Technological innovation, digital adoption and firm performance

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Outline

1. Motivation

Motivation

- What is the effect of digital adoption on firm performance?
  - advanced digital technologies (ADT): 3D printing, advanced robotics, drones, augmented or virtual reality, digital platforms, IoT, big data analytics and AI
  - firm performance outcomes: investment in employee training, management practices, innovation, firm productivity
- Investment in digitalisation accelerated by COVID-19 (EIB 2023)
  - 53% of EU firms made investments to become more digital as a response to COVID-19
  - to sell products and services online, prevent business disruption, organise remote work, and/or improve communication with customers, suppliers and employees

Structural increase in the use of advanced digital technologies (ADT)

- Rapid increase in the *use* of ADT and *decline* in the price over time
  - Brynjolfsson and McElheran (2016), Graetz and Michaels (2018), Acemoglu and Restrepo (2019), Klump et al. (2021)
- ADT expand the set of tasks within the production process that can be performed by capital
  - which decreases the share of tasks performed by labour, in particular for routine tasks (Acemoglu and Restrepo 2021, Acemoglu et al. 2022)
- Can also increase the productivity of workers in tasks they are already performing or creating new tasks for them

What we do in the paper

- Estimate effect of digital adoption on firm performance outcomes
  - investment in employee training, management practices, innovation, firm productivity
  - using data from the EIB Investment Survey (EIBIS) on 27 EU countries
- Using OLS, propensity score matching and IV
  - IV based on technological innovation (stock of digital patents in the World Corporate Top RD Investors IP database) in upstream and downstream sectors of the firms: similar to a shift-share instrumental variable

Preview of main results

OLS

Dependent: variable	Training	Management practices	Innovation (binary)	Innovation (share)	ln(VA/emp)	ln(TFP)	ln(wage/emp)
Digital	0.119***	0.149***	0.113***	0.043***	0.096***	0.073***	0.085***
	(0.006)	(0.006)	(0.007)	(0.004)	(0.009)	(0.009)	(0.007)
Sample size	38,066	41,529	35,135	35,135	36,058	34,617	39,275
R^2	0.126	0.188	0.085	0.066	0.427	0.447	0.491

Note: All regressions control for status, age and size categories, country, industry and year. Standard errors clustered by country and industry) in parentheses. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

Preview of main results - Propensity score matching

Propensity score matching

Dependent: variable	Training	Management practices	Innovation (binary)	Innovation (share)	ln(VA/emp)	ln(TFP)	ln(wage/emp)
Digital	0.244***	0.383***	0.316***	0.048***	0.058***	0.047***	0.045***
	(0.033)	(0.032)	(0.038)	(0.008)	(0.014)	(0.013)	(0.014)
Sample size	10,675	11,055	10,266	10,268	11,213	11,213	10,843
R^2				0.055	0.484	0.581	0.601
Pseudo R^2	0.091	0.093	0.058				

Note: All regressions control for status, age and size categories, country, industry and year. Standard errors clustered by country and industry) in parentheses. *p<0.1; **p<0.05; ***p<0.01.

2. Data: EIB Investment Survey (EIBIS)

The EIB Investment Survey (EIBIS)

- Since 2016, annual survey of about 13,350 non-financial enterprises in all 27 EU countries and the US (since 2019)
  - non-financial enterprises with 5+ employees
  - interviews of senior persons with responsibility for investment decisions and how they are financed (owner, CEO or CFO)
  - NACE categories C to J: manufacturing, construction, services (wholesale and retail trade, accommodation and food services), and infrastructure (electricity and gas, water supply and waste management, transportation and storage, information and communication)
- Information on firm characteristics and performance, past investment activities and future plans, sources of finance, and challenges that businesses face

