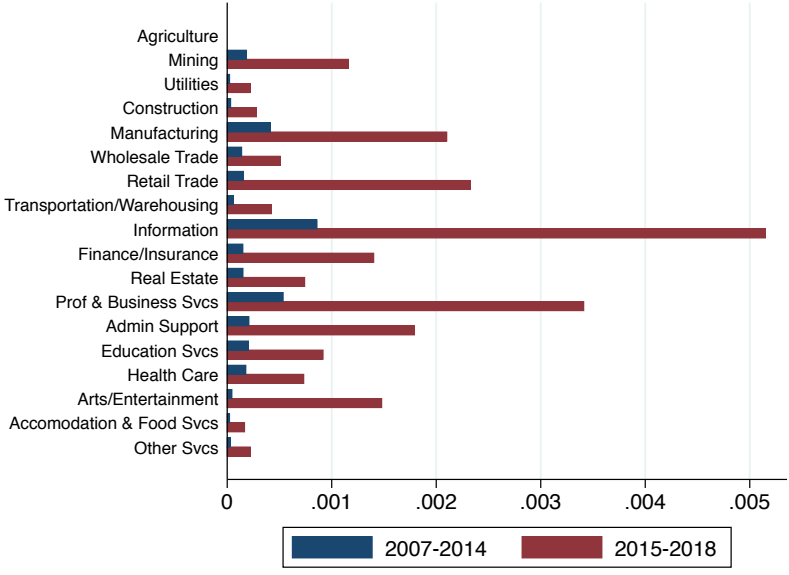
Examples:
Job title: "Senior Machine Learning Developer"
Job description: "develop Chatbots using Python with scikit learn, tensorflow and deep learning models..."
Publications: "A New Cluster-Aware Regularization of Neural Networks"
Patents: "Systems and methods for prime design using machine learning"

- Match employers to Compustat and calculate % of AI jobs at firm level
- AI measures from two datasets highly correlated (65%) and yield consistent results

Fast Growth in Share of AI Workers in the Last Decade



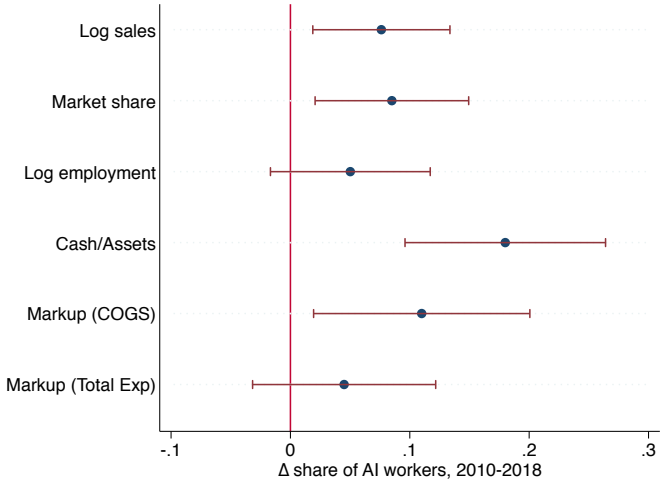
More AI Workers in All Sectors



Which Firms Adopt AI?

- Predict change in AI share from 2010–2018 based on 2010 firm characteristics:

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



Effect of AI on Firm Growth

- Long-differences regression:

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

- Two IV strategies to identify causal effect of AI
- Instrument #1: industry-level AI growth in Europe (Autor, Dorn, Hanson 2013; Acemoglu and Restrepo 2020)
  - Build 5-digit-NAICS-level AI measure from granular European firm-level data
  - Identifying assumption: AI growth in US and Europe driven by similar technological factors that vary across industries
  - First stage F-statistics between 22 and 38
- Instrument #2: Bartik IV based on firms' differences in local exposure to AI

Effect of AI on Firm Growth, 2010–2018

- OLS results:

	Δ Log Sales		Δ Log Employment		Δ Market Share	
Δ Share AI Workers	0.106**	0.146***	0.114*	0.133**	0.012	0.013
	(0.052)	(0.045)	(0.064)	(0.053)	(0.012)	(0.009)
Ind FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y

- IV results (Foreign-industry IV):

	Δ Log Sales		Δ Log Employment		Δ Market Share	
Δ Share AI Workers	0.173	0.274**	0.217	0.327*	0.024**	0.053**
	(0.185)	(0.123)	(0.177)	(0.173)	(0.011)	(0.026)
Ind FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y

AI Investments Associated with Expansion at Industry Level

- OLS results:

