AI and Jobs: Evidence from Online Vacancies

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Question

- Lots of excitement about AI
- Lots of speculation about how it will transform labor markets, replace labor, increase productivity, replace sliced bread, etc.
- It may be that:
  - there is not as much AI as presumed
  - it is replacing some jobs and transforming labor markets
  - it is helping create new products, services, and jobs
  - it is benefiting some organizations without replacing jobs
- But little evidence so far; we just don't know how AI is being deployed and used in commercial applications.
- No good data sources on AI adoption or investment.

This Paper

- **Idea:** measure AI from its "footprint" in posted jobs.
- AI adoption requires in-house specialists, associated with posting of AI/machine learning/big data jobs.
- We use a comprehensive data set of all online vacancies from BurningGlass Technologies from 2007 to the present to study:
  - whether there has been a major increase in AI activities as proxied by vacancies in AI
  - whether establishments with the greatest opportunities to substitute workers for AI are using the technology the most
  - whether establishments adopting AI have started posting fewer jobs in occupations at-risk of AI replacement
  - whether establishments adopting AI have increased their postings in not-at-risk occupations

Summary of Results: Rising Adoption of AI Technologies

- Huge recent increase in AI vacancy postings across the economy.
- Concentrated in sectors that are "producers and suppliers" of AI (Information Technologies and Business Services—sectors 51 and 54), as well as on coastal regions.
- But also significant rise in adoption of AI technologies in other establishments and sectors, as well as other regions.
- Outside of sectors 51 and 54, establishments with greatest opportunities for substitution of workers by AI show a more pronounced upsurge in postings of AI vacancies.

Summary of Results: Effects on Jobs

- Following the increase in AI vacancies, we find a significant shift in the types of jobs posted by these establishments.
- Fewer job postings in occupations at risk of replacement by AI; more job postings in occupations not at risk (even if unrelated to AI operation)
  - holds when we control for detailed industry and establishment characteristics
  - holds when we compare two establishments that are part of the same parent firm
  - if all establishments above 10th percentile of opportunities behaved as those at 10th percentile $\Rightarrow$ 36% more at-risk job postings
- Although composition of job postings change, overall impact on vacancy postings is small and insignificant.

Related Literature

- Literature measuring occupations where AI can be used
  - Felten et al. (2018), Brynjolfsson et al. (2018), and Webb (2019)
  - We use these measures to identify opportunities for replacement via AI across US establishments and sectors.
- Literature exploring how AI is being deployed by businesses
  - Survey of AI startups by Benssen et al. (2018)
  - We provide evidence consistent with view that AI is being deployed to substitute for tasks currently done by some workers.
- Literature on effects of AI on specific occupations and sectors
  - Research on financial analysts by Grennan and Michaely (2019)
  - We provide evidence of shifting occupational and task structure within establishments adopting AI for all US economic sectors.
- Burgeoning literature using Burning Glass data (Hazell and Taska 2018; Hershbein and Kahn, 2018; Deming and Noray, 2018; Dillender and Forsythe, 2019; Steffen, 2019; Modestino, Shoag, and Ballance, 2016, 2019)

AI and Substitution at the Task Level

- Consider the following framework building on Acemoglu and Autor (2011) and Acemoglu and Restrepo (2018, 2019).
- Output of a firm, y, produced by combining services, $y(x)$, of a unit measure of tasks $x \in [0, 1]$:

$$\ln y = \int_0^1 \ln y(x) dx, \tag{1}$$

- Tasks produced by human labor, $\ell(x)$, or by AI/algorithms, $a(x)$:

$$y(x) = \begin{cases} \gamma_L(x)\ell(x) + \gamma_A(x)a(x) & \text{if } x \in [0, I] \\ \gamma_L(x)\ell(x) & \text{if } x \in (I, N]. \end{cases} \tag{2}$$

- Tasks above I are not technologically automated.
- $\gamma_L(x), \gamma_A(x)$: productivity of labor and algorithms in task x.
- *comparative advantage:* $\gamma_L(x)/\gamma_A(x)$ increases in x.

AI and Substitution at the Task Level

- Firms choose $I^* \leq I$ such that below I^* all tasks produced by AI.
- Advances in AI as expansion in I^* driven by:
  - increase in I since now feasible to automate more tasks
  - improvements in $\gamma_A(x)$ in marginal tasks performed by labor (those to the right of I^*)
  - more pronounced for firms with more marginal tasks
- What does an increase in I^* do?
  - reduces employment in at-risk tasks (those in the vicinity of I^*) because of a *displacement effect*
  - increases employment in not at-risk tasks (those far away from I^*) because of a *productivity effect*
- Different from improvements in $\gamma_A(x)$ for tasks to the left of I^* (AI would substitute previous vintages of capital)

Data Overview

- Our analysis relies on two key data elements:

  1. Data on vacancy postings, from Burning Glass Technologies (BGT)

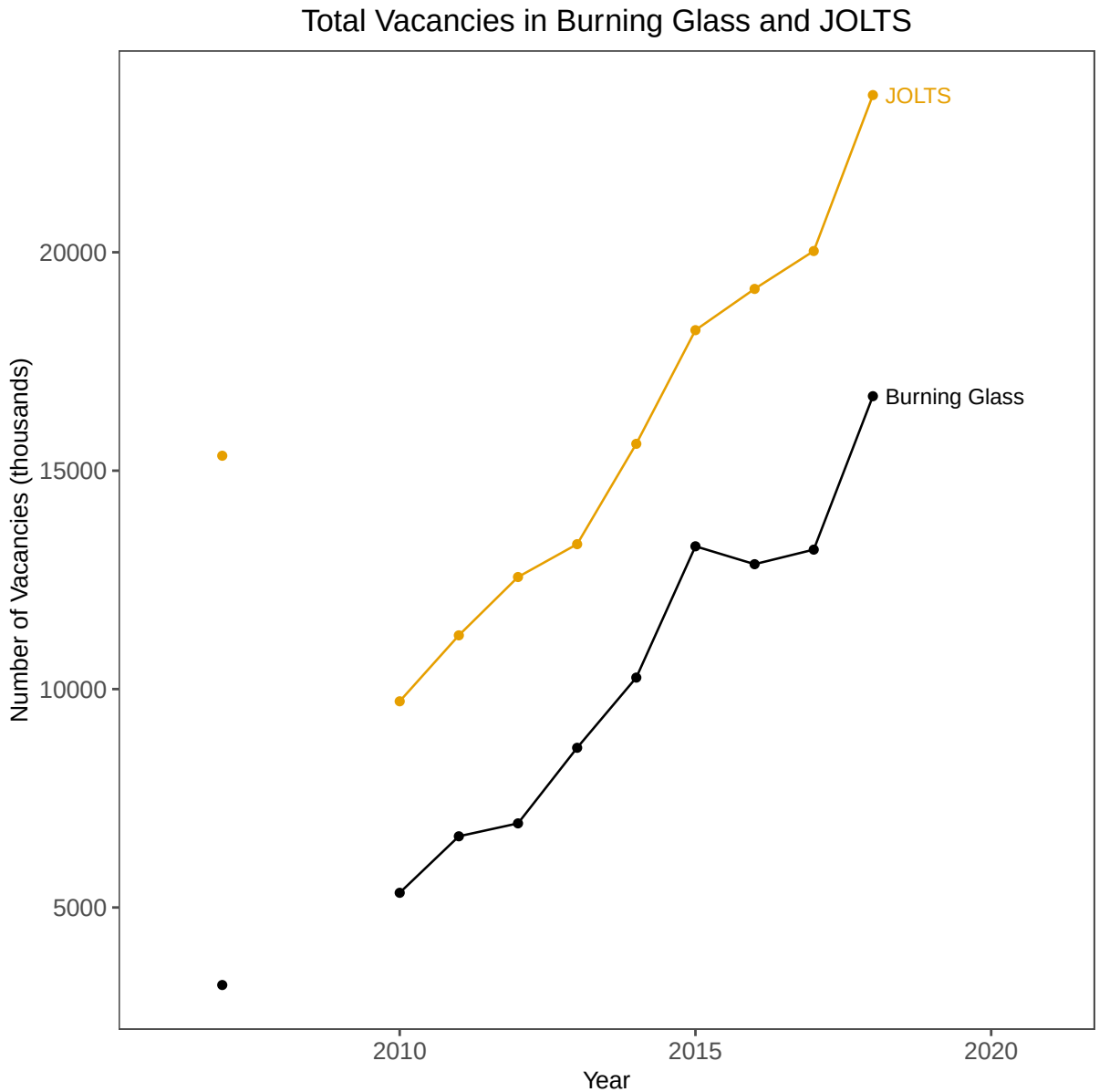
  2. Classification of occupations/job postings into at-risk and not-at-risk of replacement by AI.

- We now describe each one of these in turn.

Burning Glass Data

- Burning Glass Technologies: near-universe of online US vacancies
  - available for years 2007 and 2010-2018
  - vacancies scraped from 40,000 company websites and online job boards, with de-duplication algorithm
  - covers 60-80% of all US vacancies, online and offline
  - detailed information on location, employer, industry, occupation and skill requirements of vacancy

How Good Are Burning Glass Data?



