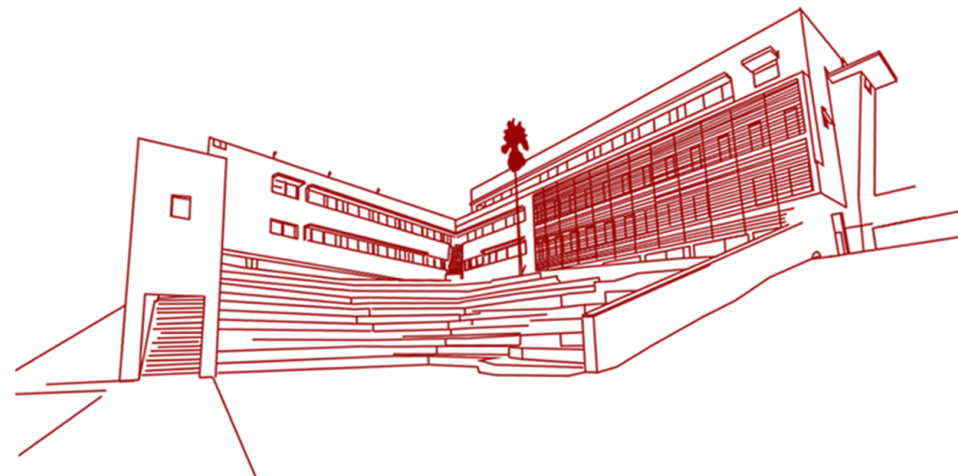




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Artificial intelligence and exporting performance: Firm-level evidence from Portugal

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Motivation

- The growing digitalization of economic activities offers new opportunities to reactivate or, even, foster the **technological diffusion machine**.
- By representing a fundamental technological shift, there are good reasons to believe that AI and AI-related digital technologies **have the power to engender strong positive effects on productivity** and, hence, on firms' expansion and success in international markets.
- The interconnection of AI and AI-related digital technologies and exporting performance at the firm level is **scarce**, yielding **mixed findings** and explanations.
-  : public incentives to firms' digitalization and export exposure, with a relevant involvement in global value chains.

Aims

- Identify the main factors explaining differences in the adoption of AI and AI-related digital technologies that enable the Industry 4.0 transformation.
- **Investigate the impact of AI and AI-related digital technologies on the the intensive (level of foreign sales) margin of exports.**
- Explore whether there are differences across industries on the impact of AI and AI-related digital technologies on the the intensive margin of exports.

Theoretical background

- **Factors driving AI and AI-related digital technologies adoption decisions:**
 - Availability of complementary resources (e.g. digital skills and infrastructures)
 - Ex-ante firm's performance, given the potentially high risk and fixed cost related to digital technologies adoption (Brynjolfsson et al. 2021)
 - Other firm-specific characteristics and external context (e.g. competition and cumulativeness of knowledge) (Malerba and Orsenigo 1996)

Theoretical background

- **Digital technologies may affect firm's international engagement through several channels:**
 - Flexible manufacturing processes, easing analysis of data in real time => reduction on operational costs and uncertainty of decision making (Dalenogare et al. 2018; Sanderson et al. 2022)
 - Reduction of search costs and informational frictions (Fernandes et al. 2019; Sanderson et al. 2022)
 - Organisation and re-configuration of activities within global value chains
 - Product quality (Buchi et al. 2020)
 - The effect on trade: product complexity [large investments in technologies] *versus* product weight (Freund-etal-2022)

Data and econometric strategy

- Two main panel datasets provided by the Portuguese National Institute of Statistic
 - *IUTIC*: part of the Community Survey on ICT Usage and E-commerce
 - *SCIE*: annual census for Portuguese firms
- 2014-2021, with gaps
- SAMPLE
 - 42,940 firm-year observations,
 - 30,377 unique firms, where 7,799 (25,68%) firms are observed at least two years
- Econometric strategy
 - similar to Calvino & Fontanelli (2023) with industry- and time-fixed effects
 - *Exporting performance* -> deflated firm's foreign sales per employee