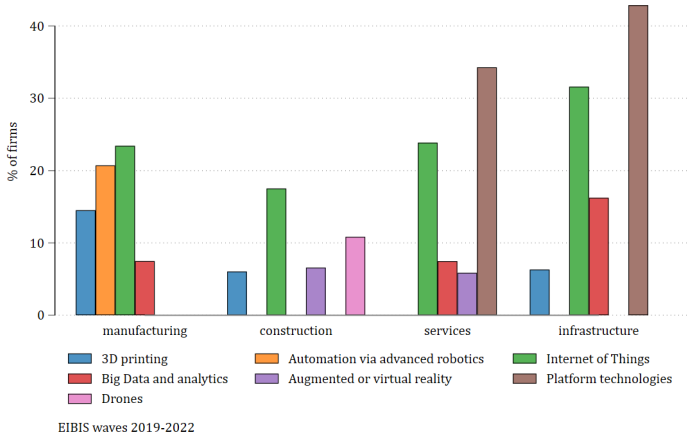
EIBIS sampling strategy

- EIBIS sample stratified disproportionally by country, industry group (sector) and firm size classes, and stratified proportionally by region within each country
  - each year sample size ranges from 180 firms in Cyprus, Luxembourg and Malta to 600 in France, Germany, Italy, Spain and the UK, and 800 in US
- EIBIS includes a panel component and a top-up sample
  - panel firms (approx. 40% in each wave): participated in a previous wave of the survey, and consented to be re-contacted in the following wave
  - top-up sample: firms that did not participate in the preceding wave

EIBIS - question on the use of advanced digital technologies

- Since wave 4, EIBIS includes questions on the adoption of four advanced digital technologies that are revelant to the sector in which the firm is operatingoperates
- "To what extent, if at all, are each of the following digital technologies used within your business? Please say if
  - you do not use the technology
  - used it in parts of the business within your business
  - or whether your entire business is organised around this technology?"