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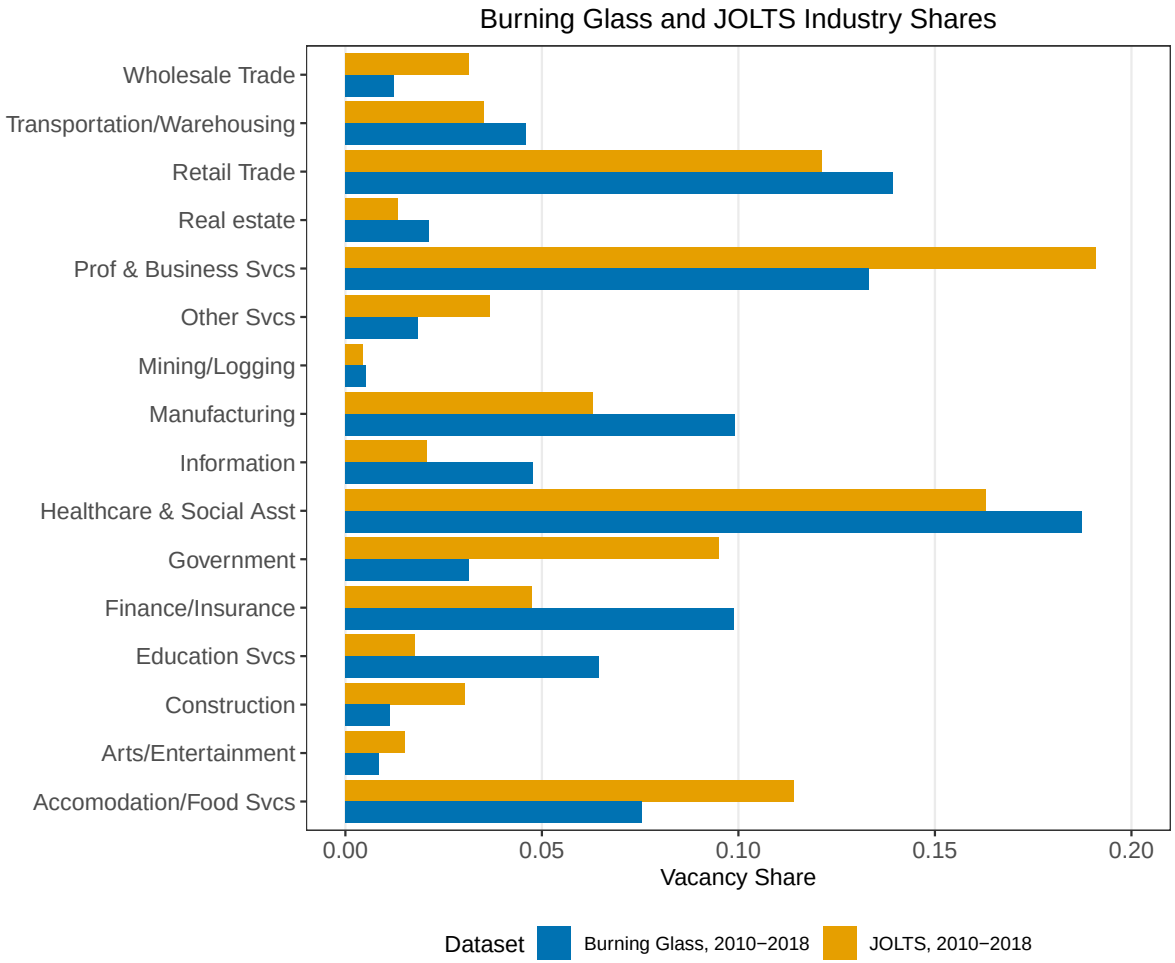
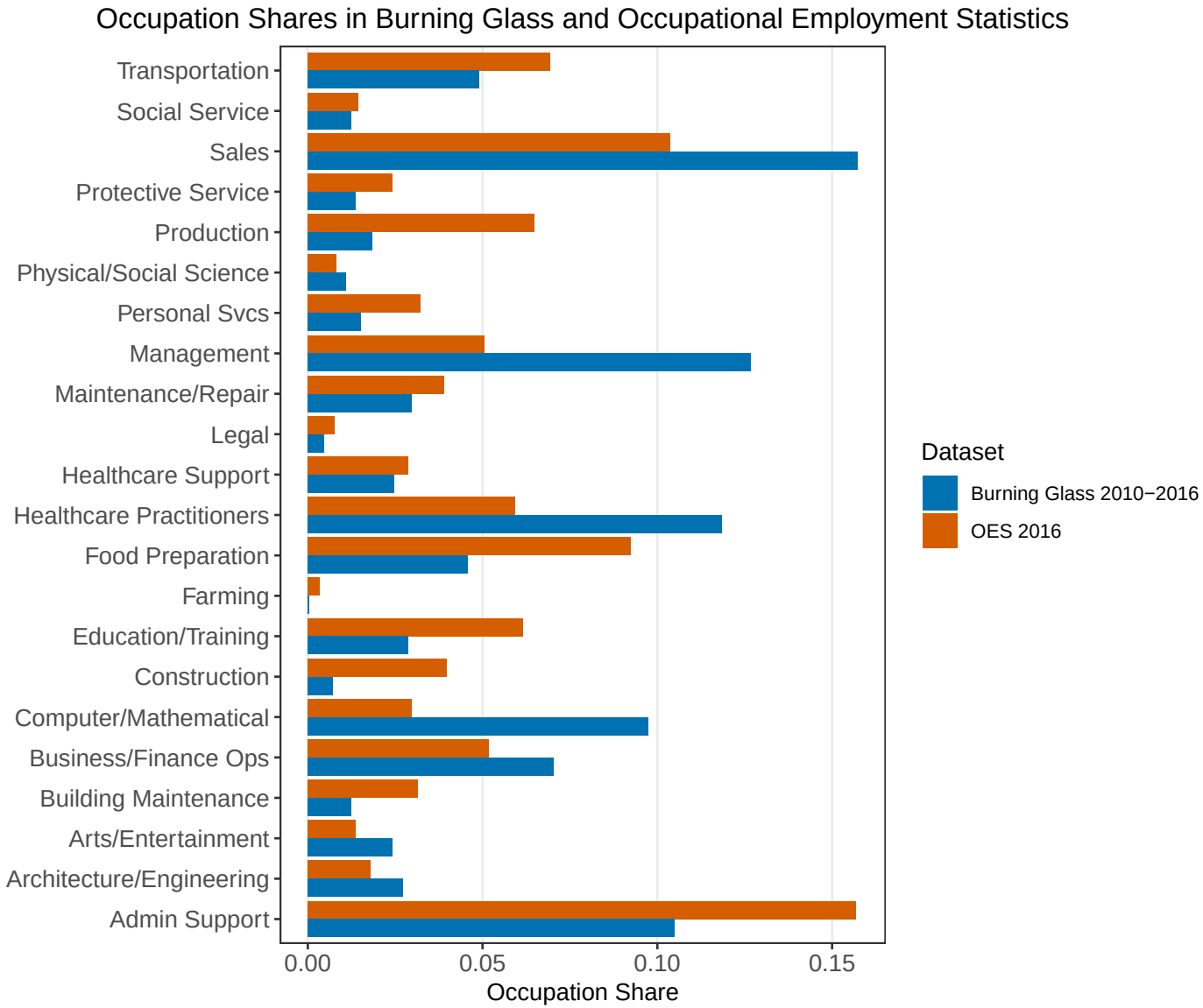


How Good Are Burning Glass Data?



- caveat: vacancies are flows, OES measures stocks

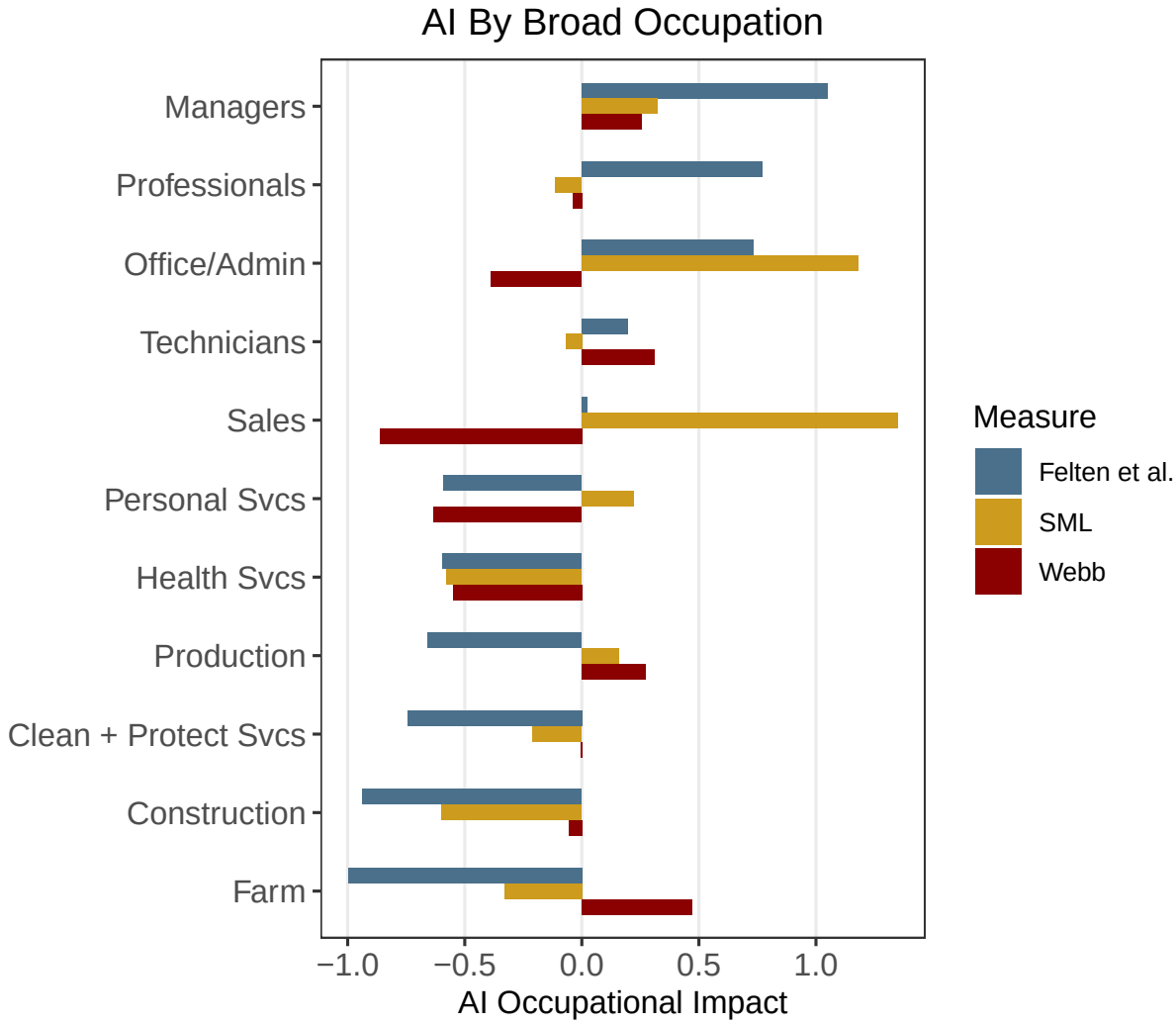
Occupations with Greatest Potential for Substitution by AI

- We use three alternative classifications.
  - **AI Occupational Impact** from Felten, Raj, and Seamans (2018)
  - **SML index** from Brynjolfsson, Mitchell, and Rock (2018)
  - **AI index** from Webb (2019)
- We use Felten et al.'s measure as our baseline.
  - based on observed and current advances in AI and their usefulness on tasks done by workers in each occupation
  - document tasks where AI has gotten better in recent years from Electronic Frontier Foundation (EFF)
  - EFF tracks tasks belonging to 16 categories, including image recognition, abstract strategy games, or speech recognition
  - they link these categories to 52 abilities required in detailed occupations according to $O*NET$
- SML and Webb's measure used in robustness exercises.

Occupations with Greatest Potential for Substitution by AI

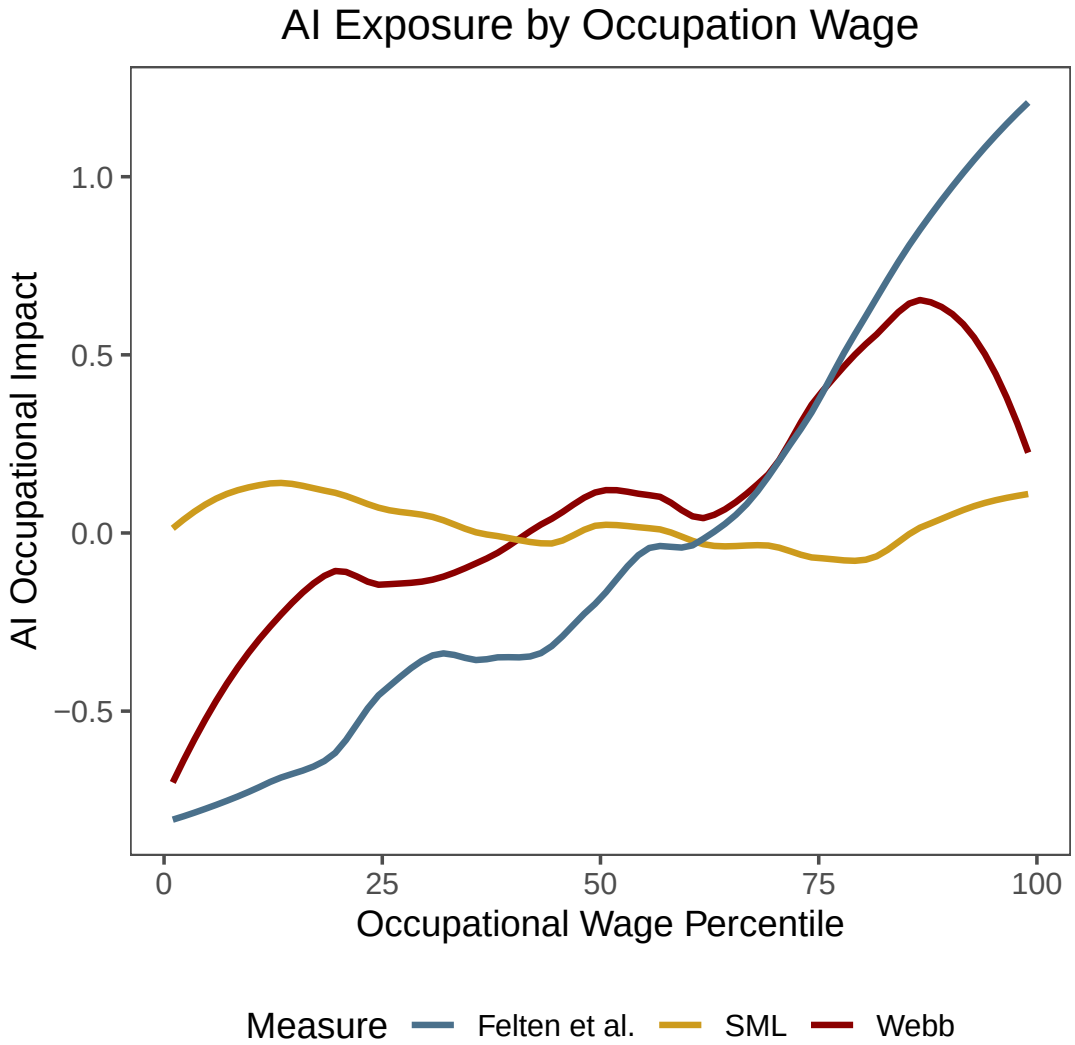
- **SML index** from Brynjolfsson, Mitchell, and Rock (2018)
  - rubric to evaluate potential for applying ML to tasks in $O*NET$
  - rubrics filled using crowd-sourcing sites
  - SML index available for detailed occupations
- **AI index** from Webb (2019)
  - identifies key capabilities of AI from text in patent data
  - matches those capabilities to job descriptions from $O*NET$
  - AI index available for detailed and Census occupations

