Quantifying the impact of AI on productivity and labor demand: evidence from U.S. Census microdata

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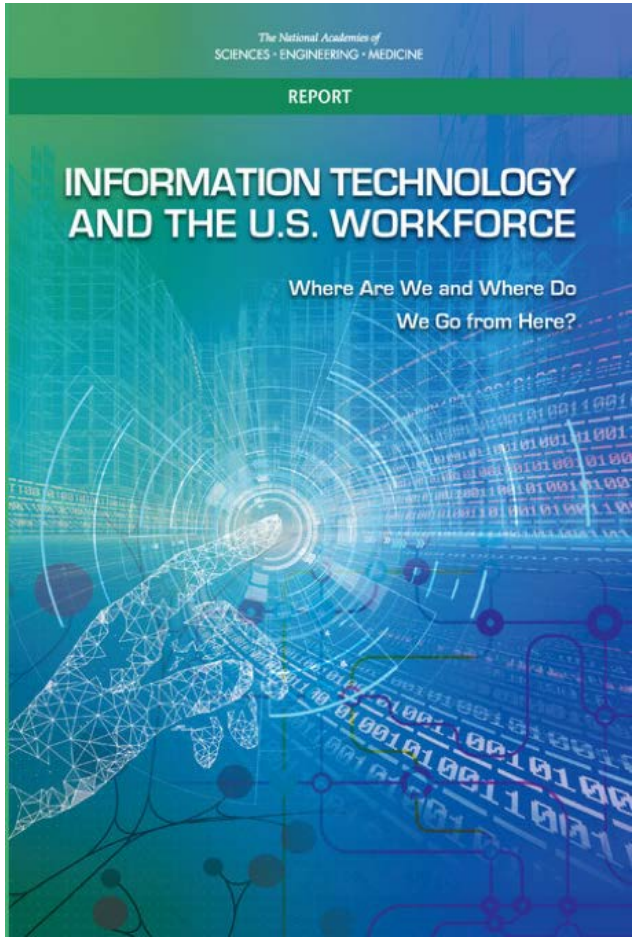
Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau or the National Bureau of Economic Research. All results have been reviewed to ensure that no confidential information is disclosed. The DRB codes for this project are: DRB-B0027-CED-20190205, CBDRB-FY19-414, and CBDRB-FY20-105.

AI as a general purpose technology?



- Many commentators view AI as an emerging general purpose technology…
- Potentially powerful enough to boost productivity growth, addressing one of the American economy's core challenges.
- It could also eventually generate significant disruption in the labor market.
- We are (probably) at a very early stage in the process of development and diffusion of AI

The need for firm level data…and the challenge of finding it

Erik Brynjolfsson, MIT

Tom Mitchell, CMU

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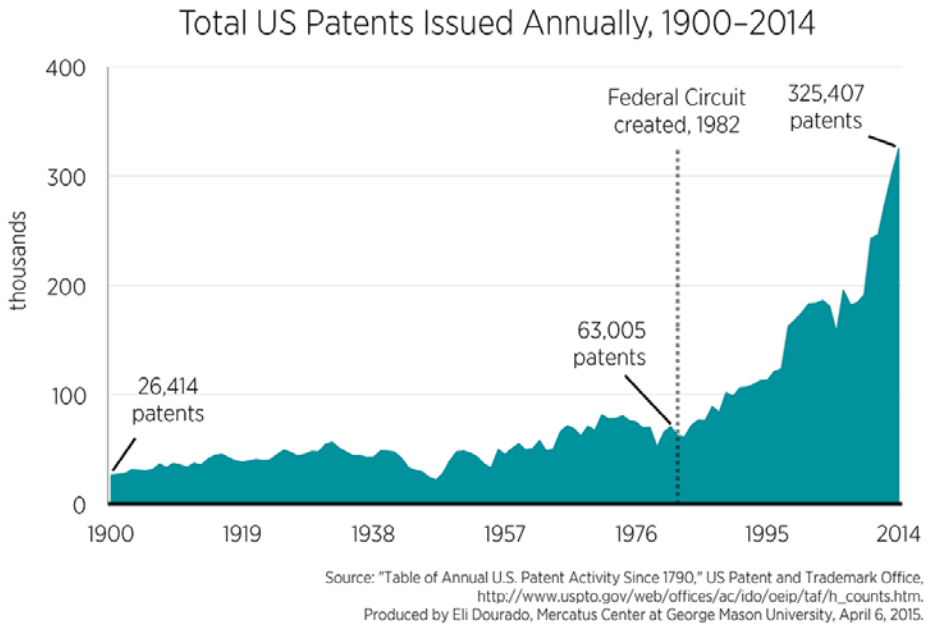
Track how technology is transforming work

Without data on how artificial intelligence is affecting jobs, policymakers will fly blind into the next industrial revolution, warn **Tom Mitchell** and **Erik Brynjolfsson**.

- The good news: we have some time to get ahead of any AI-driven disruption, putting in place policies that could cushion those displaced by new technology.
- The bad news: we lack basic data on how firms are developing and deploying AI systems.
- Current efforts to survey firms directly are laudable and necessary, but it may take years before these data acquire the panel dimension we need to measure the impacts we seek to quantify.
- Is there anything else we can do?

Our idea: use patent data to map the movement of AI concepts into commercial use…



Source: "Table of Annual U.S. Patent Activity Since 1790," US Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm.
Produced by Eli Dourado, Mercatus Center at George Mason University, April 6, 2015.

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(12) **Patent Application Publication**
Apsley et al.

(10) **Pub. No.: US 2015/0052024 A1**
(43) **Pub. Date: Feb. 19, 2015**

(54) **PROVIDING SERVICES RELATED TO ITEM DELIVERY VIA 3D MANUFACTURING ON DEMAND**

(71) Applicant: **Amazon Technologies, Inc.**, Reno, NV (US)

(72) Inventors: **Linda Knowlton Apsley**, Sammamish, WA (US); **Colin Ian Bodell**, Seattle, WA (US); **Jacob Conrad Danton**, Bellevue, WA (US); **Scott Randall Hayden**, Woodinville, WA (US); **SaiPrasad Kapila**, Redmond, WA (US); **Eric Lessard**, Goodyear, AZ (US); **Robert Benjamin Uhl**, Seattle, WA (US)

(73) Assignee: **Amazon Technologies, Inc.**, Reno, NV (US)

(21) Appl. No.: **14/076,127**

(22) Filed: **Nov. 8, 2013**

Related U.S. Application Data

(60) Continuation-in-part of application No. 13/799,877, filed on Mar. 13, 2013, which is a division of application No. 12/890,334, filed on Sep. 24, 2010, now Pat. No. 8,412,588.