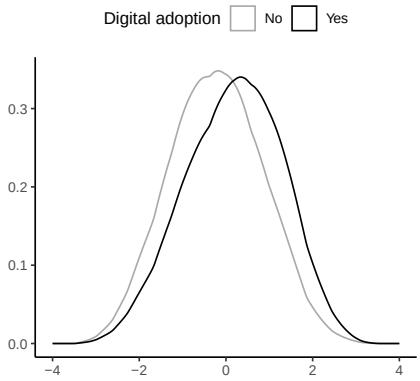
Advanced digital technologies in EIBIS



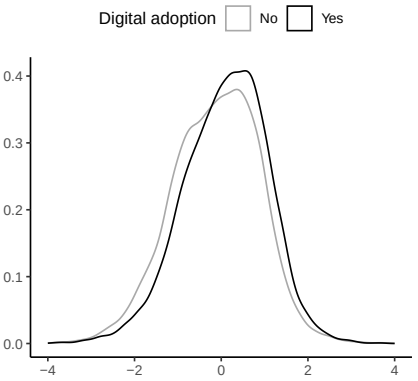
EIBIS waves 2019-2022

Firms that use digital technologies tend to be larger and more productive

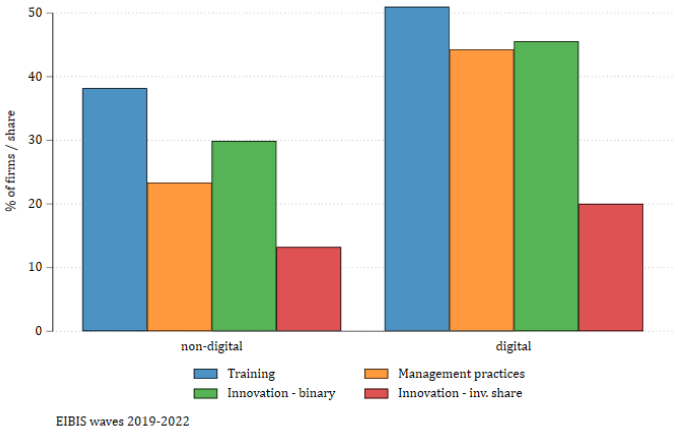
Firm size



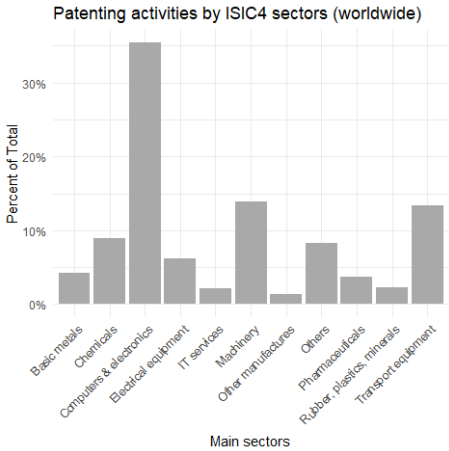
Labour productivity

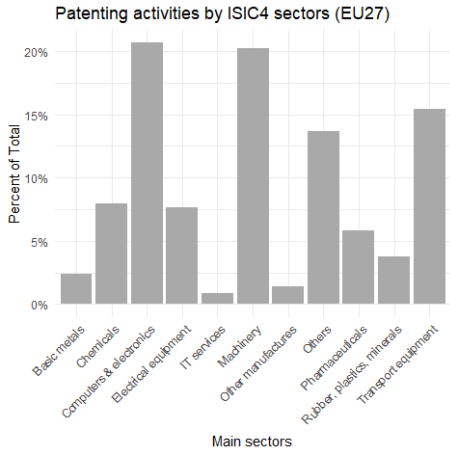


Firms that use digital technologies perform better on various outcomes



Patents in the World Corporate Top R&D Investors IP database





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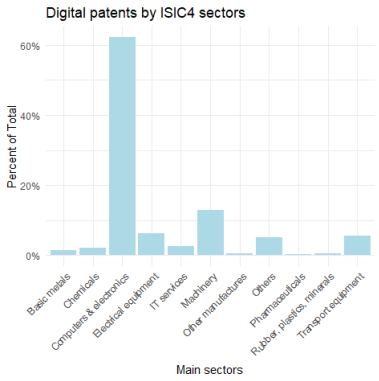

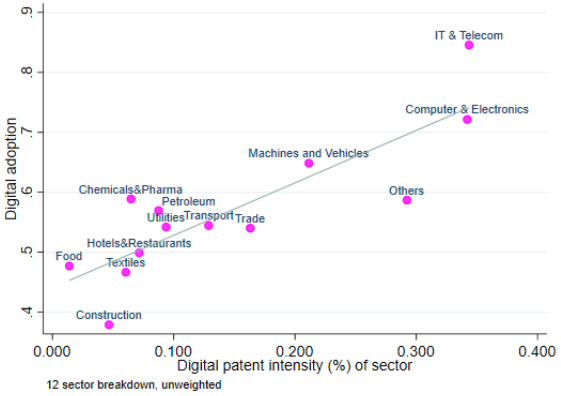

3. Main results

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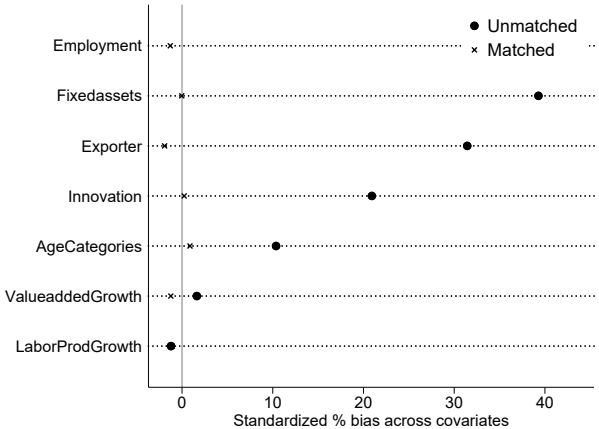
Note: All regressions control for status, age and size categories, country, industry and year. Standard errors clustered by country and industry) in parentheses. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

Reduction of bias after propensity score matching



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IV - digital patents of upstream and downstream sectors as instrument