Occupations with Greatest Potential for Substitution by AI



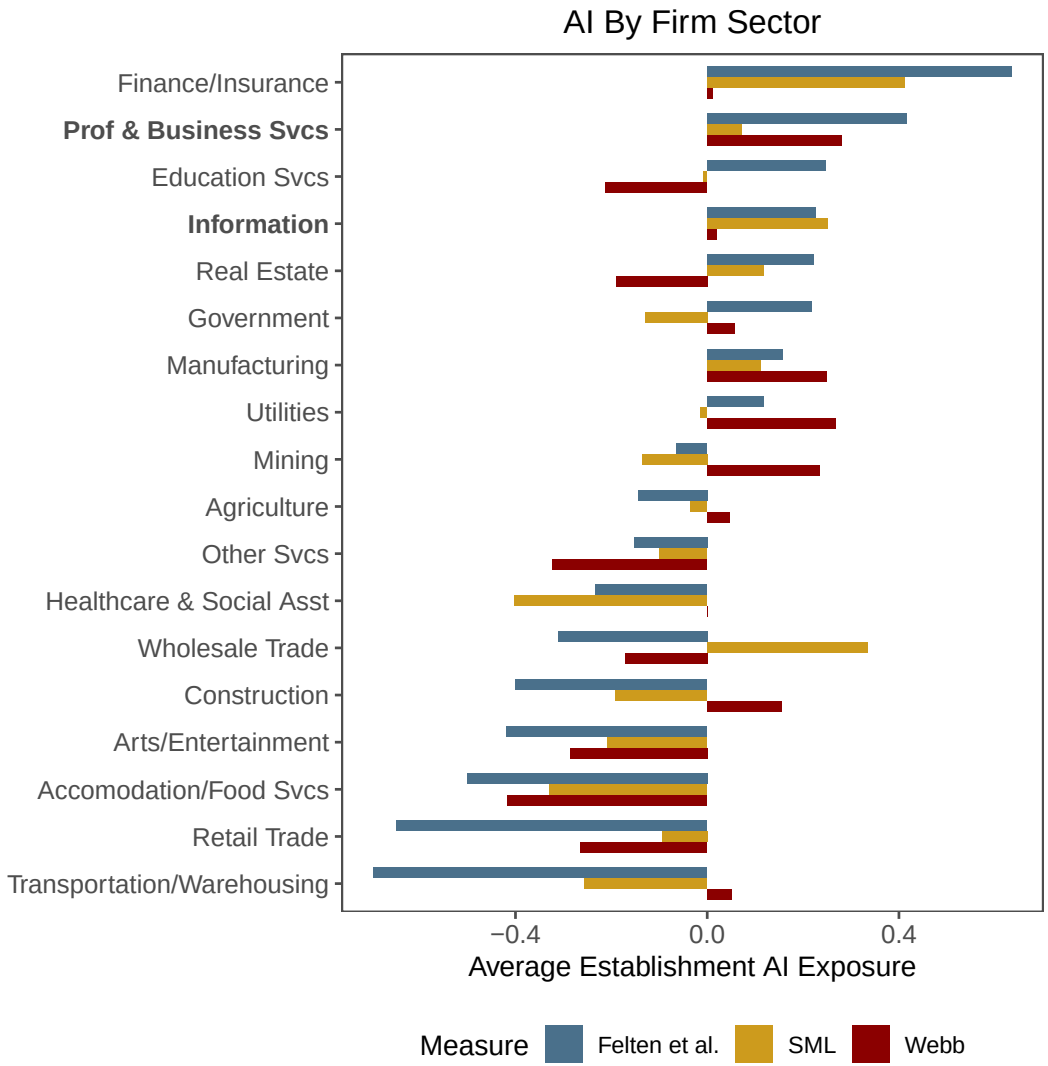
- AI Occupational Impact, SML, and Webb's index by occupation; all indices are standardized

Occupations with Greatest Potential for Substitution by AI



- AI Occupational Impact by baseline wage in each occupation; measures standardized

Industries with Greatest Potential for Substitution by AI

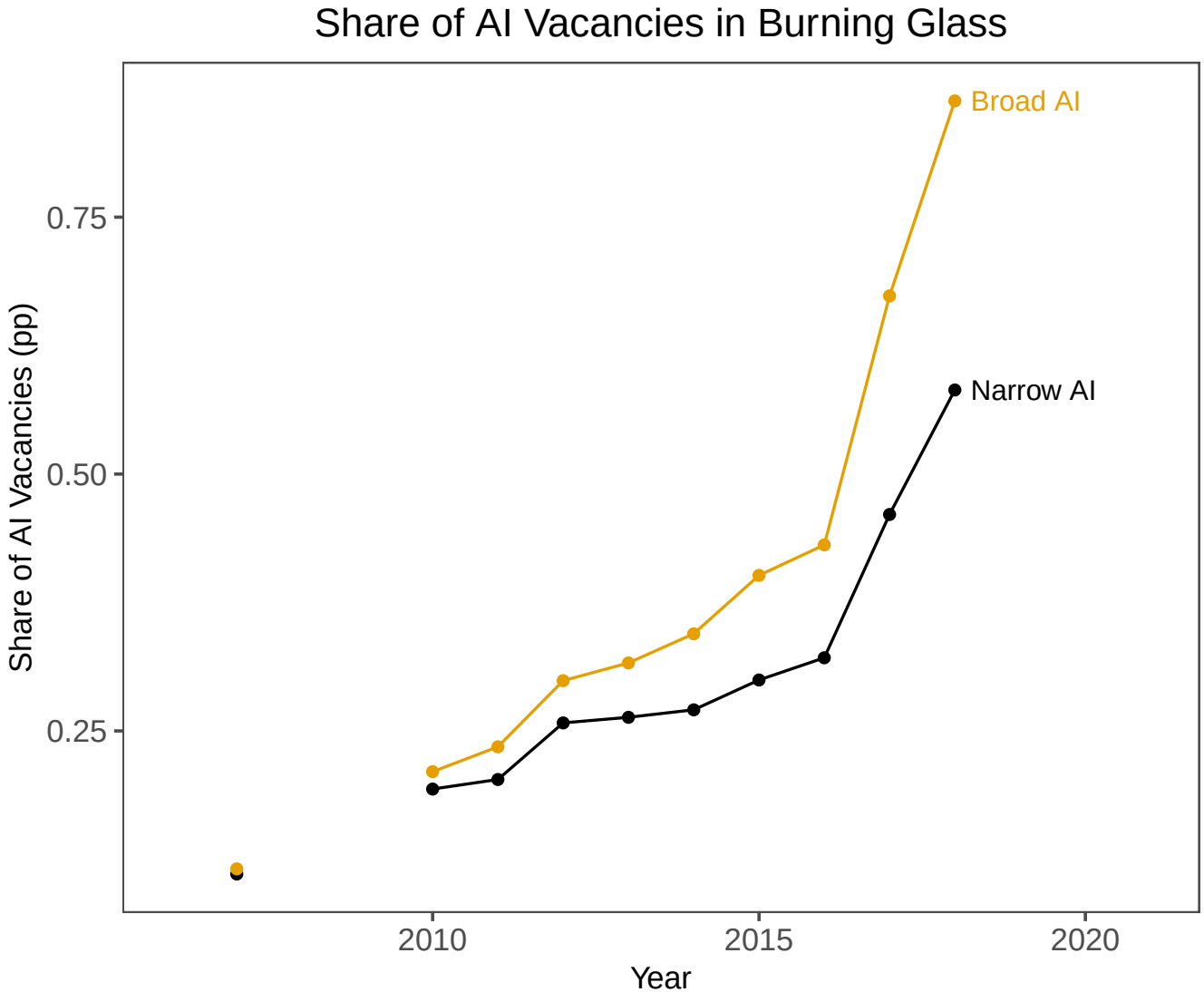


- AI Occupational Impact, SML, and Webb's index by industry; all indices are standardized

Inferring Adoption of AI from Job Postings

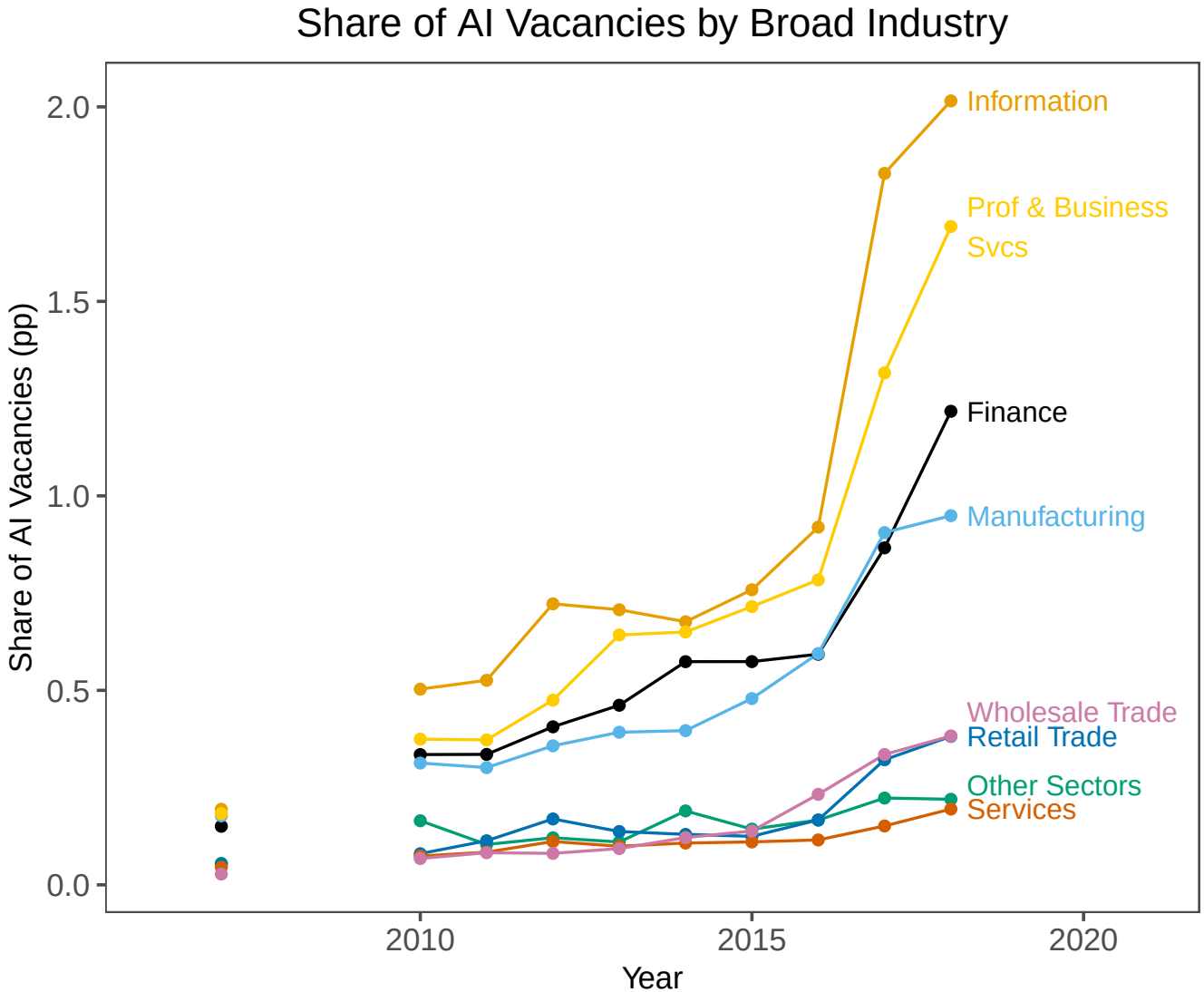
- We exploit the fact that Burning Glass collects data on 16,681 skills required in job postings, which are part of 673 skill clusters.
- **Narrow AI** vacancies: posting requiring one of these skills
  - machine learning, deep learning, neural networks, supervised and unsupervised learning, support vector machines, gradient boosting, random forests, latent Dirichlet allocation, predictive models, kernel methods, natural language processing, speech and pattern recognition, image and object recognition, computer and machine vision, image processing, machine translation, text mining, recommender systems, latent semantic analysis, sentiment analysis and classification, virtual agents, Chatbot, AI ChatBot, Keras, OpenCV, Mahout, Xgboost, Libsvm, Word2Vec
- **Broad AI** vacancies: posting associated with skill clusters
  - natural language processing, data science, artificial intelligence, or machine learning

