

## Artificial Intelligence and Firms' Systematic Risk

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# Overview

- Explosion in Artificial Intelligence (AI) investment over the past decade
  - ▶ Due to data accumulation, plunging computational costs, and methodological advances
  - ▶ AI: Machine learning (ML), computer vision (CV), natural language processing (NLP)
- *Firm-level effects*: AI investments have improved firm performance and growth
  - ▶ Returns: Positive market value effects and alpha to AI-investing firms (Rock, 2023; Babina, Fedyk, He, Hodson, 2024; Eisfeldt, Schubert, Zhang, 2024)
  - ▶ Main AI use across industries: AI spurs growth via product innovation (Babina et al 2024)
- *This paper*: **Do firms' systematic risk change when they invest more in AI?**
  - ▶ Important for firms' cost of capital, investment, employment, and capital allocation
  - ▶ **Systematic risk**: Covariance between firm's equity returns and stock market returns
  - ▶ **AI investments**: Firm-level AI investments from Babina et al (2024)

# Conceptual Framework

Are Firms AI Investments Associated with Changes in Firms' Systematic Risk (i.e., Market Betas)?

- The relationship is ex ante ambiguous
- AI investments can **reduce** firms' systematic risk
  - ▶ Better forecasting → less uncertainty about demand shocks and better adjustment to market conditions (Agrawal, Gans, Goldfarb, 2019; Tanaka, Bloom, David, Koga, 2019)
- AI investments can **increase** firms' systematic risk
  - ▶ Downside risk: AI leading to shared reliance on the same datasets, third-party dependencies, similar models tested on short-term time series (Financial Stability Board, 2017)
  - ▶ Upside risk: Growth option value of AI investments (Carlson, Fisher, Giammarino, 2004, 2006, 2010)
    - ★ Emerging technologies create *potential* investment opportunities (growth options)
    - ★ Babina, Fedyk, He, Hodson (2024): Growth from AI mainly via product innovation
    - ★ Growth options increase firm betas as growth options are riskier than assets-in-place

## Preview of Findings

- 1 **Main result: Firms' AI investments are associated with higher systematic risk**
- 2 Mechanism potentially driving this: **Growth option value of AI investments**
  - ▶ Reflects **upside risk** capturing *positive* growth option value of AI investments
  - ▶ Mostly driven by days when stock market goes up (not down) and during news about AI
  - ▶ AI-investing firms become more growth-like: Large declines in HML factor beta
- 3 Mechanisms *not* explaining the main result
  - ▶ Mechanical increase in betas due to AI-investing firms becoming larger part of market
  - ▶ Increase in financial or operating leverage
  - ▶ AI-investing firms becoming more like tech firms
  - ▶ Increased total risk or cash flow volatility
  - ▶ Increases in AI-investing firms' equity duration
  - ▶ Comovement due to institutional investor trading in AI firms

**Our results offer direct evidence that new technologies, such as AI, affect systematic risk profiles of the technology investing firms, through growth options channel**

# Roadmap

- ① Data and measures
- ② Main result: AI investments are associated with increasing market beta
  - ▶ Industry betas
  - ▶ Other technologies
  - ▶ Time trends
- ③ Mechanism: AI creates growth options
- ④ Alternative explanations
- ⑤ Other aspects of the risk profile
  - ▶ Total & idiosyncratic risk
  - ▶ Cash flow risk

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# Data

- ① **Employment profiles (resumes):** Cognism, aggregator of public profile information
  - ▶ 535 million full profiles globally; 64% coverage of US employees
  - ▶ Job histories, skills, education (education level and major), publications, patents, awards, references, hierarchical level
  - ▶ Captures actual hiring, not just demand
- ② **Job postings:** BurningGlass Technologies
  - ▶ 180 million job postings
  - ▶ Comprehensive coverage of online job openings in 2007 and 2010–2018
  - ▶ Detailed taxonomy of required skills, required experience and education

# Steps for Measuring Firms' AI Investments

AI measure introduced and extensively validated in Babina, Fedyk, He, Hodson (2024) JFE:

## 1 Identify relevant skills: BurningGlass

- ▶ Core AI skills: AI ML NLP Computer Vision
- ▶ AI-relatedness score of skill  $s$  = % of jobs requiring skill  $s$  that also require at least one core AI skill

- *“deep learning”*: 86% of job postings also list one of core areas
- *“information retrieval”*: 37% co-occurrence with core AI areas
- *“communication skills”*: 0.3% co-occurrence