Instrumental variable estimation

Dependent variable:	Training	Management practices	Innovation (binary)	Innovation (share)	ln(VA/emp)	ln(TFP)	ln(wage/emp)
Digital	0.680***	0.241*	0.456***	0.369***	1.487***	1.718***	1.698***
	(0.161)	(0.140)	(0.153)	(0.092)	(0.411)	(0.417)	(0.351)
Sample size	38,066	41,529	35,135	35,135	36,058	34,617	39,275
First-stage							
Digital patents *in*							
upstream sectors	0.029***	0.025***	0.020***	0.020***	0.024***	0.025***	0.023***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
downstream	0.025***	0.024***	0.028***	0.028***	0.022***	0.021***	0.023***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
F-test statistic	57.3	50.2	45.2	45.2	38.4	37.4	43.6

Note: All regressions control for status, age and size categories, country, industry and year. Standard errors clustered by country and industry) in parentheses. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

4. Conclusion

Conclusion

- We present novel evidence that firms using digital technologies perform better
  - advanced digital technologies (ADT): 3D printing, advanced robotics, drones, augmented or virtual reality, digital platforms, IoT, big data analytics and AI
  - firm performance outcomes: investment in employee training, management practices, innovation, firm productivity
  - with data from the EIB Investment Survey (EIBIS) on 27 EU countries
  - in line with recent results in the literature (Acemoglu et al., 2022)
- Policies aimed at increasing firm performance and managing the employment effects of digital adoption should consider the impact of upstream and downstream partners as well as the firm itself

Thank you!

Contact: c.weiss@eib.org

European Investment Bank

Additional slides

The EIB Investment Survey (EIBIS)

Definition of outcome variables (1/2)

- Innovation: What proportion of the total investment in (t-1) year was for
  - (A) Developing or introducing new products, processes or services?
  - (B) Replacing capacity?
  - (C) Expanding existing capacity?

- Training: How much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings?

- Management practices: Did your company use a formal strategic business monitoring system (that compares the firm's current performance against a series of strategic key performance indicators)?

Definition of outcome variables (2/2)

- Wage / Employment
  - How much did the company spend on wages in (t-1) financial year? We are referring here to gross wages, including all benefits and benefits in kind (i.e. including various types of non-wage compensation provided to employees in addition to their normal wages or salaries). Expressed in Euros.
  - How many people does your company employ either full or part time at all its locations including yourself? (Please include freelancers working regularly for your company. Full-time and part-time employees should each count as one employee. Employees working less than 12 hours per week should be excluded.)
- Labour productivity: log of value added over employment
- TFP: log of residuals from OLS regression of $VA = F(K, L)$

EIBIS - matched to Orbis

- An enterprise is defined as a company trading as its own legal entity: branches excluded from the target population
  - but definition broader than a typical enterprise survey, given that some company subsidiaries are their own legal entities
- Minimum number of employees is 5
  - with full-time and part-time employees being counted as one employee, and employees working less than 12 hours per week excluded
- ORBIS dataset of Bureau van Dijk used as the sampling frame
  - EIBIS matched to data on balance sheet and profit and loss statements
  - match done for each firm by Ipsos MORI, which then sends anonymised data to EIB
  - the EIB does not have the name, address, contact details or any additional
  - individual information that could identify the firms surveyed in EIBIS

EIBIS - Representativeness

- Brutscher, Coali, Delanote and Harasztosi (2020): evidence on representativeness of EIBIS for the business population of interest
  - comparison with the population of firm-level data in Eurostat SBS (e.g. average firm size, labour productivity, etc.)
  - comparisons with CompNet (extracted from confidential firm-level datasets available within National Central Banks or National Statistical Institutes)
  - comparisons with random samples from ORBIS (e.g. sales growth, cash flow ratio, leverage, returns on assets, etc.)

Orbis

- ORBIS is a popular source of administrative data for cross-country analyses at the firm level
  - majority of information comes from business registers collected by local chambers of commerce to fulfil legal and administrative requirements
  - Bureau van Dijk organises the data and arranges them in a standard "global" format to facilitate company comparisons across countries
  - Kalemli-Ozcan et al. (2015) and Bajgar et al. (2020): discussion of the (dis)advantages of using ORBIS for economic analysis of firm dynamics