AI Vacancies Over Time



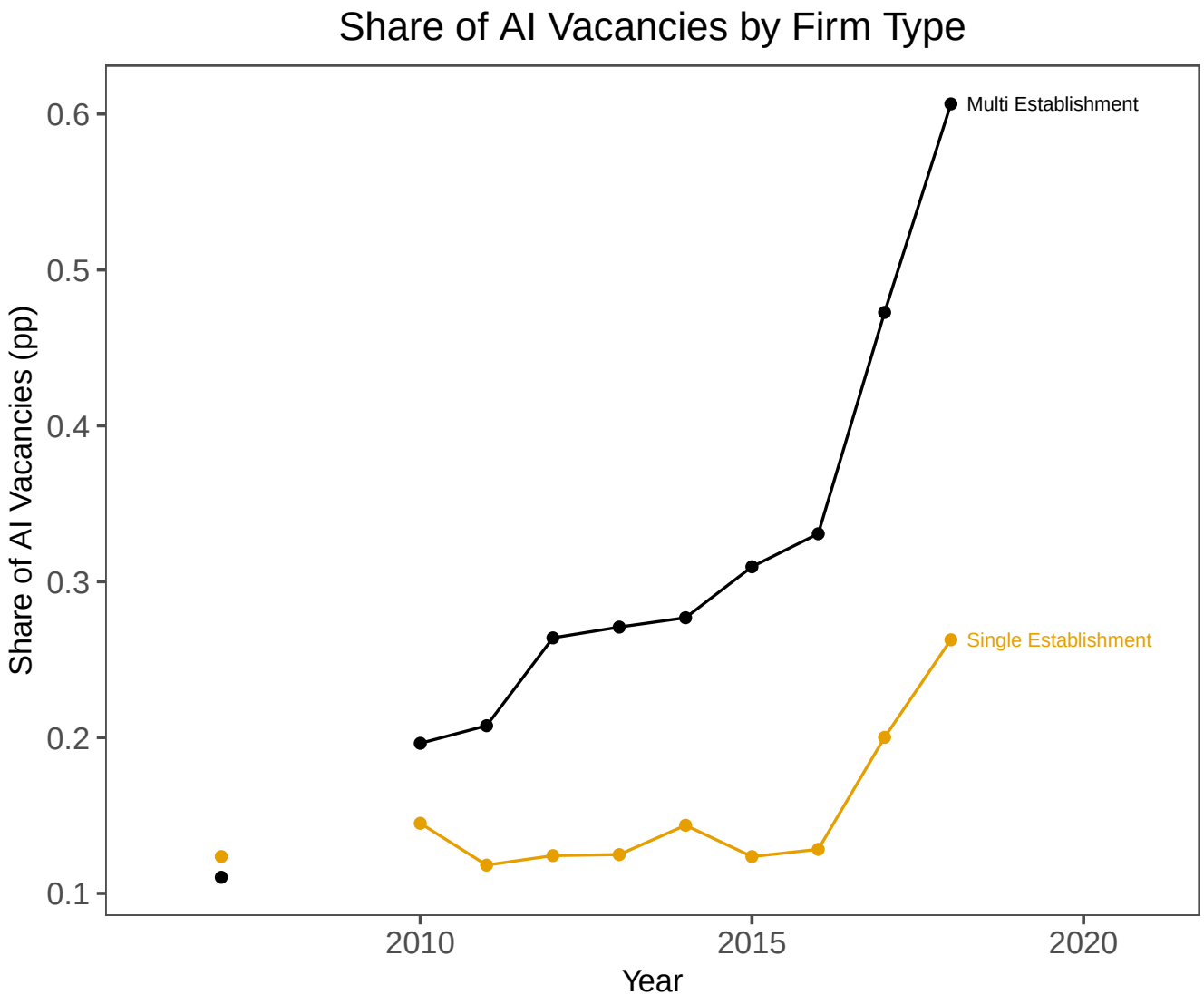
- narrow AI vacancies up from 0.1% to 0.6%

AI Vacancies Over Time



- AI vacancies rising in retail, wholesale, manufacturing, finance, information technologies, business services

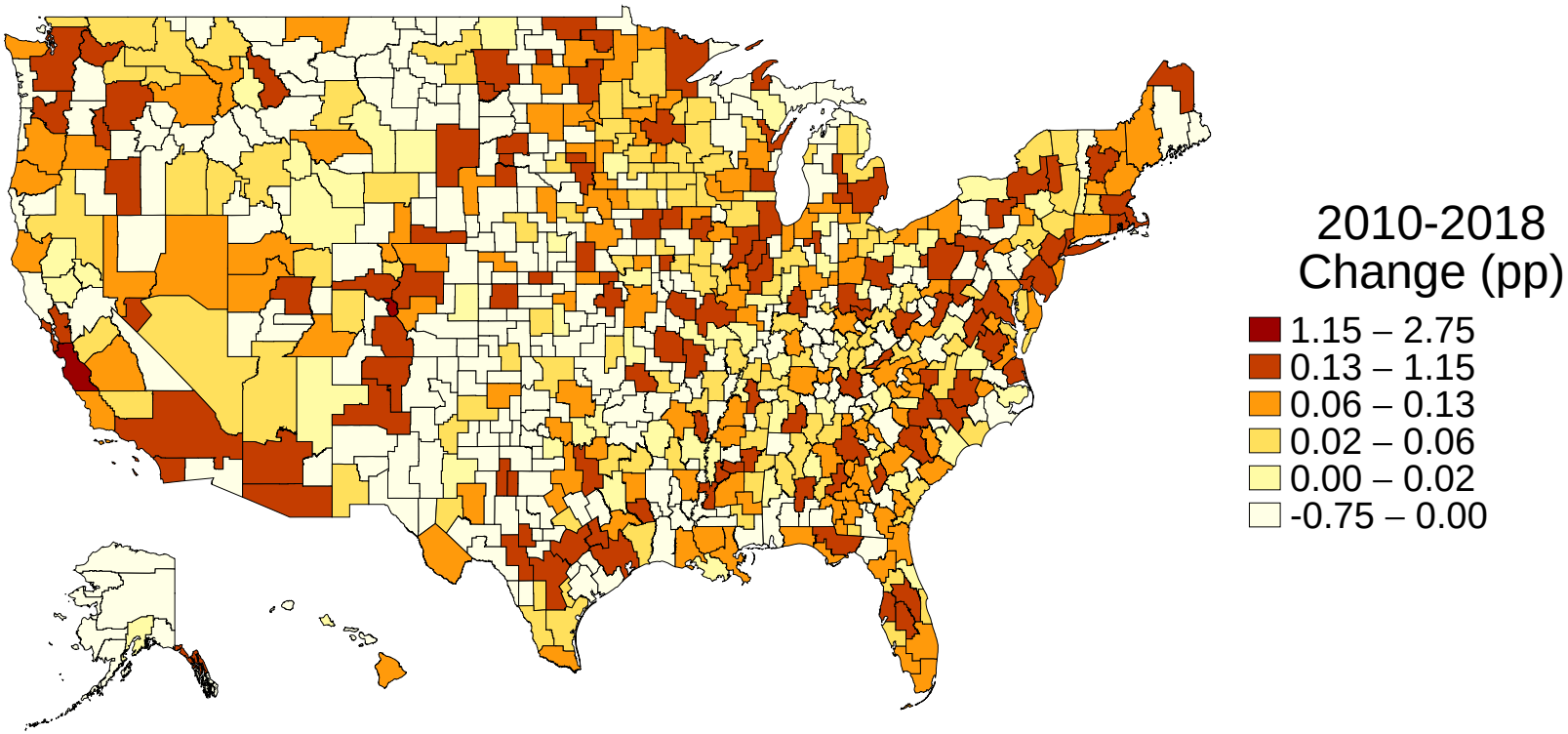
AI Vacancies Over Time



- rise of AI vacancies more pronounced in multi-establishment firms

Geography of AI Vacancies

Change in AI Share of Vacancies, Commuting Zone Level



Exposure to Opportunities for AI

- **AI exposure measure** at the establishment level, s:

$$\text{AI exposure}_{st_0} = \sum_j \text{Share postings}_{jst_0} \times \text{AI Occupational Impact}_j$$

- Summation runs over 815 detailed occupations, j.
- $\text{AI Occupational Impact}_j$ stands for Felten et al.'s measure.
- AI exposure measure based on $t_0 = 2010 - 2012$ job postings or $t_0 = 2007$ in robustness exercises.
- Establishments with a higher $\text{AI exposure}_{st_0}$ have greater opportunities to replace some of their current workers with AI software as these algorithms improve.
- We standardize exposure measure across establishments to ease interpretation.

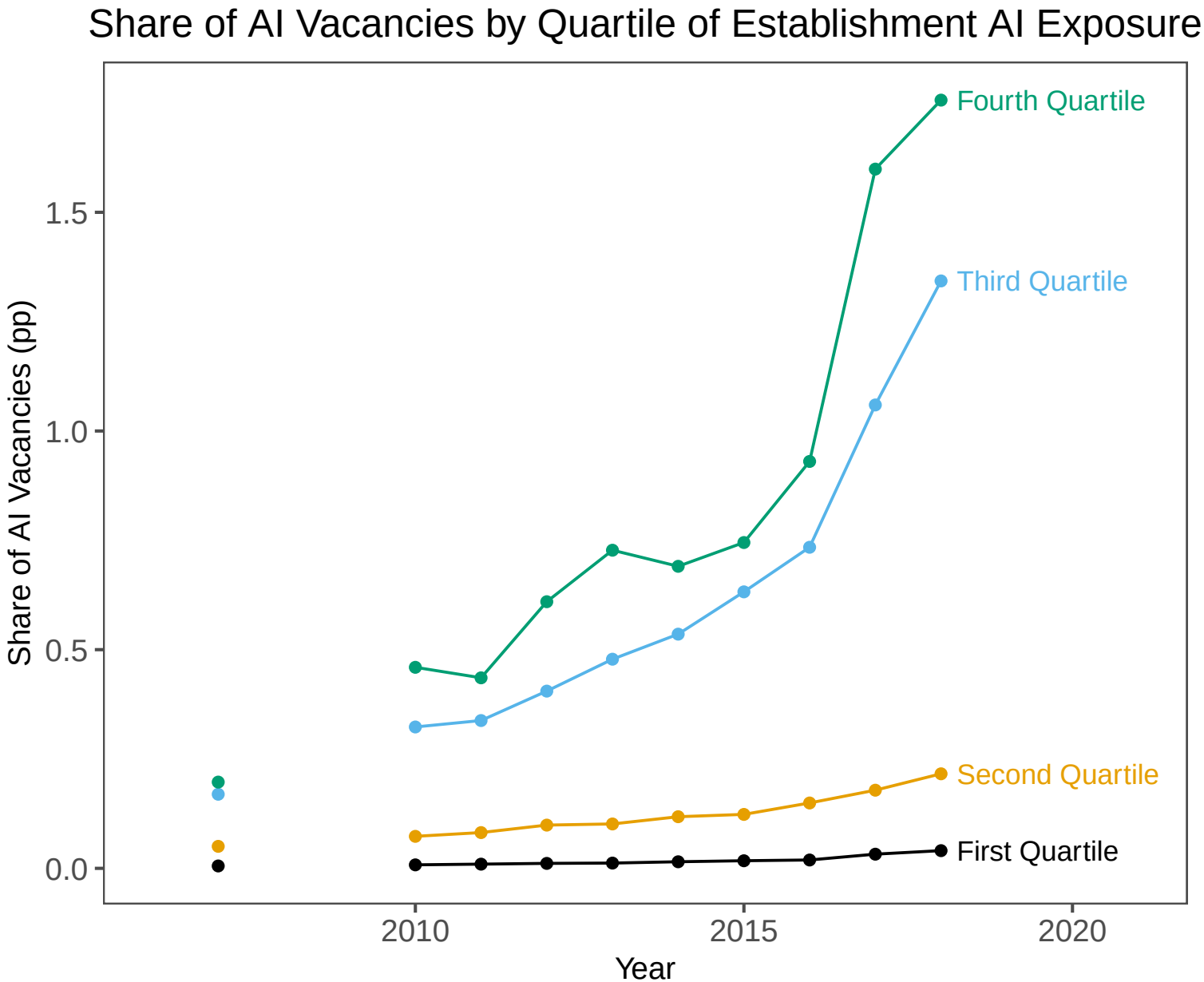
Empirical Strategy

- Empirical models at the establishment level:

$$\Delta Y_s = \beta \cdot \text{AI exposure}_{st_0} + \theta X_s + \alpha_{f(s)} + \delta_{i(s)} + \eta_{z(s)} + \varepsilon_s$$

- ΔY_s: vacancy growth between 2010-2012 and 2016-2018
- Approximated by Δ in IHS of vacancy counts to deal with zeros ($IHS(x) = \ln(x + \sqrt{(x^2+1)})$). Also use $\Delta \ln(x+1)$ and shares.
- X_s : establishment characteristics, including parent firm size and share of baseline postings related to retail and clerical jobs
- $\alpha_{f(s)}$: firm fixed effects in some specifications.
- $\delta_{i(s)}$: industry fixed effects (at 4-digit for 85% of sample).
- $\eta_{z(s)}$: commuting-zone fixed effects.
- Exclude sectors 51 and 54—producers and suppliers of AI.
- β : differential effect of improvements in AI technologies on firms with greatest opportunities to replace workers with AI.