Publication Classification

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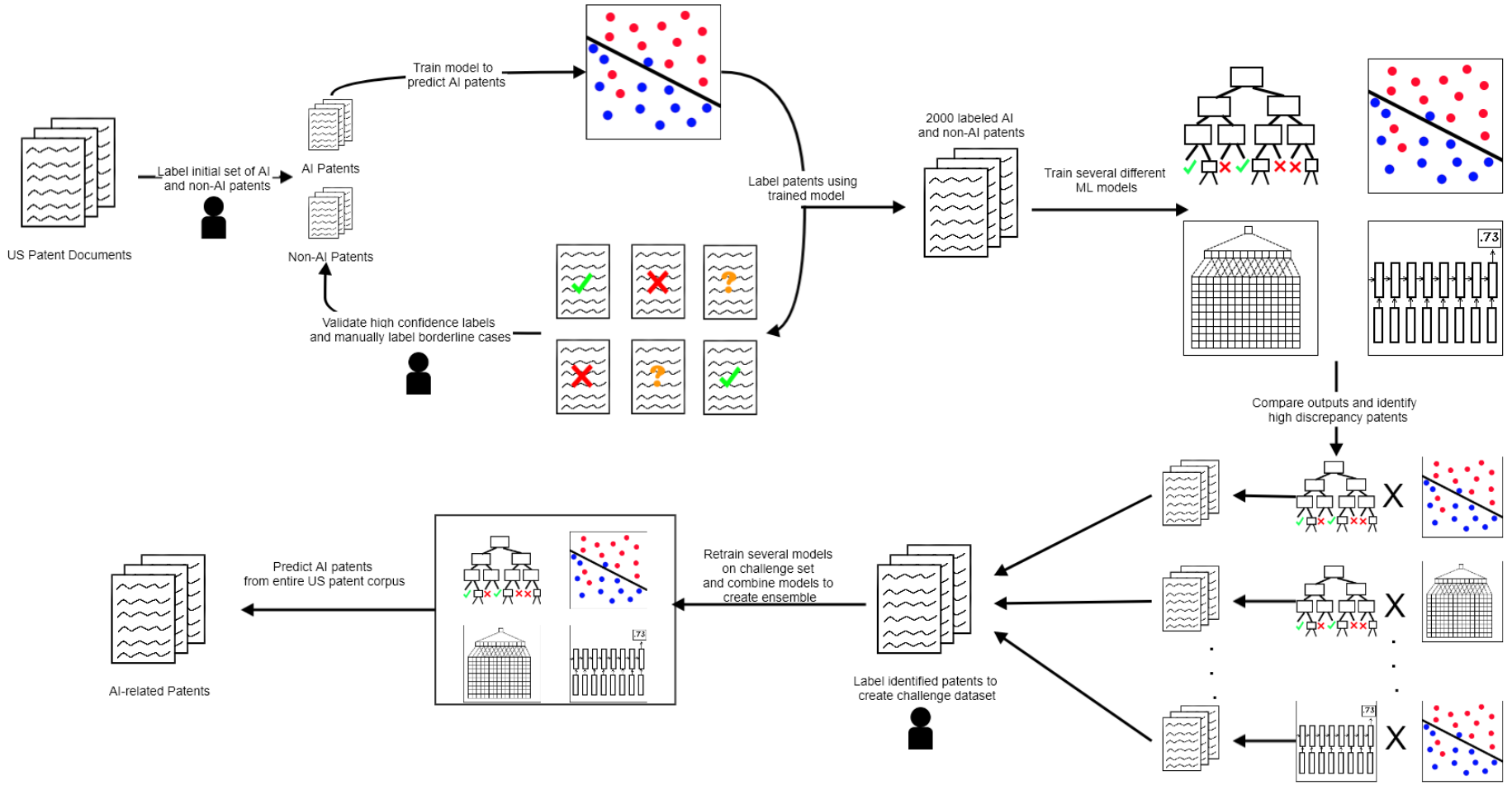
G06Q 30/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G06Q 30/0635*** (2013.01)
USPC **705/26.81**

(57) **ABSTRACT**

Methods and systems can be provided for providing items manufactured on demand to users. A user request for an item can be received. The item can have 3D manufacturing instructions associated therewith. A delivery method for the item can be determined. A manufacturing apparatus can be selected to manufacture the item based on the 3D manufacturing instructions. Instructions can be sent to the manufacturing apparatus to manufacture the item based on the 3D manufacturing instructions. Delivery instructions can be provided for delivering the item according to the delivery method.

Using AI to find AI inventions…



Our methods find far more AI patents than other approaches taken by economists

- Cockburn et al. (2019) take a “standard approach,” focusing on a relatively small set of key words and patent classes.
- This approach identifies fewer than 14,000 patents between 1990 and 2014, and it includes large numbers of ”robotics hardware” patents.
- Webb et al. (2019) take a similar, more focused approach, identifying 2,000+ patents related to ”machine learning” and 4,000+ related to “neural networks.”
- Our approach identifies 52,896 patents that are AI related with 95% confidence and 146,952 patents that are AI related with 70% confidence.
- We identify most of the AI patents tagged by other economists as ”AI patents” but also capture a very large number that traditional techniques omit.