Empirical variables

Table 1: Descriptive statistics of empirical variables

	All firms		Large firms		Young firms		No-exporting firms	
	Mean	Sd.	Mean	Diff.	Mean	Diff.	Mean	Diff.
Exporting variables								
Exporting performance	5,679	6,847	11.207	6.276***	3.873	-2.011***	-	-
No-exporting firms (0/1)	0.625	0.484	0.399	-0.257***	0.747	0.136***	-	-
Digital technologies variable								
Industry 4.0 (0/1)	0.083	0.276	0.192	0.123***	0.086	0.004	0.055	-0.065***
ICT skills								
ICT specialists (0/1)	0.310	0.462	0.776	0.532***	0.201	-0.121***	0.184	-0.276***
ICT training (0/1)	0.253	0.435	0.598	0.393***	0.168	-0.094***	0.172	-0.179***
Digital infrastructure								
Ultra-Fast Broadband (0/1)	0.418	0.492	0.500	0.101***	0.479	0.074***	0.428	0.039***
Cloud computing adopter (0/1)	0.166	0.372	0.336	0.192***	0.163	0.004	0.157	-0.024***
Other empirical variables								
Firm's size	2.840	1.927	6.360	4.000***	2.061	-0.867***	2.313	-1.406***
Firm's turnover	14.261	2.491	17.732	3.939***	13.049	-1.344***	14.262	-2.300***

Notes: ***, **, * indicate that the difference in means is statistically significant at the 1%, 5%, 10%, respectively.

Explanatory factors of adoption at firm-level

Table 2: Adoption of Industry 4.0 enabling technologies: estimated effects

	Industry 4.0 technologies						
	I4.0	Robots	Big Data	3D Printing	Machine Learning	Artificial Intelligence	Internet of Things
Size class 20-49	0.019** (0.008)	0.005 (0.011)	0.024** (0.011)	0.009 (0.008)	0.144 (0.092)	-0.014 (0.020)	0.019 (0.022)
Size class 50-249	0.033*** (0.008)	0.055*** (0.012)	0.021* (0.011)	0.010 (0.007)	0.055 (0.085)	0.014 (0.019)	0.085*** (0.021)
Size class 250+	0.083*** (0.010)	0.118*** (0.015)	0.090*** (0.015)	0.039*** (0.010)	0.162* (0.084)	0.085*** (0.023)	0.176*** (0.025)
Ultra-Fast Broadband (≥ 100 Mibts/sec)	0.037*** (0.006)	0.021** (0.021)	0.045*** (0.009)	0.017*** (0.006)	0.025 (0.054)	0.041** (0.014)	0.032* (0.018)
Cloud Adopter	0.085*** (0.007)	0.027*** (0.009)	0.136*** (0.010)	0.015*** (0.007)	0.020 (0.052)	0.111*** (0.092)	0.198*** (0.017)
ICT Specialists	0.070*** (0.007)	0.091*** (0.011)	0.085*** (0.011)	0.025*** (0.007)	-0.078 (0.059)	-	-
ICT Training (for other employees)	0.037*** (0.007)	0.023*** (0.009)	0.076*** (0.010)	0.030*** (0.007)	0.126** (0.049)	-	-
Observations	15,055	6,073	9,253	6,073	571	3,675	3,675
R^2	0.230	0.259	0.135	0.114	0.194	0.071	0.112
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Positive selection

Notes: The adoption regressions are linear probability models that employ a dummy variable for each digital technology as dependent variable and includes size, other firm-specific characteristics, and relevant digital skills and infrastructures as main explanatory factors. The dummy variable "I4.0" takes value 1 if a firm adopts any of the six digital technologies related to Industry 4.0 technologies under scrutiny. Each regression includes 2-digit sector and year fixed effects. Robust standard errors in parenthesis. Significance levels: *, 10%; **, 5%; ***, 1%.