Opportunities for Substitution and AI Postings



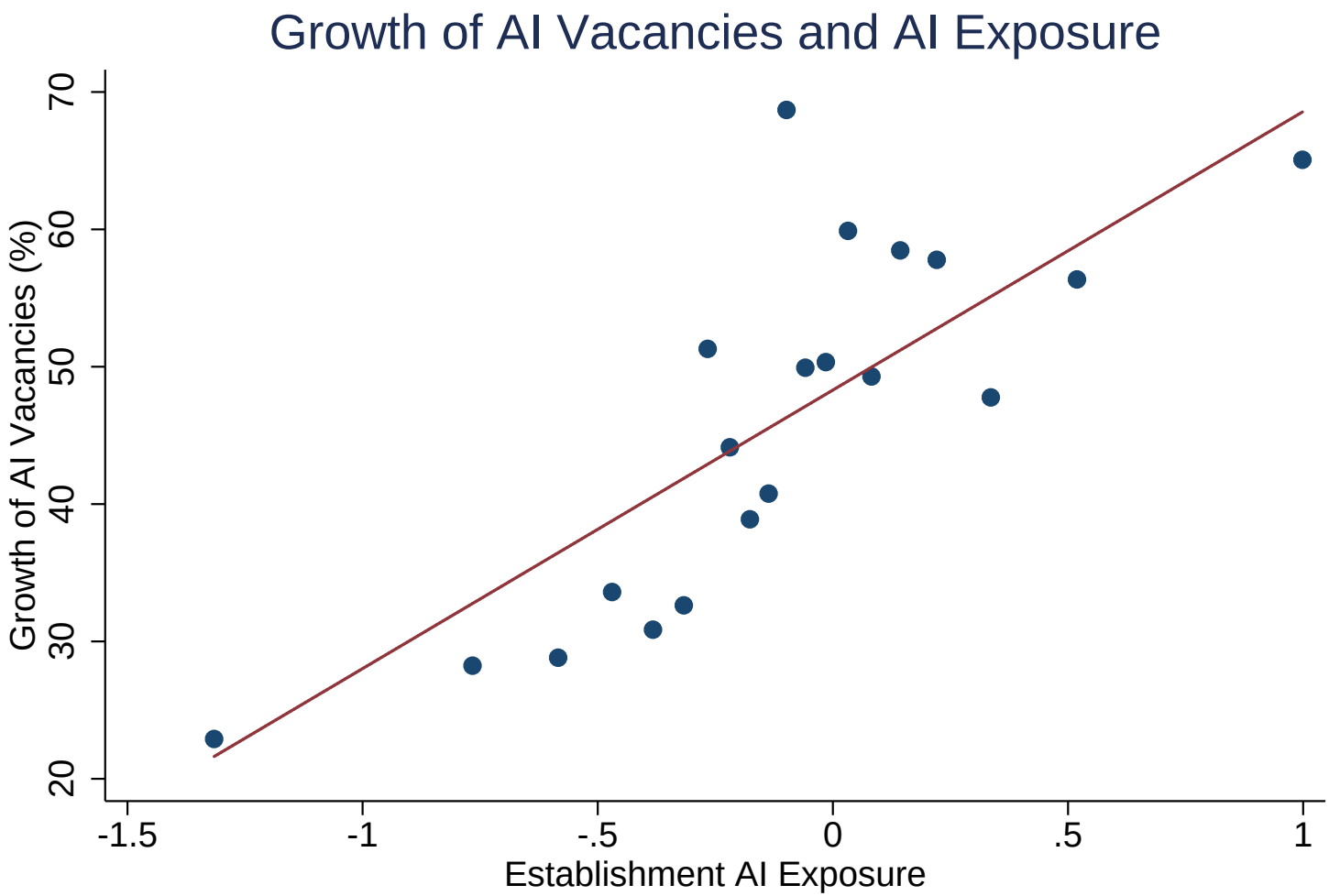
Opportunities for Substitution and AI Postings

	Dependent Variable: Growth of AI Vacancies 2010-2018 (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	37.828***	39.273***	34.388***	23.406***	20.277***	26.006***
	(3.027)	(3.053)	(2.673)	(1.722)	(1.735)	(2.939)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.067	0.078	0.123	0.144	0.196	0.622

Note: SEs clustered by firm, weighting by average 2010-2018 establishment size

- Dep var: growth of AI vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 20% increase in AI postings during 2010-2018.
- If all establishments above 10th percentile of opportunities behaved as those at 10th percentile we would have 23% fewer AI vacancies.

Opportunities for Substitution and AI Postings



Coefficient is 20.28, SE is 1.73

Opportunities for Substitution and AI Postings

	Dependent Variable: Growth of AI Vacancies 2010-2018 (log[y+1])					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	33.210***	34.523***	30.144***	20.460***	17.820***	22.836***
	(2.717)	(2.738)	(2.355)	(1.536)	(1.543)	(2.586)
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.071	0.083	0.132	0.155	0.209	0.630

Note: SEs clustered by firm, weighting by average 2010-2018 establishment size

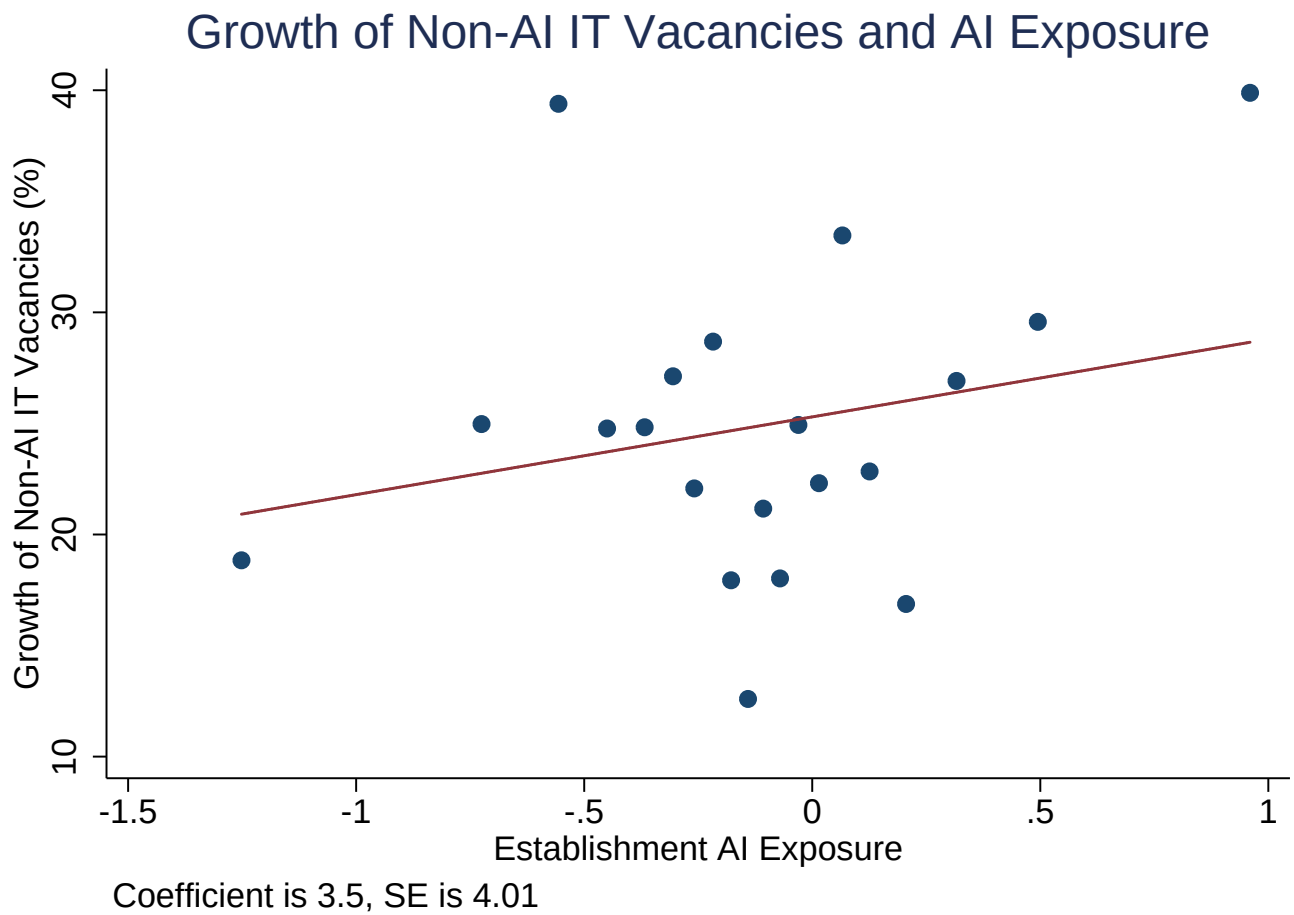
- Dep var: change in log of one plus AI vacancies between 2010-2012 and 2016-2018.
- Results similar to using IHS.

Opportunities for Substitution and AI Postings

	Dependent Variable: Change in Share of AI Vacancies 2010-2018 (pp)					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	0.357***	0.365***	0.325***	0.243***	0.177***	0.103**
	(0.029)	(0.030)	(0.026)	(0.028)	(0.021)	(0.043)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	314,332	314,332	314,332	314,332	295,449	314,332
R^2	0.025	0.027	0.042	0.050	0.085	0.534
Note:	SEs clustered by firm, weighting by average 2010-2018 establishment size					

- Dep var: change in share of AI vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 0.18 pp increase in share of AI postings during 2010-2018.

It Is Not Just Relabeling



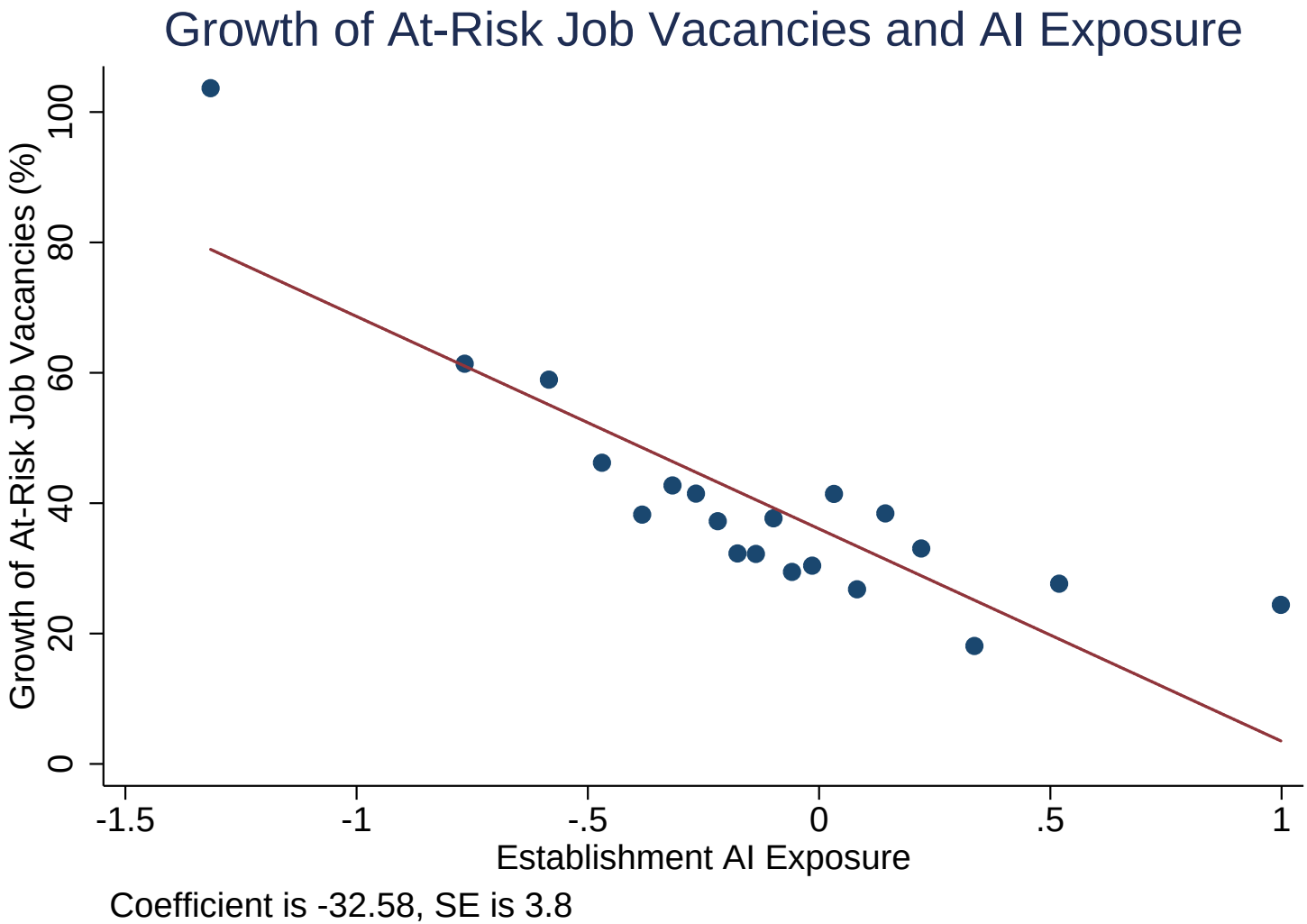
- Caveat: some IT jobs have a high AI Occupational Impact, and are therefore candidates for substitution by AI.
- To account for this, control for baseline share of non-AI IT job postings.