AI patenting has grown rapidly in recent years

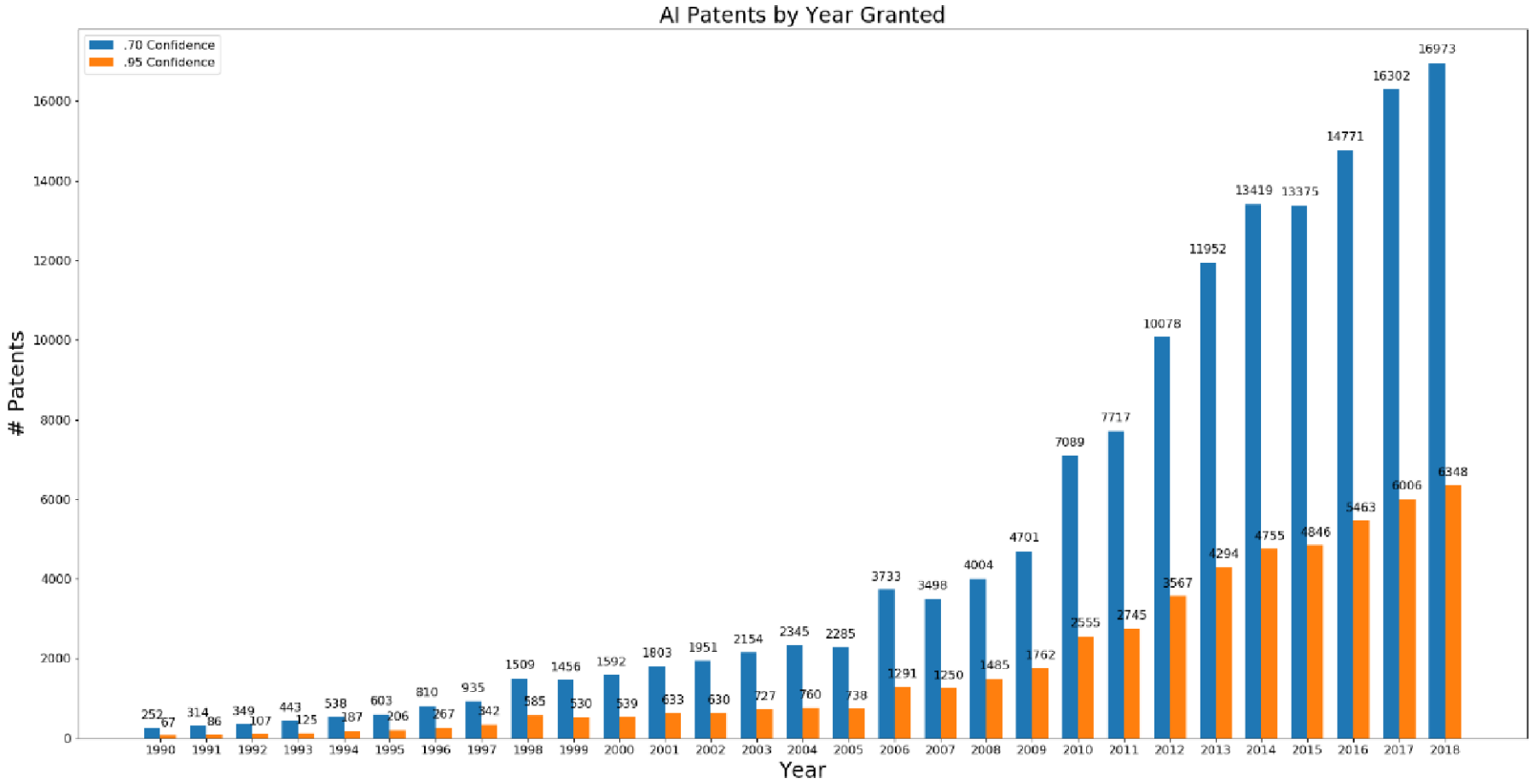


Figure 2. AI Patents by Grant Year

AI patenting is widely distributed across patent classes…

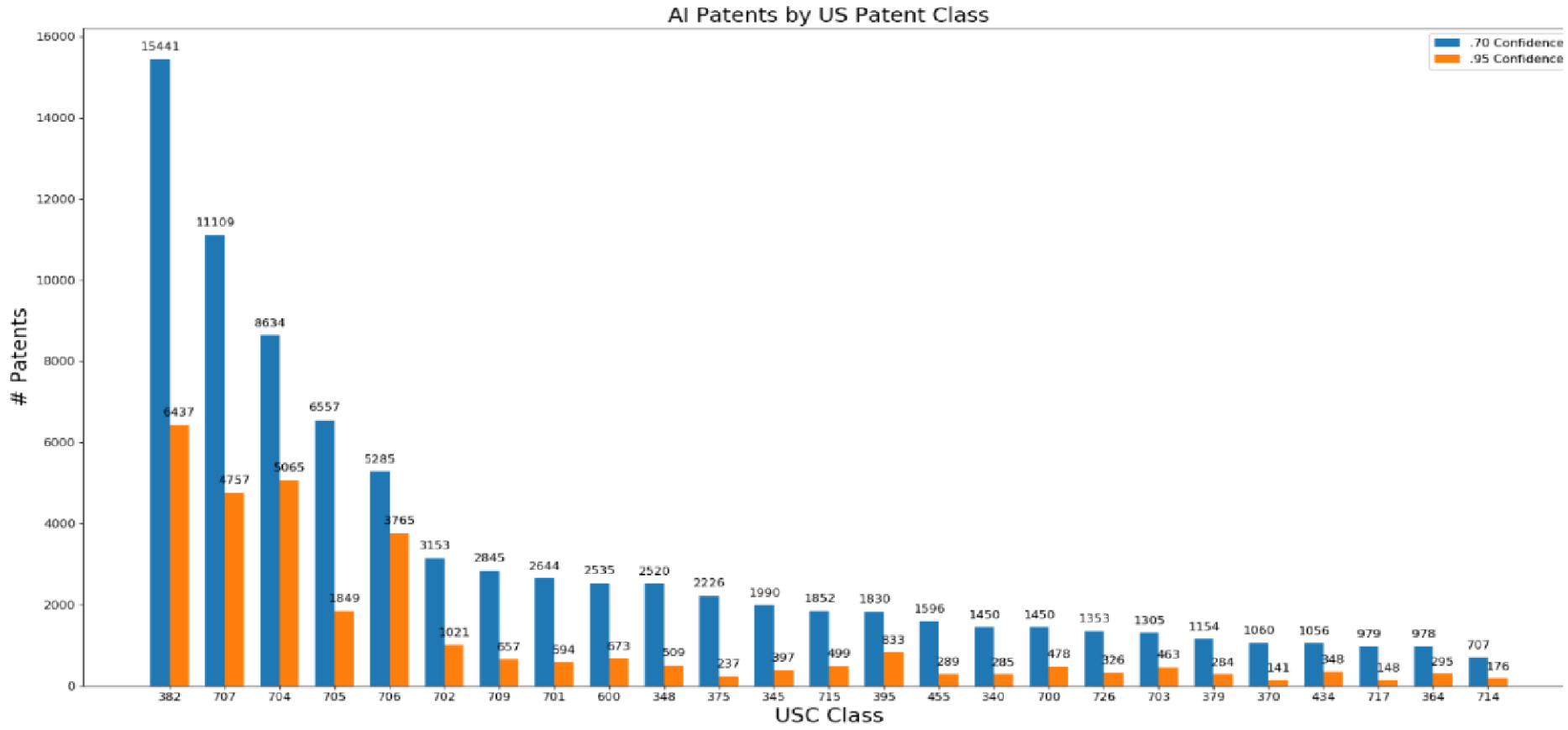
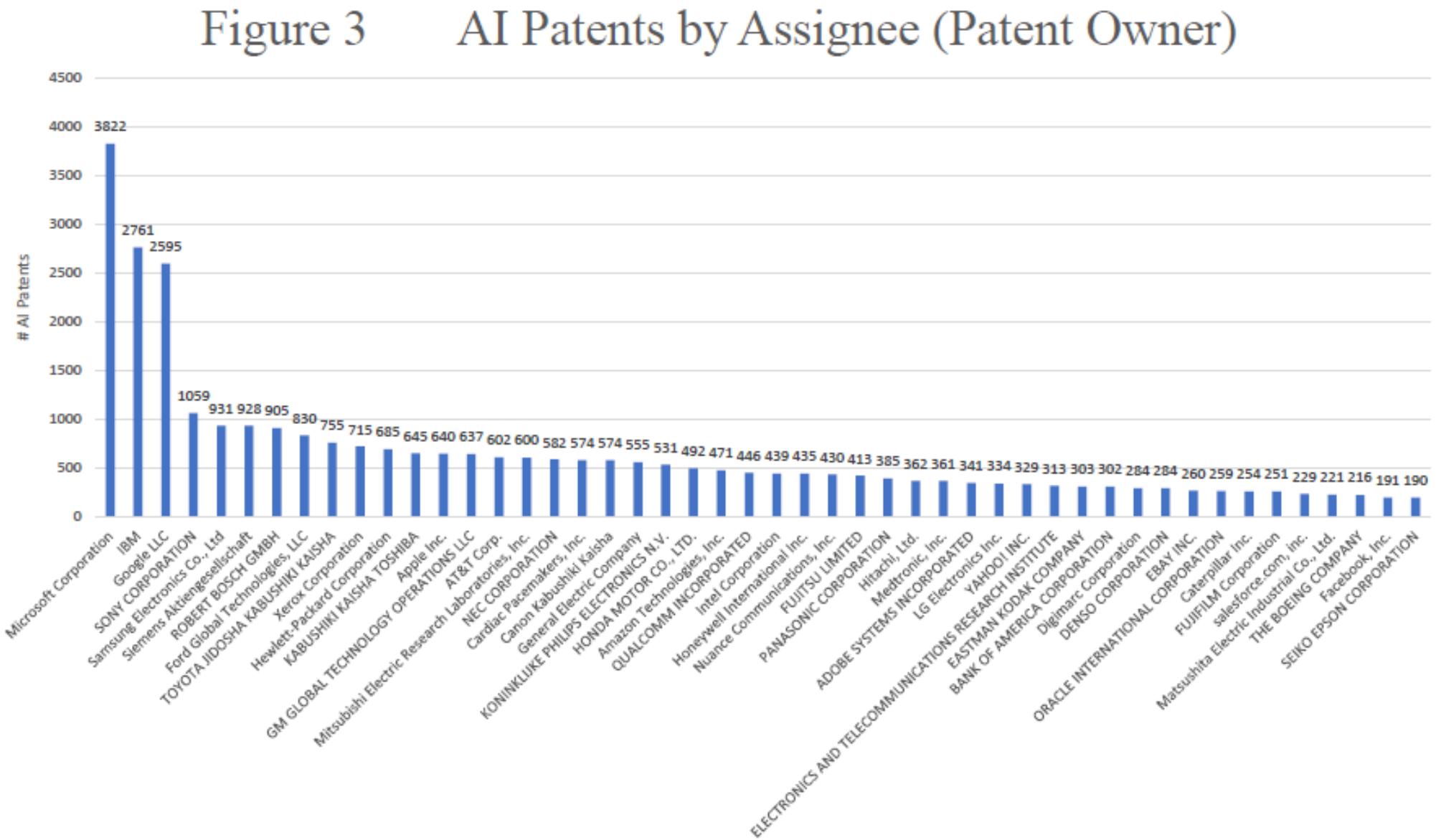