Estimated impacts on exporting performance

Table 3: Exporting performance and digital technologies adoption

	Industry 4.0 technologies						
	I4.0	Robots	Big Data	3D Printing	Machine Learning	Artificial Intelligence	Internet of Things
Adopter=1	0.503*** (0.133)	0.698*** (0.209)	-0.422*** (0.175)	0.510*** (0.273)	0.474 (0.550)	0.163 (0.232)	-0.031 (0.211)
Size class 20-49	1.010*** (0.114)	1.124*** (0.220)	1.039*** (0.173)	1.118*** (0.219)	-0.409 (0.967)	0.806*** (0.303)	0.813*** (0.307)
Size class 50-249	2.431*** (0.106)	2.127*** (0.207)	2.305*** (0.165)	2.137*** (0.207)	0.783 (0.857)	1.763*** (0.283)	1.771*** (0.285)
Size class 250+	2.621*** (0.030)	2.022*** (0.237)	2.303*** (0.190)	2.037*** (0.237)	0.266 (0.863)	2.035*** (0.326)	2.060*** (0.329)
Number of other digital technologies	-	1.632*** (0.360)	4.339*** (0.324)	2.597*** (0.326)	5.341*** (0.810)	2.751*** (0.340)	3.007*** (0.374)
Observations	21,730	6196	9,410	6,196	619	3765	3,707
R^2	0.344	0.358	0.356	0.351	0.455	0.340	0.337
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The exporting performance regressions are OLS models that includes a (log) of sales in international markets per employee as dependent variable and industry 4.0 technologies adoption, size, and other firm-specific characteristics as main explanatory factors. The dummy variable "I4.0" takes value 1 if a firm adopts any of the six digital technologies related to Industry 4.0 technologies under scrutiny. Each regression includes 2-digit sector and year fixed effects. Robust standard errors in parenthesis. Significance levels: *, 10%; **, 5%; ***, 1%.

Impacts on exporting performance across industries

Table 4: Exporting performance and digital technologies adoption across industries

	Industry 4.0 technologies						
	I4.0	Robots	Big Data	3D Printing	Machine Learning	Artificial Intelligence	Internet of Things
Manufacturing & Utilities	0.455*** (0.214)	1.943*** (0.250)	-0.870*** (0.267)	1.954*** (0.288)	0.558 (1.009)	0.508 (0.372)	-0.315 (0.339)
Construction	-0.018 (0.763)	-0.296 (1.397)	0.070 (0.810)	2.287 (2.129)	2.451 (3.084)	-0.196 (1.379)	0.712 (1.078)
Wholesale & Retail	1.111*** (0.341)	2.147*** (0.711)	0.992*** (0.353)	1.983 (1.276)	-1.159 (1.175)	0.994* (0.563)	-0.561 (0.487)
Transport & Storage	1.371* (0.768)	2.630*** (1.297)	1.292 (0.800)	-2.452 (2.838)	4.891* (2.466)	-0.167 (1.367)	1.101 (1.130)
Accommodation & Food	0.161 (0.393)	-0.682*** (0.208)	0.222 (0.324)	1.586 (1.603)	3.957 (2.525)	0.401 (0.730)	1.713*** (0.586)
Information & Communication	0.748 (0.458)	0.174 (1.740)	0.878* (0.461)	-2.191 (3.547)	-0.044 (1.436)	1.050 (0.747)	-0.211 (1.782)
Professional & Scientific	-0.319 (0.953)	-5.649* (3.120)	-0.992 (0.976)	0.829 (1.799)	1.003 (3.691)	1.839* (1.079)	2.254** (1.051)
Administrative & Real Estate	-0.347 (0.550)	-1.454 (1.246)	-0.302 (0.568)	2.023 (2.085)	2.503 (2.329)	0.729 (0.879)	0.225 (0.808)

Notes: The exporting performance regressions are OLS models for each industry and includes a (log) of sales in international markets per employee as dependent variable and industry 4.0 technologies adoption, size, and other firm-specific characteristics as main explanatory factors. The dummy variable "I4.0" takes value 1 if a firm adopts any of the six digital technologies related to Industry 4.0 technologies under scrutiny. Each regression includes year fixed effects. Robust standard errors in parenthesis. Significance levels: *, 10%; **, 5%; ***, 1%.

Concluding remarks

- The uncovering of heterogeneous exporting effects across different digital technologies and different industries.
- Evidence for **positive selection** towards large firms: only largest firms are able to deal with high risk and fixed costs related to AI and AI-related technologies.  Potential to exacerbate existing divides among firms and no positive impact at aggregate level.
- The **degree of openness and sophistication** towards AI and AI-related technologies strengthen firm's position in international markets. However,... these technologies have scope to disrupt trade patterns (reduction on production costs; diffusion across countries; product characteristics).
- Firms at the initial stage of the adoption process seem to find more difficulty to build unique competitive competences to engender exporting gains.

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Thank you!



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