Robustness

	Dependent Variable: Growth of AI Vacancies 2010-2018					
	Webb AI index		SML index		Broad AI as outcome	
Establishment AI Exposure	10.406***	7.715**	5.689***	10.960***	24.224***	32.854***
	(3.245)	(3.139)	(2.036)	(3.083)	(1.906)	(3.261)
Firm Size Decile	Y	N	Y	N	Y	N
Establishment CZ FE	Y	Y	Y	Y	Y	Y
4 digit NAICS FE	Y	N	Y	N	Y	N
Firm FE	N	Y	N	Y	N	Y
Observations	895,916	1,046,155	895,916	1,046,155	837,304	970,103
R^2	0.190	0.634	0.189	0.634	0.302	0.654

- Exposure measures based on Webb and SML also predict adoption of AI, but coefficients smaller than before.
- Results robust to using broad definition of AI postings in last two columns.

At-Risk Jobs Decline



- **At-risk jobs:** top 50% occupations with the highest AI impact according to Felten et al.

At-Risk Jobs Decline

	Dependent Variable: Growth of At-Risk Vacancies 2010-2018 (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	−32.953***	−36.735***	−40.918***	−40.145***	−32.582***	−47.793***
	(5.066)	(5.223)	(5.040)	(3.865)	(3.800)	(3.141)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.019	0.048	0.069	0.090	0.153	0.784

Note: SEs clustered by firm, weighting by average 2010-2018 establishment size

- Dep var: growth of at-risk vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 32% decline in postings of at-risk jobs during 2010-2018.
- If all establishments above 10th percentile of opportunities behaved as those at 10th percentile we would have 36% more vacancies for at-risk jobs.

Robustness

	Dependent Variable: Growth of Feltenable Vacancies 2010-2018 (log[y+1])					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	−26.520***	−30.043***	−33.953***	−32.967***	−26.016***	−39.393***
	(4.695)	(4.847)	(4.687)	(3.520)	(3.463)	(2.874)
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.016	0.046	0.067	0.088	0.152	0.787
Note:			SEs clustered by firm, weighting by average 2010-2018 establishment size			

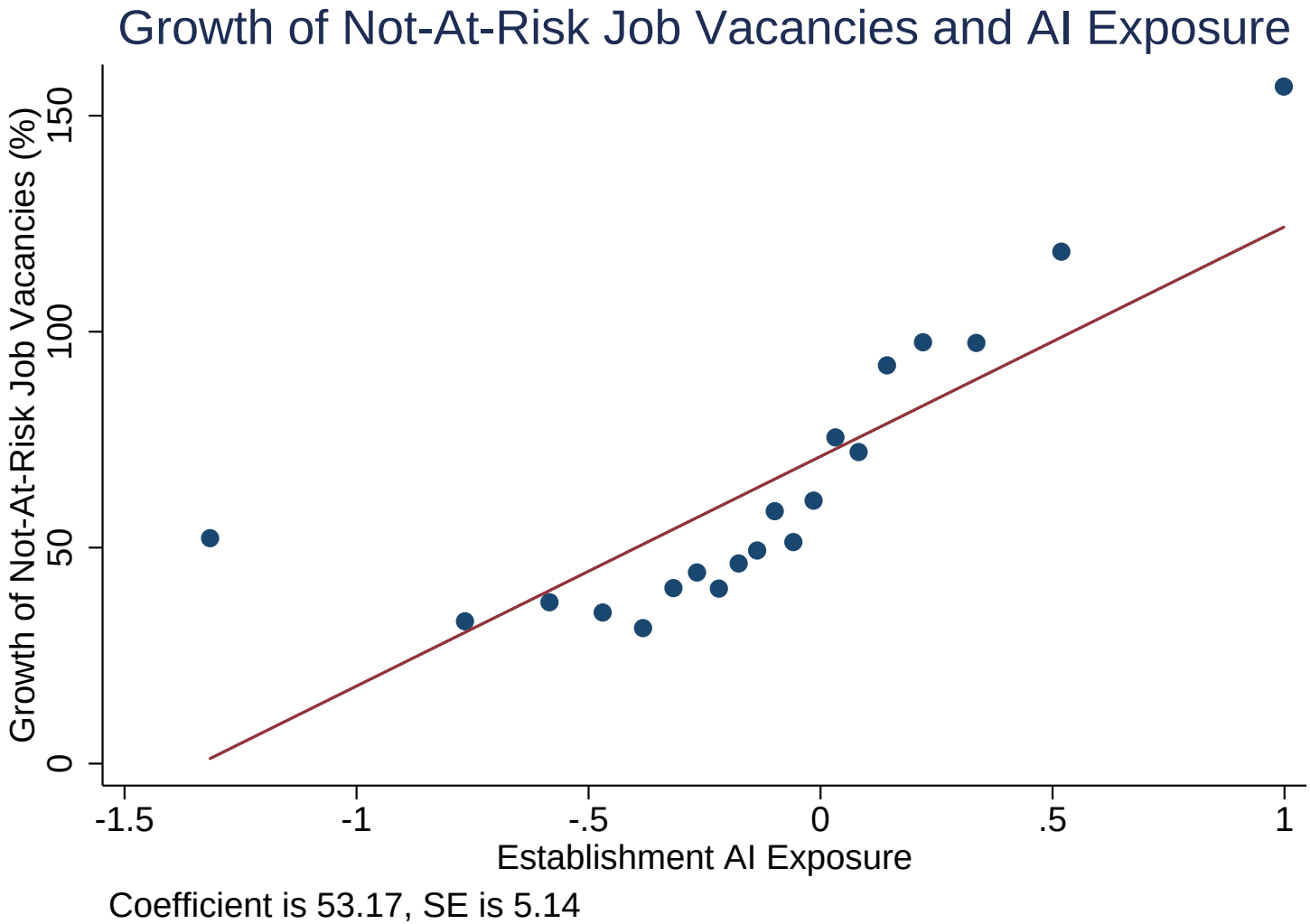
- Dep var: change in log of one plus at-risk vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 26% decline in postings of at-risk jobs during 2010-2018.
- Results similar to using IHS.

Robustness

	Dependent Variable: Growth of At-Risk Vacancies 2010-2018					
	Webb		SML		Felten, Top Quartile	
Establishment AI Exposure	−43.490***	−38.101***	−44.209***	−53.275***	−26.124***	−42.286***
	(9.929)	(6.195)	(5.502)	(4.519)	(3.010)	(3.000)
Firm Size Decile	Y	N	Y	N	Y	N
Establishment CZ FE	Y	Y	Y	Y	Y	Y
4 digit NAICS FE	Y	N	Y	N	Y	N
Firm FE	N	Y	N	Y	N	Y
Observations	895,916	1,046,155	895,916	1,046,155	837,304	970,103
R^2	0.147	0.834	0.158	0.838	0.142	0.741

- Exposure measures based on Webb and SML also predict a similar decline in at-risk job postings.
- Results robust to defining at-risk jobs as the top 25% occupations with the highest AI impact according to Felten et al.

Not-At-Risk Jobs Expand



- **Not-at-risk jobs:** bottom 50% occupations with the lowest AI impact according to Felten et al.

Not-At-Risk Jobs Expand

	Dependent Variable: Growth of Not-At-Risk Vacancies 2010-2018 (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	9.029	5.081	0.901	32.293***	53.169***	53.556***
	(5.771)	(5.803)	(5.650)	(4.818)	(5.137)	(3.701)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.002	0.029	0.050	0.084	0.158	0.802
Note:	SEs clustered by firm, weighting by average 2010-2018 establishment size					

- Dep var: growth of not-at-risk vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 53% increase in postings of not-at-risk jobs during 2010-2018.
- If all establishments above 10th percentile of opportunities behaved as those at 10th percentile we would have 60% fewer vacancies for not-at-risk jobs.
- Not-at-risk jobs exclude AI vacancies, so this is not explained by hiring workers needed to install and operate AI.

Robustness

	Dependent Variable: Growth of NonFeltenable Vacancies 2010-2018 (log[y+1])					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	5.155	1.651	−2.553	26.274***	45.129***	45.138***
	(5.439)	(5.460)	(5.311)	(4.486)	(4.740)	(3.352)
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	970,418	970,418	970,418	970,418	837,596	970,418
R^2	0.001	0.026	0.049	0.084	0.160	0.806

Note: SEs clustered by firm, weighting by average 2010-2018 establishment size

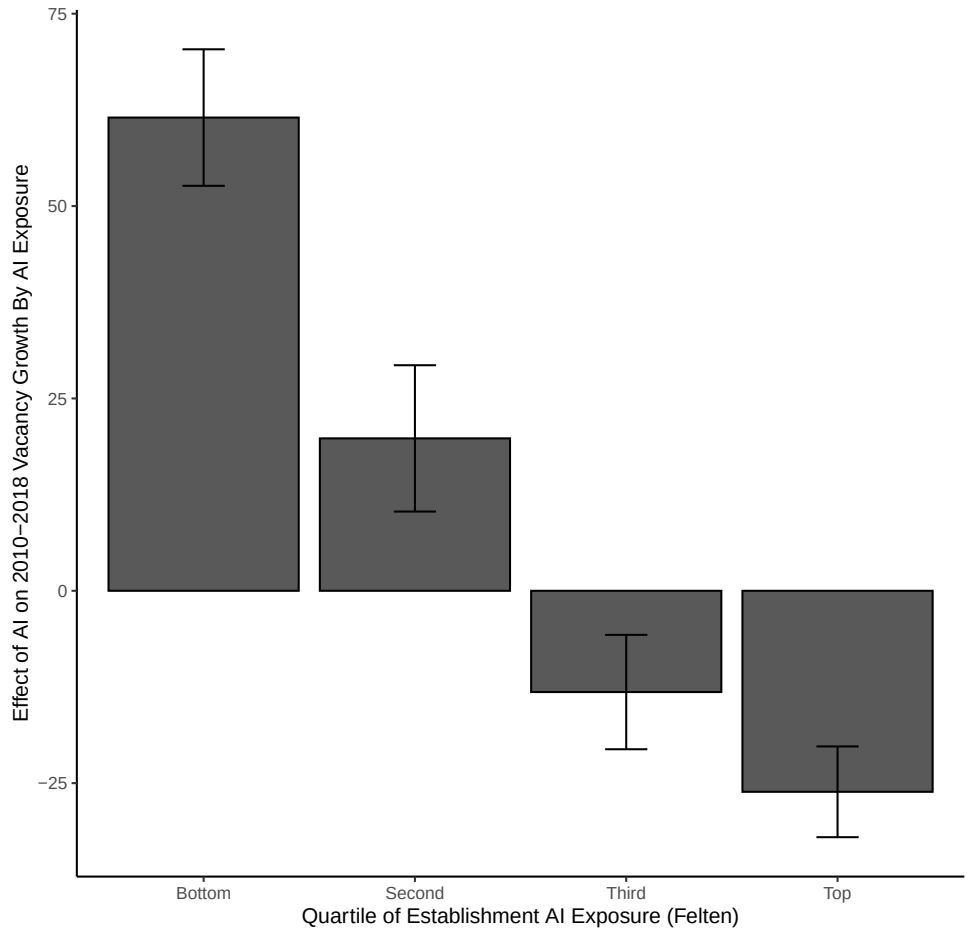
- Dep var: change in log of one plus not-at-risk vacancies between 2010-2012 and 2016-2018.
- One standard deviation in AI exposure associated with 45% increase in postings of not-at-risk jobs during 2010-2018.
- Results similar to using IHS.