Figure 5. AI Patents by USPC Class

And across firms….



AI patenting is concentrated in a few metro areas within the United States…

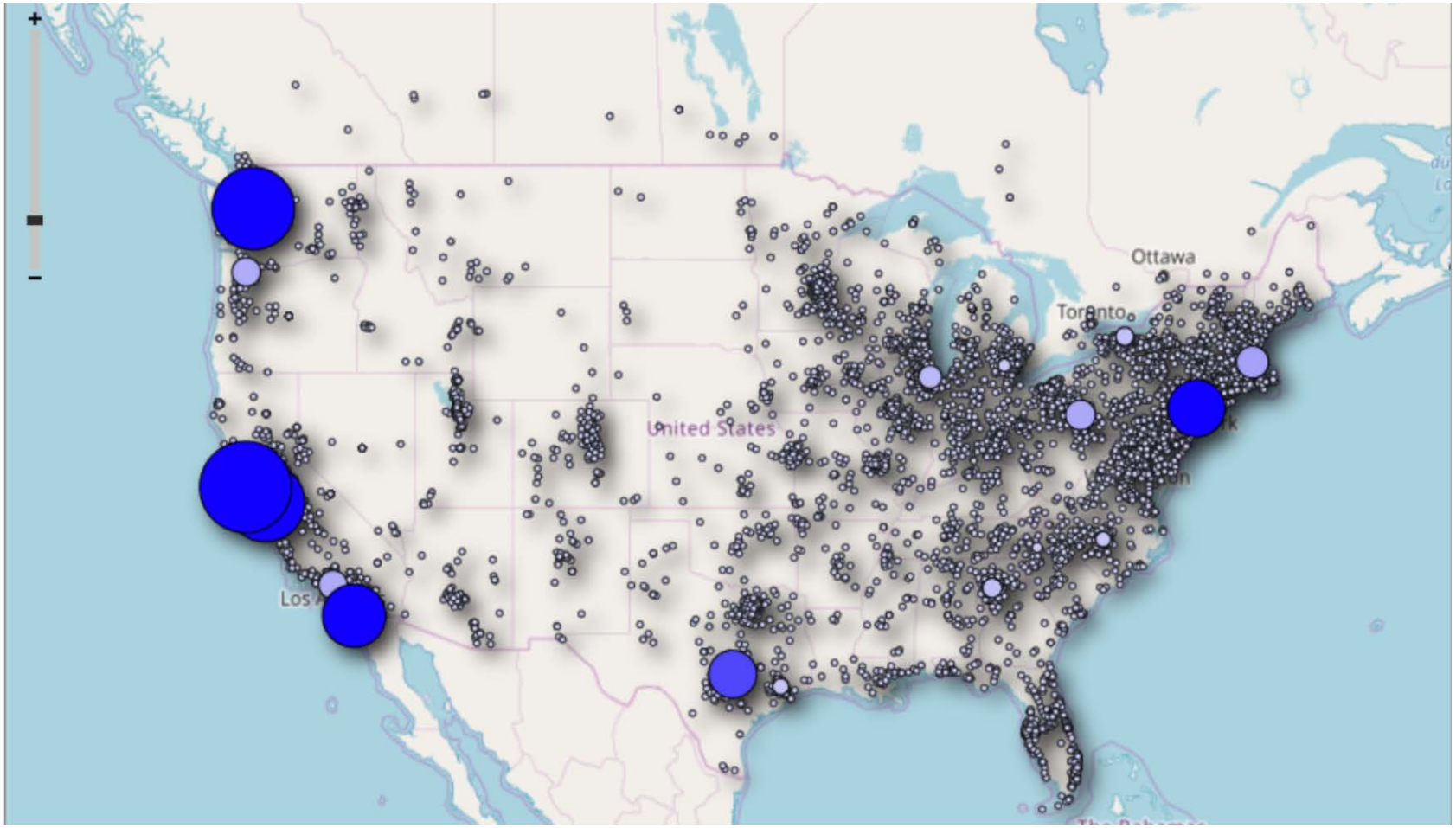


Figure 4 Inventor Heat Map of AI Patents in U.S

U.S.-based inventors appear to play a dominant role in this domain

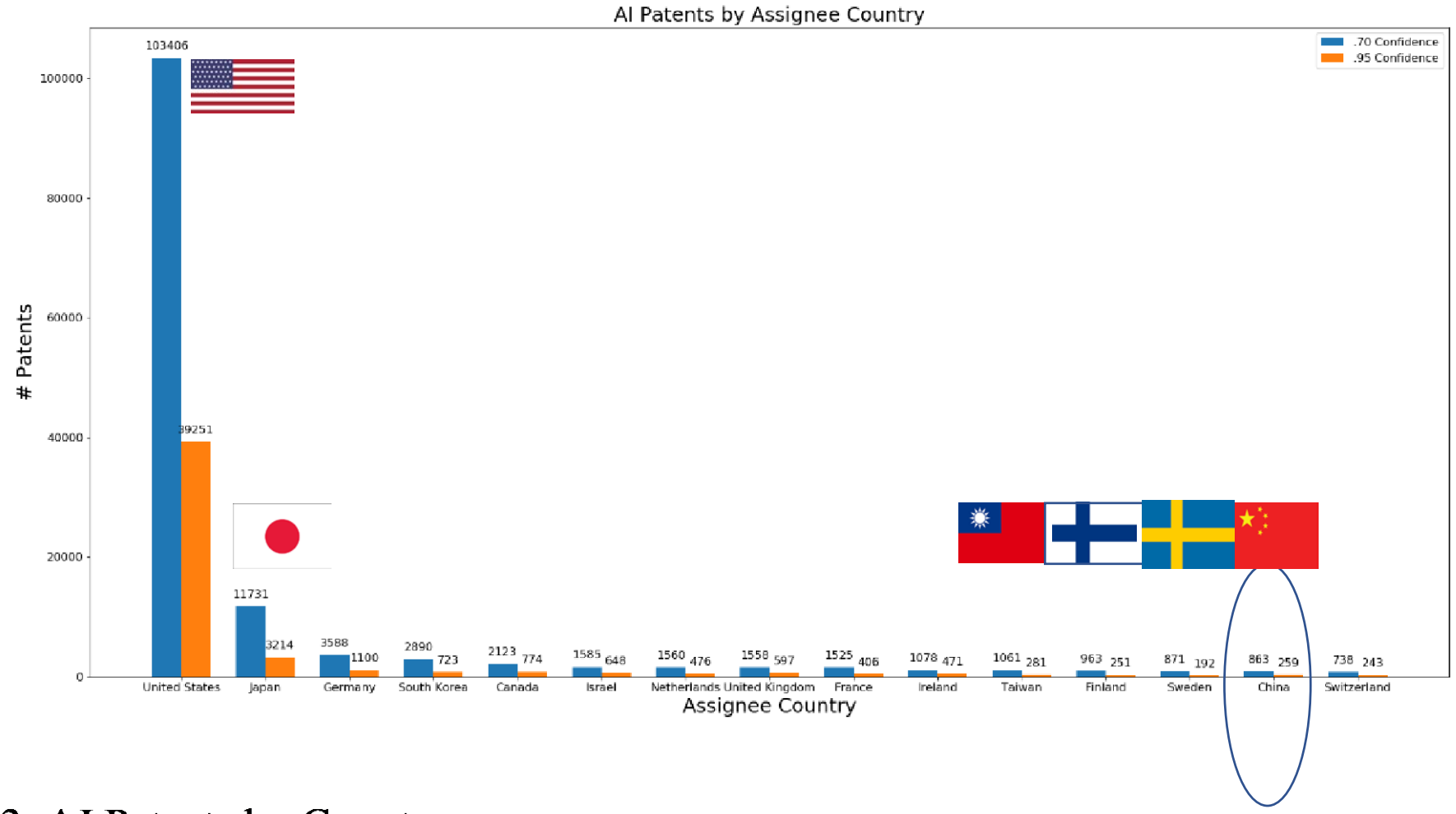
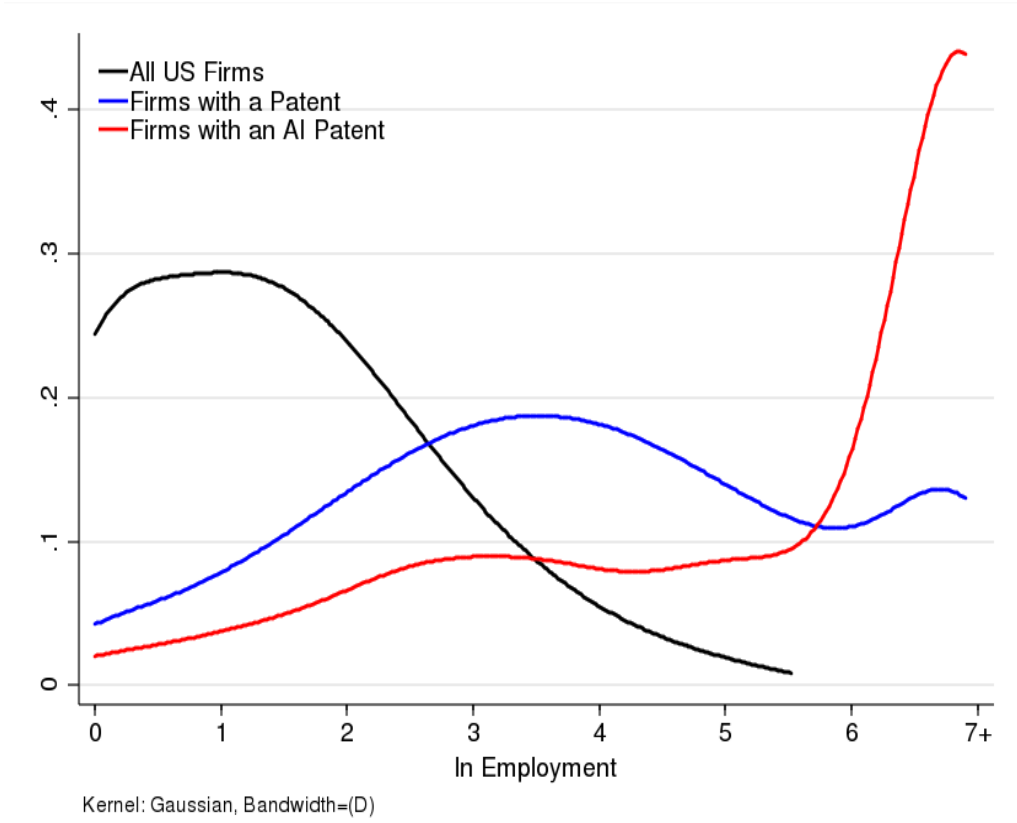