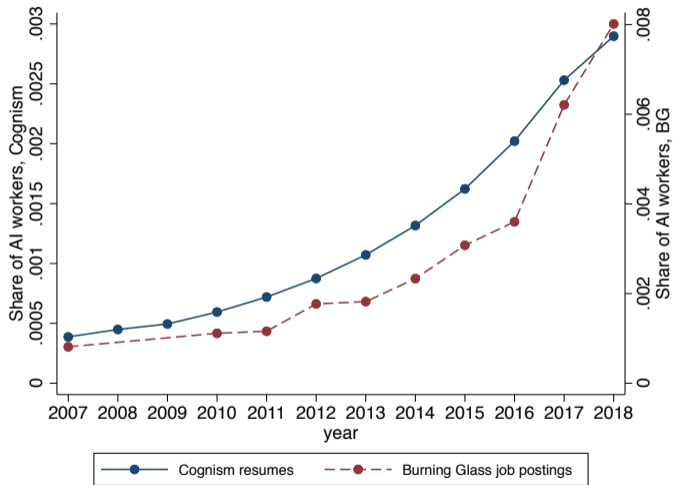
## Steps for Measuring Firms' AI Investments

- 2 Locate highly relevant skills in resumes (co-occurrence 70%+)
  - ▶ Job title & description + patents, publications, awards during the job

- *Job title: "Senior **Machine Learning** Developer"*
- *Job description: "develop Chatbots using Python with **scikit learn**, **tensorflow** and **deep learning** models..."*
- *Publication: "A New Cluster-Aware Regularization of **Neural Networks**"*

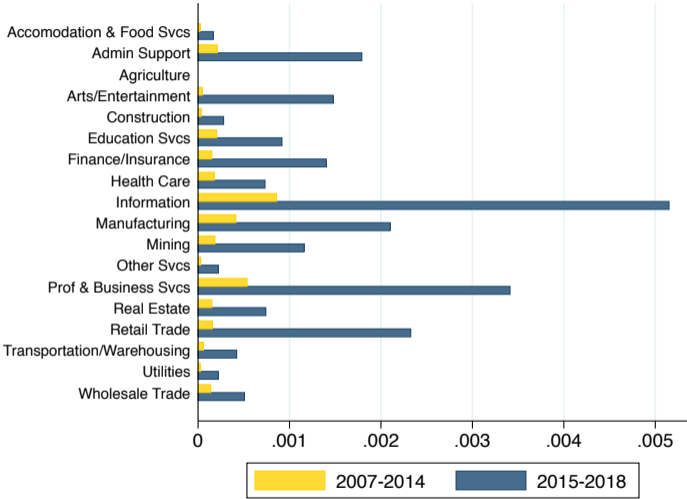
- 3 Match employers to Compustat and calculate % of AI jobs at firm level over time

# Fast Growth in AI-skilled Human Capital



Babina, Fedyk, He, Hodson (2024 (a))

# Fast growth of AI use by US public firms across all industries



Babina, Fedyk, He, Hodson (2024 (a))

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# Empirical Specification: AI Investments and Firms' Systematic Risk

- Main approach: Long-differences regression at firm-level

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

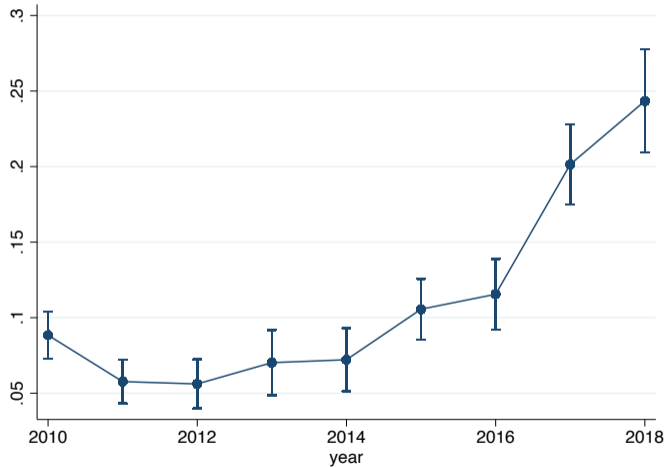
- ▶  $\beta_i$ : Covariance between a firm's equity returns and stock market returns
  - ★ Comes from either CAPM or 4-factor model (controls for firm size, value, momentum)
- ▶  $ShareAIWorkers_i$ : Proxies for AI investments; standardized to 1 standard deviation
  - ★ Today show results with resume based AI-skilled worker measure (captures actual employees)
  - ★ All results are robust to using AI-skilled job posting measure (measures demand for workers)
- ▶ Controls: Industry fixed effects, firm-level and commuting-zone-level controls in 2010
- ▶ Sample: US public non-tech firms (exclude NAICS sectors 51 and 54)
  - ★ This excludes tech firms like Nvidia or Google

## Main Result: Firms' AI investments are Associated with **Increased** Systematic Risk (as Measured by Market Betas)

	$\Delta\beta$ (CAPM)		$\Delta\beta$ (4-factor)	
$\Delta$ Share AI Workers	0.110*** (0.018)	0.054*** (0.015)	0.052*** (0.011)	0.057*** (0.012)
NAICS2 FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Mean of Dep Var	-0.169	-0.169	-0.008	-0.008
S.d. of Dep Var	0.326	0.326	0.261	0.261
Interquartile range Dep Var	0.462	0.462	0.348	0.348
Coeff Norm by Sd	0.337	0.167	0.198	0.218
Coeff Norm by Interquartile	0.238	0.118	0.148	0.163
Adj R-Squared	0.234	0.372	0.207	0.260
Observations	846	846	846	846