Robustness

	Dependent Variable: Growth of Not-At-Risk Vacancies 2010-2018					
	Webb		SML		Felten, Bottom Quartile	
Establishment AI Exposure	53.266***	65.484***	48.770***	54.313***	61.504***	60.880***
	(8.474)	(3.911)	(7.734)	(7.133)	(4.526)	(3.539)
Firm Size Decile	Y	N	Y	N	Y	N
Establishment CZ FE	Y	Y	Y	Y	Y	Y
4 digit NAICS FE	Y	N	Y	N	Y	N
Firm FE	N	Y	N	Y	N	Y
Observations	895,916	1,046,155	895,916	1,046,155	837,304	970,103
R^2	0.164	0.837	0.155	0.836	0.196	0.770

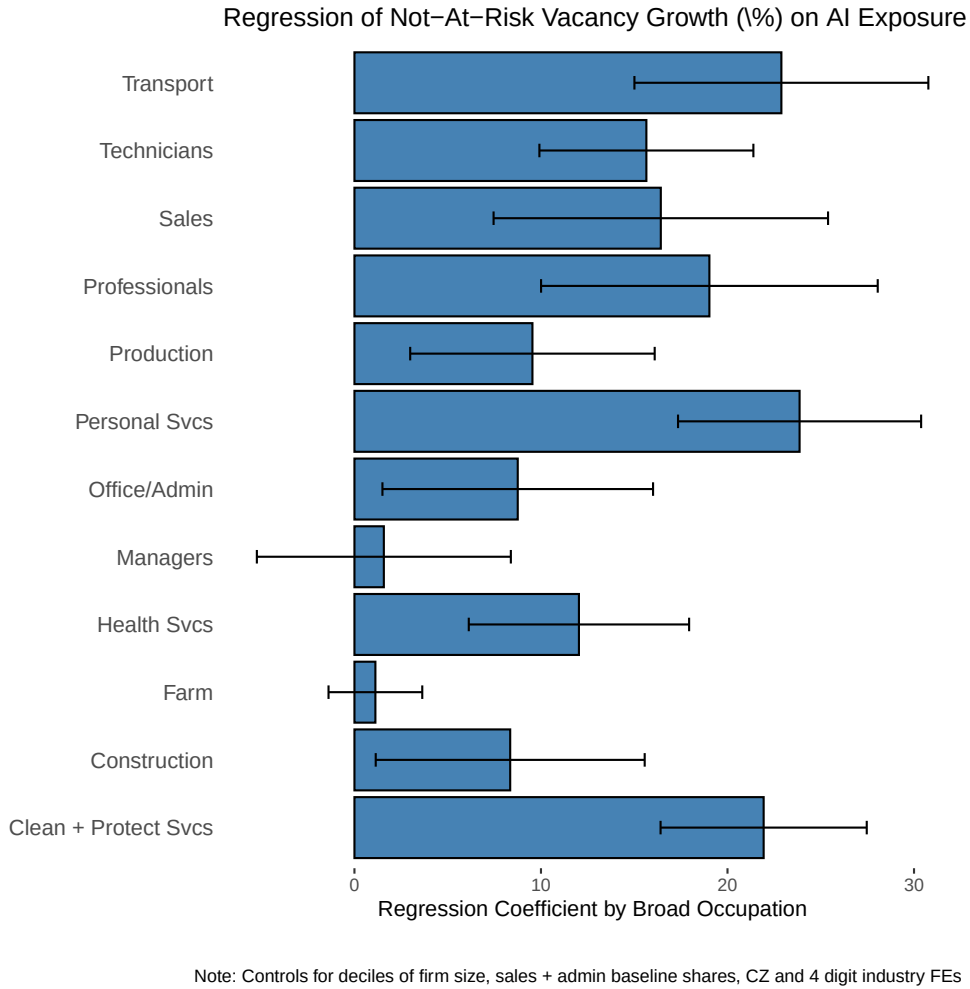
- Exposure measures based on Webb and SML also predict a similar increase in not-at-risk job postings.
- Results robust to defining not-at-risk jobs as the bottom 25% occupations with the lowest AI impact according to Felten et al.

Vacancy Postings by Quartile of AI Occupational Impact



- Expansion in posting of not-at-risk jobs apparent in both bottom and second quartiles of AI occupational impact.
- Decline in posting of at-risk jobs apparent in both top and third quartiles of AI occupational impact.

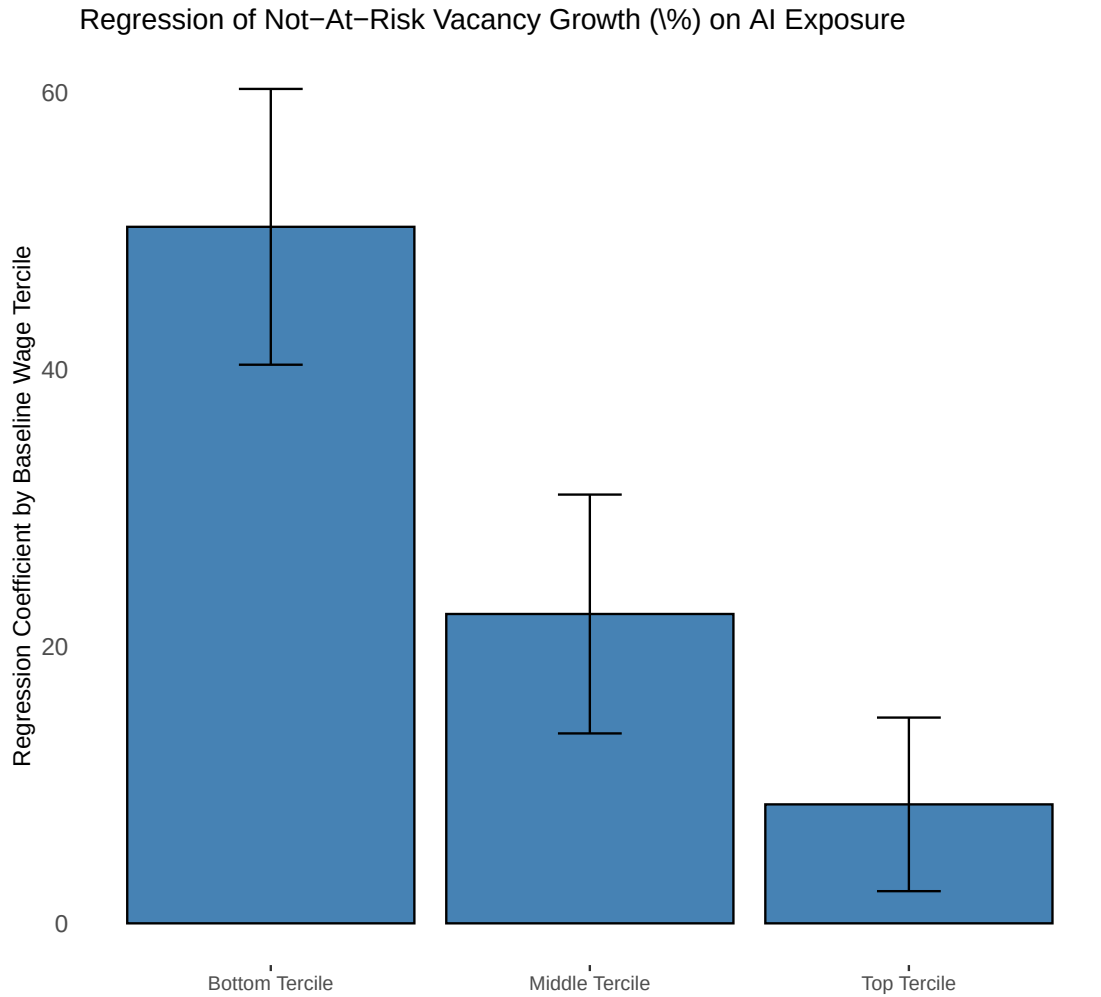
Explaining Rise in Postings of Not-at-risk Jobs



Note: Controls for deciles of firm size, sales + admin baseline shares, CZ and 4 digit industry FEs

- Increase in not-at risk job postings commonplace across occupational groups, not about jobs needed to deploy AI.
- Consistent with productivity effect in our model.

Explaining Rise in Postings of Not-at-risk Jobs



Note: Controls for deciles of firm size, sales + admin baseline shares, CZ and 4 digit industry FEs

- But rise more pronounced among low-wage occupations.

Are Adopters of AI Creating New Tasks and Jobs?

	Dependent Variable: Growth of Vacancies in New Occupations 2010-2018					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	−6.911	−5.307	−6.866	−5.177	−4.050	−0.990
	(6.819)	(6.815)	(7.289)	(8.238)	(8.496)	(10.830)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	538,441	538,441	538,441	538,441	469,835	538,441
R^2	0.008	0.021	0.033	0.036	0.177	0.558
Note:	SEs clustered by firm, weighting by average 2010-2018 establishment size					

- No evidence of firms posting jobs in occupations where it didnt hire in 2010-2012.
- New tasks and jobs (other than AI vacancies) are not just a byproduct of the deployment of AI.
- To the extent that AI is bringing new jobs and tasks, it is not doing so in firms where substitution takes place.

Are Adopters of AI Creating New Tasks and Jobs?

	Dependent Variable: Growth in Number of Unique Job Titles 2010-2018					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	7.071	4.654	2.730	−3.948	−6.616	−4.043
	(8.003)	(8.158)	(7.585)	(7.301)	(9.272)	(11.112)
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	Y	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	314,301	314,301	314,301	314,301	295,417	314,301
R^2	0.003	0.030	0.057	0.062	0.084	0.570
Adjusted R^2	0.003	0.030	0.054	0.059	0.080	0.367
Note:	SEs clustered by firm, weighting by average 2010-2018 establishment size					

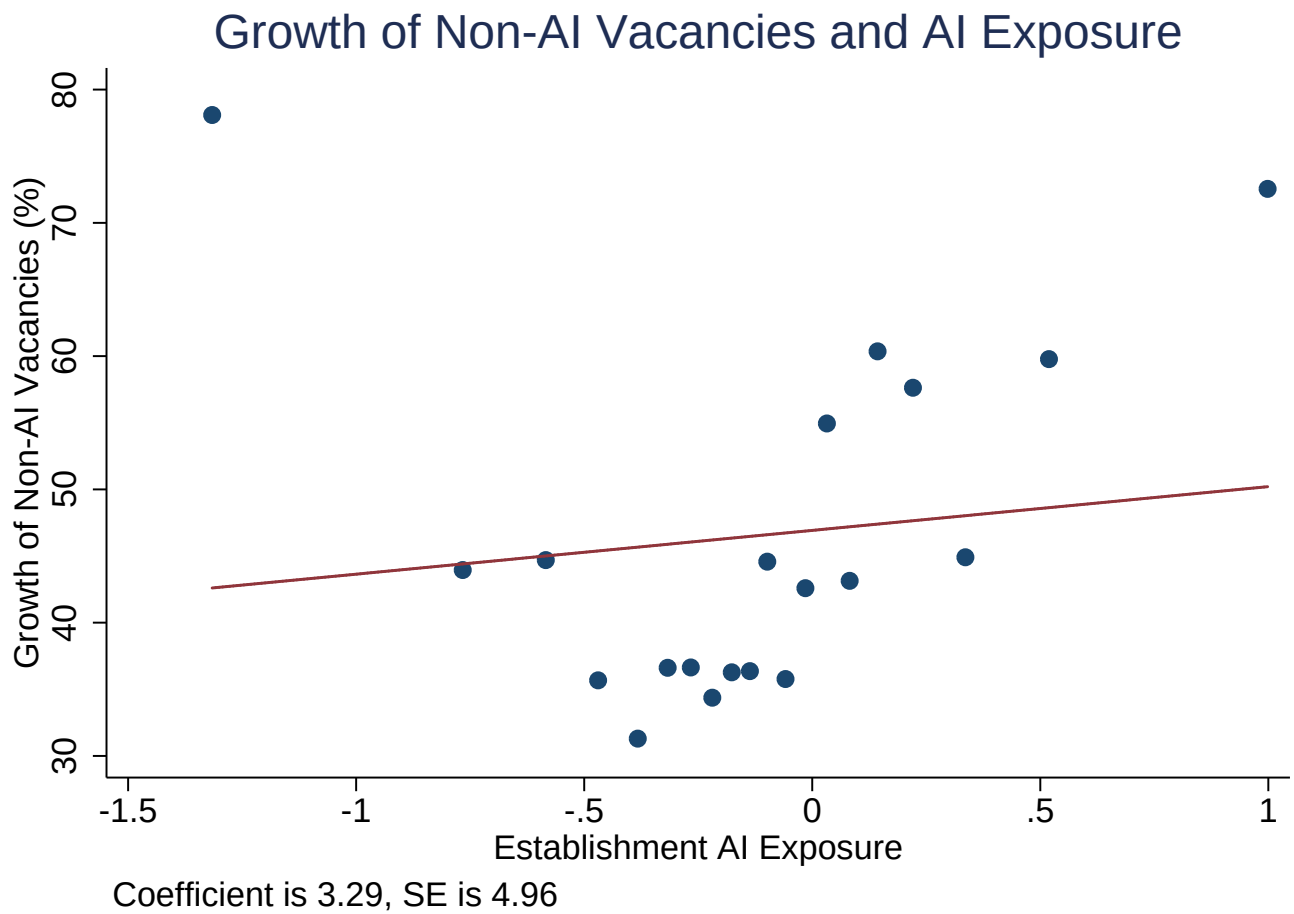
- Same conclusion when looking at increase in unique job titles among postings.