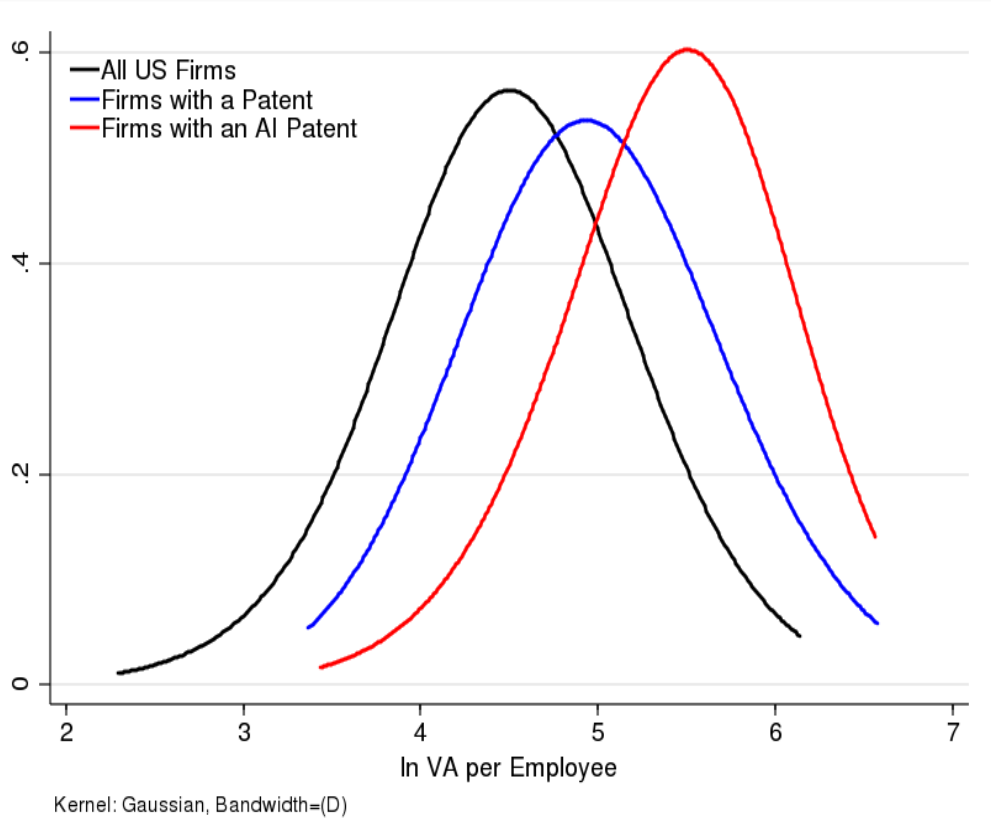


Figure 3. AI Patents by Country

USPTO Patent to Census Crosswalk – recent work by Graham et al. (2018) generated a patent-to-firm crosswalk for USPTO and Census data. We can apply this crosswalk to the set of AI patents and assess firm performance before and after a firm innovates in AI.