- AI investments are associated with increase in market betas of 17–22% standard deviation

# Time Trends of Changing Firm Systematic Risk



## Decomposing Market Betas into Industry Betas

Dependent variables: Estimate each firm's beta separately to the tech sector ( $\beta_{IT}$ ), to its own industry ( $\beta_{Industry}$ ), and to all other sectors ( $\beta_{Other}$ )

	$\Delta\beta_{IT}$		$\Delta\beta_{Industry}$		$\Delta\beta_{Other}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta$ Share AI Workers	0.090*** (0.017)	0.050*** (0.016)	0.063*** (0.019)	0.040** (0.018)	0.111*** (0.017)	0.053*** (0.014)
NAICS2 FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y
Mean of Dep Var	-0.337	-0.337	-0.164	-0.164	-0.194	-0.194
S.d. of Dep Var	0.277	0.277	0.320	0.320	0.342	0.342
Interquartile range Dep Var	0.394	0.394	0.399	0.399	0.479	0.479
Coeff Norm by Sd	0.325	0.179	0.197	0.125	0.325	0.156
Coeff Norm by Interquartile	0.229	0.126	0.158	0.100	0.232	0.111
Adj R-Squared	0.197	0.338	0.190	0.319	0.280	0.410
Observations	845	845	845	845	845	845

- Relationship between individual firms' AI investments and industry betas is positive and significant across industry sectors

## Firms Betas and Other Technologies: (non-AI) IT Investments

Leverage job postings data to measure firms' investments in IT and robotics

	$\Delta\beta$ (CAPM)		$\Delta\beta$ (4-factor)	
$\Delta$ Share Other IT Workers	-0.057 (0.047)	-0.056 (0.037)	-0.033 (0.040)	-0.036 (0.039)
NAICS2 FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Mean of Dep Var	-0.162	-0.162	0.025	0.025
S.d. of Dep Var	0.321	0.321	0.266	0.266
Interquartile range Dep Var	0.512	0.512	0.386	0.386
Coeff Norm by Sd	-0.179	-0.174	-0.125	-0.135
Coeff Norm by Interquartile	-0.112	-0.109	-0.086	-0.093
Adj R-Squared	0.156	0.381	0.250	0.296
Observations	829	829	829	829

- No significant relationship between other (non-AI) IT investments and systematic risk

## Firms Betas and Other Technologies: Robotics

Leverage job postings data to measure firms' investments in IT and robotics

	$\Delta\beta$ (CAPM)		$\Delta\beta$ (4-factor)	
$\Delta$ Share Robot Workers	0.065 (0.047)	0.042 (0.034)	0.009 (0.021)	0.025 (0.023)
NAICS2 FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Mean of Dep Var	-0.162	-0.162	0.025	0.025
S.d. of Dep Var	0.321	0.321	0.266	0.266
Interquartile range Dep Var	0.512	0.512	0.386	0.386
Coeff Norm by Sd	0.204	0.131	0.035	0.093
Coeff Norm by Interquartile	0.128	0.082	0.024	0.064
Adj R-Squared	0.162	0.379	0.247	0.295
Observations	829	829	829	829

- No significant relationship between investments in robotics and systematic risk

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# Main Mechanism: AI Investments Create Growth Options

- Emerging technologies create *potential* investment opportunities (growth options)
- AI creates growth options: AI leads to firm growth (Babina, Fedyk, He, Hodson 2024)
  - ▶ Growth mainly due to product innovation: AI-investing firms have more trademarks and product patents, and updates to product offerings

# Main Mechanism: AI Investments Create Growth Options

- Growth options increase firm beta (Carlson, Fisher, and Giammarino, 2004, 2006, 2010)
  - ▶ Growth options are riskier than assets-in-place
  - ▶ Firm beta increases as growth options become more in-the-money
  - ▶ Firm beta declines as growth options convert to assets in place
- Predictions confirmed by data
  - ① **Increase in market beta** in AI-investing firms due to created growth options
  - ② Market betas increase specifically during periods of **good market conditions** and **news about AI** (when growth options become more in-the-money)
  - ③ AI-investing firms become more **growth-like firms** (decreasing HML factor beta)
  - ④ Eventually beta drops as growth is realized (may be too early to see in the data)

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## Alternative Explanations *not* Explaining Main result

- Mechanical increase in betas due to AI-investing firms becoming larger part of market
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# Conclusion

- First paper to examine how firm risk profiles change with investments in AI
- This paper shows that AI investments are associated with increased systematic risk
  - ▶ This increased systematic risk appears to be benign: AI-investing firms experience reductions in cash flow volatility, no change in total return volatility, and the increases in their market betas concentrate on the upside (during good market conditions)
  - ▶ Suggests new technologies create option value of investing in them
  - ▶ Other mechanisms not supported by the data (increased leverage, reverse causality, equity duration, investor capital comovement)
- **Our findings suggest a novel market implication of new technologies: They do not only affect firm growth but also change firms' risk profiles**