No Effect on Overall Postings

	Dependent Variable: Growth of Non-AI Vacancies 2010-2018					
	Felten		SML		Webb	
Establishment AI Exposure	3.285	-2.290	4.537	−2.835	7.555	11.993***
	(4.956)	(3.171)	(6.612)	(4.110)	(8.854)	(5.219)
Firm Size Decile	Y	N	Y	N	Y	N
Establishment CZ FE	Y	Y	Y	Y	Y	Y
4 digit NAICS FE	Y	N	Y	N	Y	N
Firm FE	N	Y	N	Y	N	Y
Observations	837,596	970,418	896,283	1,046,562	896,283	1,046,562
R^2	0.145	0.826	0.147	0.827	0.146	0.727

- Conditional on 4-digit industry fixed effects, no effect on total job postings.
- Effects on at-risk and not-at-risk cancel out.
- But significant change in composition of postings away from at-risk ones.

No Effect on Overall Postings



- Bin-scatterplot for the model in column 1, using AI exposure based on Felten et al. measure.

Effect on Typical Wages of Jobs Posted

	Dependent Variable: Establishment Wage Growth 2010-2018 (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Establishment AI Exposure	−4.372***	−4.244***	−4.578***	−12.335***	−16.112***	−18.610***
	(0.528)	(0.523)	(0.532)	(0.683)	(0.641)	(0.730)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y	N
Establishment CZ FE	N	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N	N
4 digit NAICS FE	N	N	N	N	Y	N
Firm FE	N	N	N	N	N	Y
Observations	307,886	307,886	307,886	307,886	289,783	307,886
R^2	0.066	0.068	0.080	0.174	0.259	0.641

Note: SEs clustered by firm, weighting by average 2010-2018 establishment size

- In line with shift in composition of jobs posted, we estimate a shift in postings towards occupations that pay lower wages on average.
- Impute mean establishment wage from occupation-state wage (2010-2012 Occupational Employment Statistics)
- Measures typical wage of jobs posted by establishment

Spillover Effects

- One important caveat: Acemoglu, Lelarge and Restrepo (2019) — firms adopting robots expand at the expense of firms not adopting robots in the same sector (in French data).
- This form of substitution across firms/establishments may operate in our context, with important implications for labor demand.
- In particular, rise in not-at-risk postings among establishments with opportunities for substitution may come at expense of postings in competitors who cannot leverage AI.
- We explore this possibility by estimating

$$\Delta Y_s = \beta \cdot \text{AI exposure}_{st_0} + \beta^S \cdot \overline{\text{AI exposure}}_{m(s)t_0} + \theta X_s + \eta_{z(s)} + \varepsilon_s$$

- β^S captures this reallocation to other establishments in the same market ($m(s)$ defined by 4-digit industry for tradables, and 4-digit industry and commuting zone for non-tradables).

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Spillover Effects

	Dependent Variable: Growth of Not-At-Risk Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	36.508***	33.181***	30.579***	36.998***	40.911***
	(3.030)	(2.860)	(2.784)	(2.896)	(2.857)
Market AI Exposure	−58.004***	−59.977***	−66.654***	−36.837***	−10.930*
	(4.577)	(4.230)	(3.923)	(4.964)	(6.048)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y
Establishment CZ FE	N	N	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N
3 digit NAICS FE	N	N	N	N	Y
Observations	830,832	830,832	830,832	830,832	830,832
R^2	0.015	0.046	0.069	0.090	0.127
Note:	SEs clustered by market, weighting by average 2010-2018 establishment size				

- Due to spillovers, aggregate job posting in not-at-risk jobs will not go up as much as suggested by establishment regressions.
- caveat: cannot separately identify detailed industry fixed effects or firm fixed effects, since these are almost collinear with our definition of markets

Spillover Effects

	Dependent Variable: Growth of At-Risk Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	−34.944***	−38.131***	−40.176***	−41.008***	−39.173***
	(2.743)	(2.531)	(2.393)	(2.454)	(2.415)
Market AI Exposure	4.122	2.229	−2.364	0.351	5.667
	(4.616)	(4.204)	(3.820)	(3.890)	(4.501)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y
Establishment CZ FE	N	N	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N
3 digit NAICS FE	N	N	N	N	Y
Observations	830,832	830,832	830,832	830,832	830,832
R^2	0.019	0.053	0.073	0.093	0.127
Note:	SEs clustered by market, weighting by average 2010-2018 establishment size				

- No spillovers in at-risk job postings among competitors.

Spillover Effects

	Dependent Variable: Growth of AI Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	27.874***	28.994***	26.926***	24.033***	23.496***
	(1.975)	(1.943)	(1.741)	(1.869)	(1.855)
Market AI Exposure	23.777***	24.425***	19.314***	3.213	−0.719
	(3.946)	(3.953)	(3.185)	(3.043)	(5.177)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y
Establishment CZ FE	N	N	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N
3 digit NAICS FE	N	N	N	N	Y
Observations	830,832	830,832	830,832	830,832	830,832
R^2	0.077	0.087	0.130	0.146	0.169
Note:	SEs clustered by market, weighting by average 2010-2018 establishment size				

- No robust evidence of spillovers on AI adoption among competitors.

Spillover Effects

	Dependent Variable: Growth of Non-AI Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	−7.978**	−11.140***	−13.770***	−10.369***	−7.170**
	(3.183)	(2.979)	(2.842)	(2.916)	(2.907)
Market AI Exposure	−30.627***	−32.423***	−38.741***	−20.945***	−5.359
	(5.063)	(4.710)	(4.317)	(4.873)	(5.911)
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	N	Y	Y	Y	Y
Establishment CZ FE	N	N	Y	Y	Y
2 digit NAICS FE	N	N	N	Y	N
3 digit NAICS FE	N	N	N	N	Y
Observations	830,832	830,832	830,832	830,832	830,832
R^2	0.010	0.038	0.061	0.081	0.115
Note:	SEs clustered by market, weighting by average 2010-2018 establishment size				

- Due to spillovers, aggregate job posting in non-AI vacancies could decline.
- caveat: cannot separately identify industry fixed effects or firm fixed effects, since these are almost collinear with our definition of markets

Spillover Effects

- Complementary IV strategy for spillover effects

$$\Delta Y_s = \beta \cdot \text{AI exposure}_{st_0} + \beta^S \cdot \overline{\text{AI exposure}}_{m(s)t_0} + \theta X_s + \eta_{z(s)} + \varepsilon_s$$

- Instrument $\overline{\text{AI exposure}}_{m(s)t_0}$ using AI exposure among HQ of competitors:

$$\text{market HQ AI exposure}_{m(s)t_0} = \sum_{s' \in m(s) \setminus s} \omega_{s't_0} \text{HQ AI exposure}_{s't_0}$$

- **Relevance:** When firms roll AI in their HQ there are synergies to using it in secondary establishments.
- **Identification:** For non-tradables, HQ of competitors belong to different markets facing different shocks and demand conditions.
- Focus on sample of establishments in non-tradable sector (excluding agriculture, mining, and manufacturing)

Spillover Effects

	Dependent Variable: Growth of Not-At-Risk Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	34.053***	29.588***	39.490***	43.369***	60.808***
	(3.511)	(3.293)	(3.346)	(3.221)	(5.380)
Market AI Exposure	−56.513***	−61.051***	−35.539***	−34.287***	−86.088***
	(4.962)	(4.330)	(5.913)	(8.045)	(15.005)
Headquarters IV	Y	Y	Y	Y	Y
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	Y	Y	Y	Y	Y
Establishment CZ FE	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	Y	N	N
3 digit NAICS FE	N	N	N	Y	Y
Sectors 44-45, 72 only	N	N	N	N	Y
Observations	707,127	707,127	707,127	707,127	135,743
R^2	0.043	0.070	0.092	0.131	0.186

Note: SEs clustered by market, weighting by average 2010-2018 establishment size. Excludes Sectors 11, 21 and 31-33.

- Rise in posting of not-at-risk jobs at the expense of other establishments in same market.
- Holds even when we focus on retail and personal services in column 5.

Spillover Effects

	Dependent Variable: Growth of At-Risk Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	−38.298***	−41.317***	−43.498***	−39.969***	−43.786***
	(2.763)	(2.595)	(2.708)	(2.648)	(4.184)
Market AI Exposure	12.598***	10.016***	15.430***	2.817	−7.716
	(4.150)	(3.595)	(4.887)	(6.991)	(12.217)
Headquarters IV	Y	Y	Y	Y	Y
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	Y	Y	Y	Y	Y
Establishment CZ FE	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	Y	N	N
3 digit NAICS FE	N	N	N	Y	Y
Sectors 44-45, 72 only	N	N	N	N	Y
Observations	707,127	707,127	707,127	707,127	135,743
R^2	0.049	0.070	0.088	0.126	0.182

Note: SEs clustered by market, weighting by average 2010-2018 establishment size. Excludes Sectors 11, 21 and 31-33.

- No spillovers in at-risk job postings among competitors.

Spillover Effects

	Dependent Variable: Growth of AI Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	28.742***	25.839***	22.105***	21.167***	27.500***
	(2.005)	(1.756)	(1.880)	(1.947)	(4.706)
Market AI Exposure	25.265***	21.350***	−4.071	−10.376	4.711
	(4.967)	(3.673)	(3.603)	(8.849)	(15.169)
Headquarters IV	Y	Y	Y	Y	Y
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	Y	Y	Y	Y	Y
Establishment CZ FE	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	Y	N	N
3 digit NAICS FE	N	N	N	Y	Y
Sectors 44-45, 72 only	N	N	N	N	Y
Observations	707,127	707,127	707,127	707,127	135,743
R^2	0.089	0.139	0.160	0.181	0.160

Note: SEs clustered by market, weighting by average 2010-2018 establishment size. Excludes Sectors 11, 21 and 31-33.

- No robust evidence of spillovers on AI adoption among competitors.

Spillover Effects

	Dependent Variable: Growth of Non-AI Vacancies 2010-2018 (%)				
	(1)	(2)	(3)	(4)	(5)
Establishment AI Exposure	−8.593**	−12.910***	−8.219**	−4.911	16.854***
	(3.455)	(3.230)	(3.330)	(3.249)	(5.117)
Market AI Exposure	−26.590***	−30.415***	−16.573***	−32.876***	−84.695***
	(4.922)	(4.284)	(5.717)	(7.773)	(14.474)
Headquarters IV	Y	Y	Y	Y	Y
Baseline Share, Sales + Admin	Y	Y	Y	Y	Y
Firm Size Decile	Y	Y	Y	Y	Y
Establishment CZ FE	N	Y	Y	Y	Y
2 digit NAICS FE	N	N	Y	N	N
3 digit NAICS FE	N	N	N	Y	Y
Sectors 44-45, 72 only	N	N	N	N	Y
Observations	707,127	707,127	707,127	707,127	135,743
R^2	0.033	0.058	0.077	0.114	0.164

Note: SEs clustered by market, weighting by average 2010-2018 establishment size. Excludes Sectors 11, 21 and 31-33.

- Although establishments with opportunities for AI are not expanding, deployment of AI seems to reduce job postings in competitors.

Conclusion

- Significant upsurge in AI adoption inferred from vacancy postings. AI is probably not just a gimmick.
- Outside sectors 51 and 54, firms adopting AI appear to be the ones with the greatest opportunities to substitute some of their workforce with algorithms.
- No effect on total postings at these firms, but significant shift away from postings of jobs at-risk of replacement.
- No evidence that AI is either destroying jobs big time or creating net employment growth.
- Some evidence of spillovers across competing firms.