AI invention increases employment…

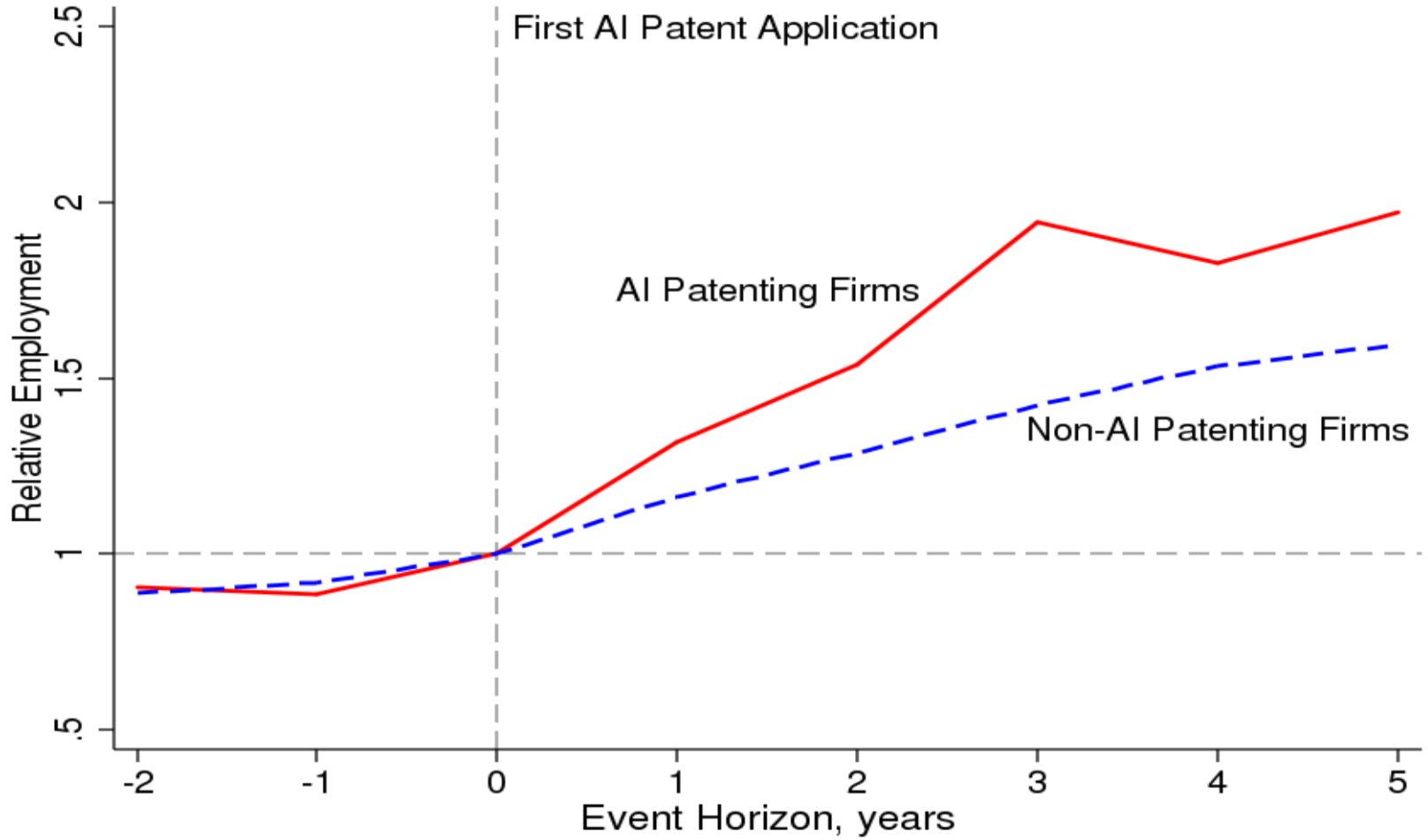


Figure 7. Pre/Post AI Patent Employment Growth

AI invention increases revenue…