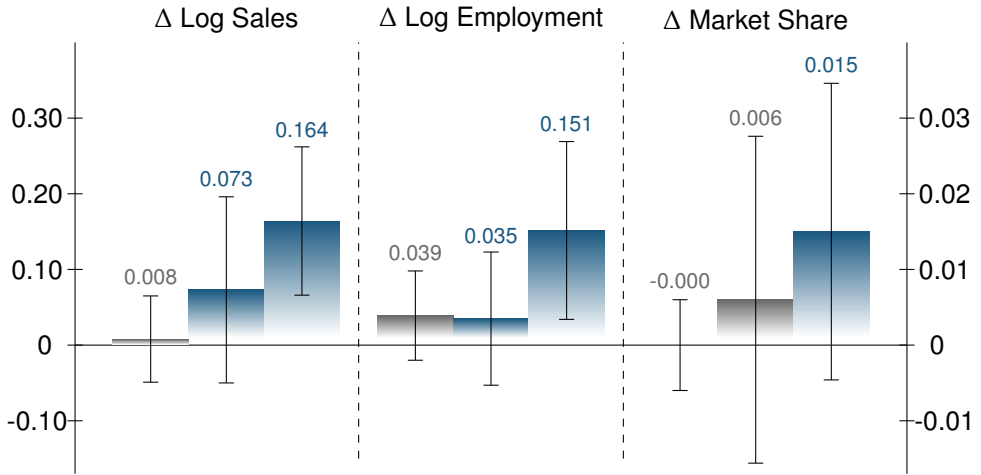
	Δ Log Sales		Δ Log Employment	
Δ Share AI Workers	0.125***	0.151***	0.130**	0.158***
	(0.039)	(0.029)	(0.063)	(0.056)
Sector FE	Y	Y	Y	Y
Controls	N	Y	N	Y

- IV results (Foreign-industry IV):

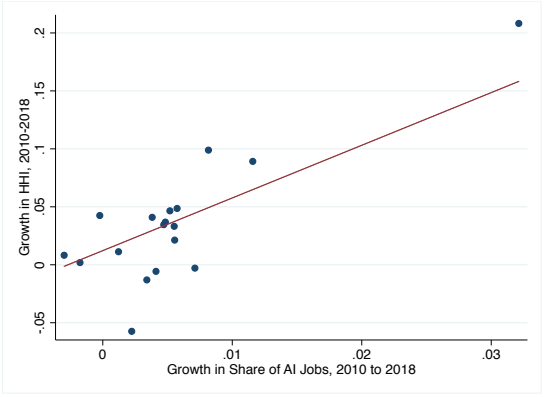
	Δ Log Sales		Δ Log Employment	
Δ Share AI Workers	0.210***	0.248***	0.177*	0.218***
	(0.047)	(0.038)	(0.106)	(0.074)
Sector FE	Y	Y	Y	Y
Controls	N	Y	N	Y

Growth is Concentrated in Big Firms

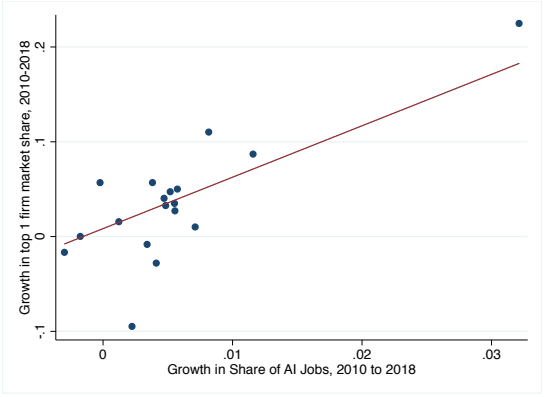
Subsamples: firms ranked (terciles) based on employment as of 2010



AI Investments Associated with Increased Industry Concentration



(a) HHI



(b) Top Firm Market Share

Mechanisms

Mechanisms

1. Productivity growth

	Δ Log Sales Per Worker		Δ Revenue TFP	
Δ Share AI Workers	-0.028	-0.006	-0.015	0.004
	(0.038)	(0.035)	(0.033)	(0.035)
Ind FE	Y	Y	Y	Y
Controls	N	Y	N	Y

Mechanisms

1. Productivity growth

	Δ Log Sales Per Worker		Δ Revenue TFP	
Δ Share AI Workers	-0.028	-0.006	-0.015	0.004
	(0.038)	(0.035)	(0.033)	(0.035)
Ind FE	Y	Y	Y	Y
Controls	N	Y	N	Y

2. Market power

	Δ Log Markup (COGS)		Δ Log Markup (Total Exp)		Δ Lerner Index	
Δ Share AI Workers	0.001	0.031	-0.001	0.010	-0.005	0.004
	(0.016)	(0.028)	(0.006)	(0.011)	(0.003)	(0.006)
Ind FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y

Mechanisms

3. Economies of scale: AI allows ex-ante large and efficient firms to expand

- AI and big data can induce economies of scale and reinforce winner-take-all effects (Farboodi, Mihet, Philippon, Veldkamp 2019)
- Aghion, Bergeaud, Boppart, Klenow, Li (2019): falling costs of spanning multiple markets due to IT $\Rightarrow$ most efficient firms expand into new markets

	Δ Log # of Counties		Δ Log # of Product Managers	
Δ Share AI Workers	0.067***	0.078***	0.165***	0.134***
	(0.020)	(0.024)	(0.046)	(0.067)
Ind FE	Y	Y	Y	Y
Controls	N	Y	N	Y

Conclusion

- AI leads to higher firm growth
  - AI allows firms to grow even larger, capturing more market share
  - No significant impact on productivity and markups
- Industry-level shift towards ex-ante larger firms
  - The impact of AI is most pronounced among the largest, most productive firms
  - AI investments are associated with higher industry concentration
- Our results highlight the role of technology in shaping industry concentration and superstar firms