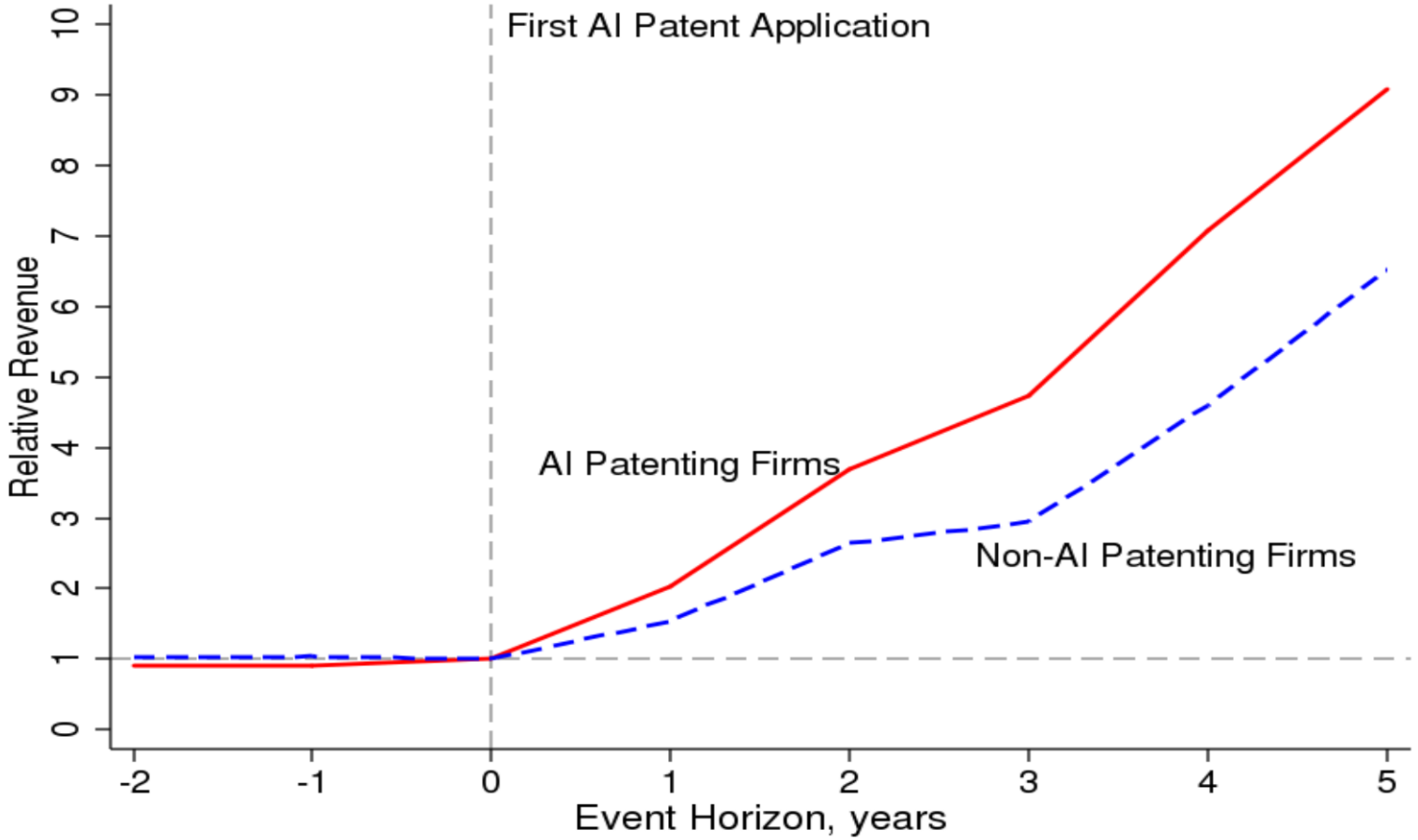
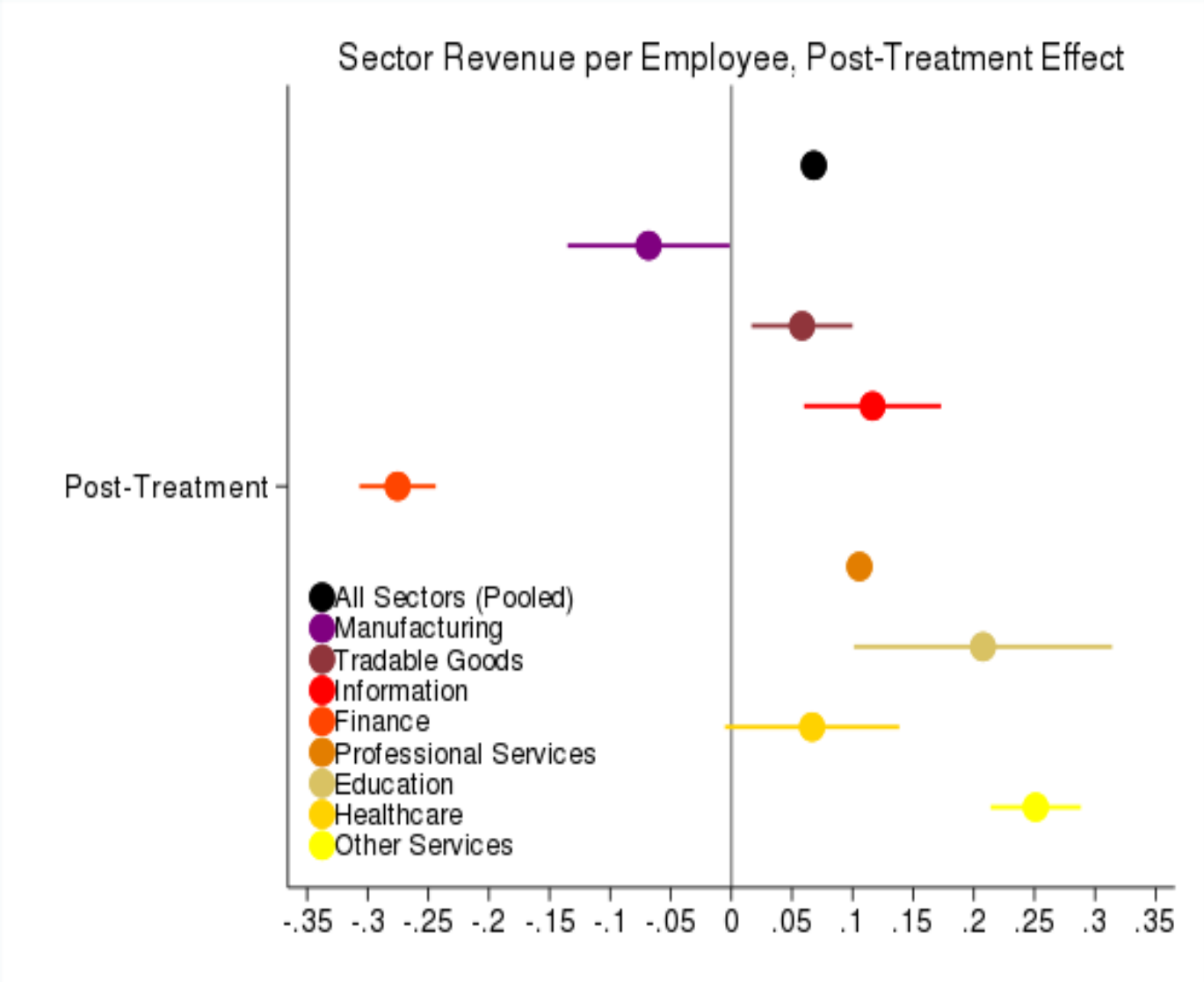


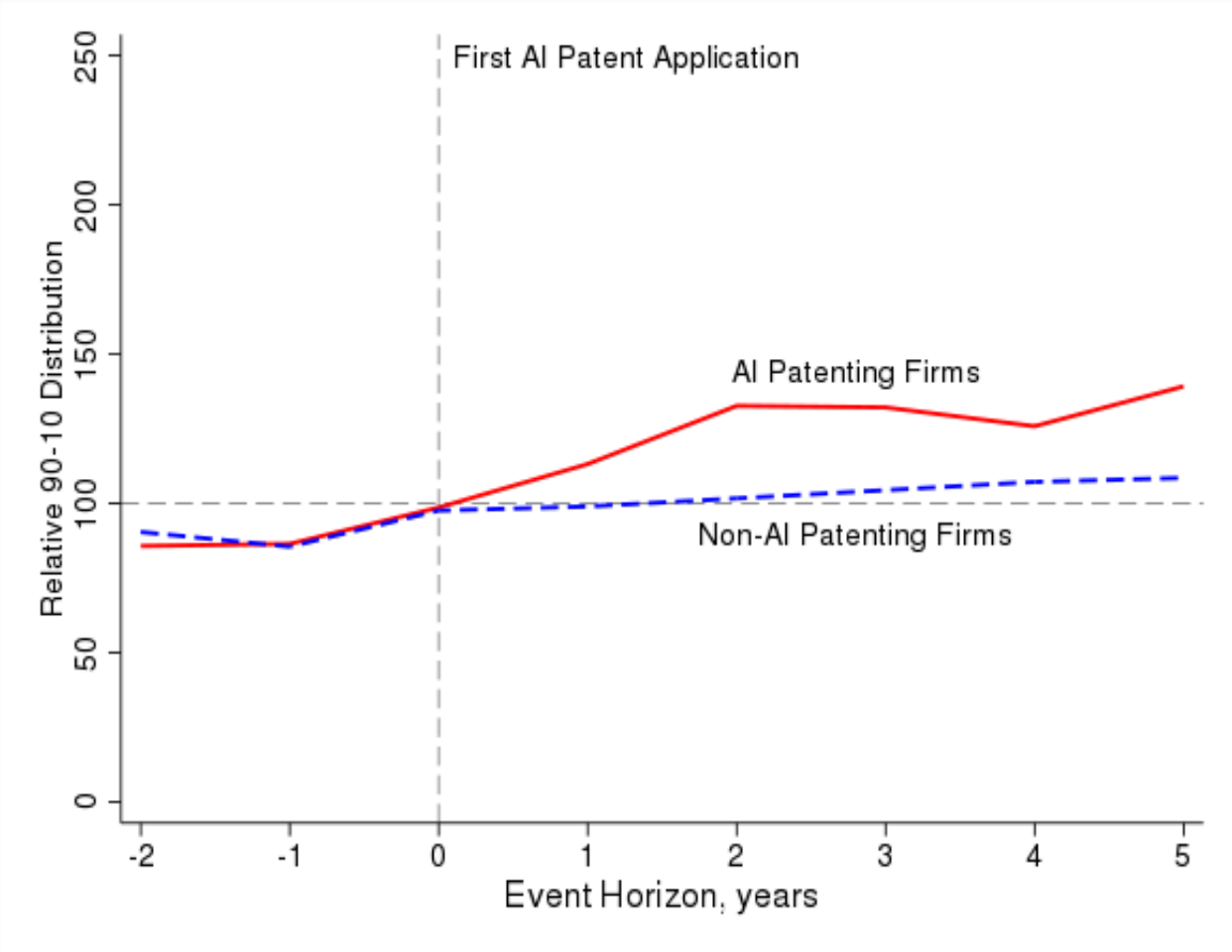
Figure 8. Pre/Post AI Patent Revenue Growth

AI impact on revenue per employee varies across sectors



AI impact on revenue per employee varies across service subsectors

AI widens within firm earnings inequality



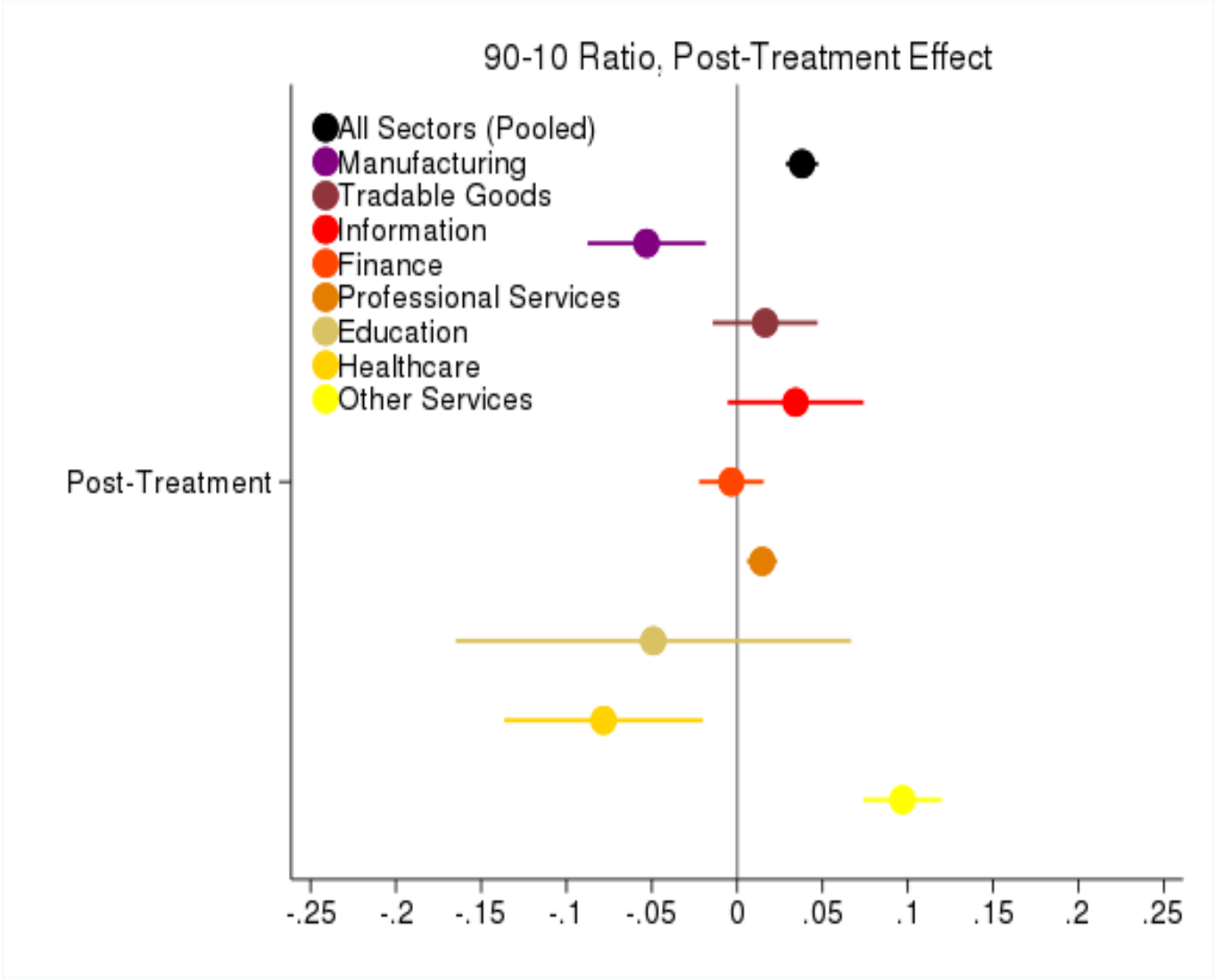
AI invention widens within-firm earnings inequality in the full sample

Table 8: Impact of AI Innovations on 90-10, 90-50 and 50-10 Earnings Ratio, 1997-2016 (full matched set of firms)

	90-10 Earnings Ratio	90-50 Earnings Ratio	50-10 Earnings Ratio
AI Treatment (1/0)	-0.0377***	-0.00690**	-0.0213***
	(0.00324)	(0.00220)	(0.00210)
Post AI Year	-0.00375	-0.00162	-0.00477**
	(0.00275)	(0.00186)	(0.00178)
AI Treatment x Post AI Year	**0.0108****	**0.00321**	**0.0142*****
	(0.00349)	**(0.00237)**	**(0.00226)**
Ln Employment	0.0537***	0.0204***	0.0410***
	(0.00171)	(0.00115)	(0.00111)
Age	-0.0690***	-0.0561***	-0.00927***
	(0.00282)	(0.00190)	(0.00182)
Multinational Status (1/0)	-0.00884*	-0.00876***	-0.00538*
	(0.00367)	(0.00252)	(0.00239)
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	704,000	704,000	704,000
R-squared	0.712	0.704	0.682

Robust Standard Errors clustered at the 4-digit NAICS industry level. *, ** and *** denotes significance at the 5%, 1% and 0.1% respectively. Each regression includes a constant, which is not displayed here.

AI impact on earnings inequality varies across sectors



Summary of key findings

- We introduce a new approach to the measurement of firm-level AI invention.
- Our approach suggests that AI invention is far more pervasive than previous analyses indicated.
- We match data on AI inventions to Census microdata on firms and employees.
- We find positive, statistically (and economically) significant associations between AI patenting and proxies for labor productivity.
- We also find positive, statistically (and economically) significant associations between AI patenting and increases in within-firm earning inequality.

Next steps

- We will continue to explore the impact of AI invention, studying both the intensive and extensive margins.
- We also intend to bring into our analyses data on the use of other firms' AI inventions.
- New census microdata can shed light on firm's use of AI.
- Firm-level data on the recruitment/employment of specialists with AI-related skills may shed light on AI use within firms.