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Planul Național
de Redresare și Reziliență

Digital readiness for artificial intelligence – the case of Romania

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European Operations Management Association - EurOMA Conference
Digital manufacturing
Milan, Italy, 13-18.06.2025

Agenda



1. Introduction and context



2. Literature review and research questions



3. Sample and methodology



4. Results



5. Discussion

Digital transformation is reaching new levels with the emergence of Artificial Intelligence (AI).

- AI is a new technology/tool that expands the technological landscape
 - Digital transformation relies on solutions such as big data, sensors, cloud, etc. and traditional tools
 - These solutions favour the use of AI
- AI journey embedded into digital transformation
 - Firm-level digital readiness models (Hizam et al., 2020) predict that implementing an additional digital technology could be easier if a company already has experience with digital technologies
 - Resource-based view of the firm
 - Knowledge: absorptive capacity: to recognise the value and assimilate it
 - Attitude: technological readiness: to have the propensity to use it

We investigate the relation of AI to other digital technologies and the performance implications of their (AI and other digital technologies) usage.

Literature review and research questions

We have plenty of positive evidence about the influence of AI on business performance, there are also studies expressing doubts.

Relationship of AI to other digital technologies.

Companies pair traditional and new technologies.

Some technological prerequisites are required before implementing AI, such as big data and cloud computing, high-speed and scalable computational power, and rich data (Enholm et al., 2022; Wamba-Taguimdje et al., 2020).

Works usually approach the technological solutions as bundled together and do not scrutinize their potential influence on each other.

RQ1:

What types of digital technologies influence the adoption of AI?

Performance implications of digital technologies and AI.

The latest technologies to increase operational and business performance (e.g., Vu et al., 2024). AI has similar positive promises regarding business performance improvements (Chowdhury et al., 2022).

There are less optimistic works (Rana et al., 2021; Filippucci et al., 2024), and even a negative influence is detected.

RQ2:

To what extent do digital technologies and AI justify higher productivity?

Sample

We used the ‘ICT usage in enterprises’ (i.e., ICT survey) firm-level data from Eurostat in 2023 for Romania (Eurostat, 2024a). Romania is an extreme case of digitalisation within Europe since the country is the least developed in the EU27.

Economic Activity (NACE Rev. 2 Section)	Population	% of Total	Sample	% of Total	Ratio Diff	Included	AI users	%	no AI users	%
A Agriculture, Forestry and Fishing	0	0.00%	3	0.03%	-0.03%	NO	0	0%	3	0.03%
B Mining And Quarrying	350	0.64%	4	0.04%	0.60%	NO	0	0%	4	0.04%
C Manufacturing	11324	20.85%	3494	35.63%	-14.78%	YES	73	23.62%	3418	36.06%
D Electricity, Gas, Steam and Air Conditioning Supply	166	0.31%	94	0.96%	-0.65%	YES	9	2.91%	85	0.90%
E Water Supply;Sewerage, Waste Management and Remediation Activities	698	1.29%	280	2.86%	-1.57%	YES	4	1.29%	276	2.91%
F Construction	9167	16.88%	1039	10.59%	6.28%	YES	9	2.91%	1027	10.84%
G Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	12309	22.66%	1774	18.09%	4.58%	YES	52	16.83%	1719	18.14%
H Transportation and Storage	4646	8.55%	750	7.65%	0.91%	YES	14	4.53%	732	7.72%
I Accommodation and Food Service Activities	4103	7.55%	359	3.66%	3.89%	YES	2	0.65%	356	3.76%
J Information and Communication	2030	3.74%	606	6.18%	-2.44%	YES	75	24.27%	530	5.59%
K Financial and Insurance Activities	602	1.11%	0	0.00%	1.11%	NO	0	0%	0	0%
L Real Estate Activities	571	1.05%	66	0.67%	0.38%	NO	0	0%	66	0.70%
M Professional, Scientific and Technical Activities	2535	4.67%	500	5.10%	-0.43%	YES	50	16.18%	450	4.75%
N Administrative and Support Service Activities	3356	6.18%	796	8.12%	-1.94%	YES	21	6.80%	770	8.12%
O Public Administration and Defence; Compulsory Social Security	0	0.00%	0	0.00%	0.00%	NO	0	0%	0	0%
P Education	262	0.48%	0	0.00%	0.48%	NO	0	0%	0	0%
Q Human Health and Social Work Activities	1294	2.38%	0	0.00%	2.38%	NO	0	0%	0	0%
R Arts, Entertainment and Recreation	433	0.80%	3	0.03%	0.77%	NO	0	0%	3	0.03%
S Other Service Activities	464	0.85%	39	0.40%	0.46%	NO	0	0%	39	0.41%
T Activities of Households as Employers; Undifferentiated Goods-And Services-Producing Activities of Households for Own Use	0	0.00%	0	0.00%	0.00%	NO	0	0%	0	0%
U Activities of Extraterritorial Organisations and Bodies	0	0.00%	0	0.00%	0.00%	NO	0	0%	0	0%
Total	54,310	100%	9,807	100%			309	100%	9,478	100%

Economic Activity (NACE Rev. 2 Section)	Population	% of Total	Sample	% of Total	Ratio Diff	Included	AI users	%	no AI users	%
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U Activities of Extraterritorial Organisations and Bodies	0	0.00%	0	0.00%	0.00%	NO	0	0%	0	0%
Total	54,310	100%	9,807	100%			309	100%	9,478	100%

Operationalisation

Variable name	Scale	Items / Questions
DEPENDENT		
Productivity	= (Total turnover – costs of goods sold) / number of employees	
AI	AI_tech	Does your enterprise use any of the following Artificial Intelligence (AI) technologies?
		a) AI technologies performing analysis of written language (e.g. text mining)
		b) AI Technologies converting spoken language into a machine-readable format (speech recognition)
		c) AI Technologies generating written or spoken language (natural language generation, speech synthesis)
		d) AI Technologies identifying objects or persons based on images or videos (image recognition, image processing)
		e) Machine learning (e.g. deep learning) for data analysis
		f) AI Technologies automating different workflows or assisting in decision making (e.g. AI-based software robotic process automation)
		g) AI Technologies enabling physical movement of machines via autonomous decisions based on observation of surroundings (autonomous robots, self-driving vehicles, autonomous drones)
	UseAI	0 = No use of AI; 1 = At least 1 AI technology is used)

Digital technologies	Internet_speed	1-5
	Website	0 = None; All features - 8
	Mobile_app	0 = No; 1 = Yes
	socialmedia	0 = None; 3 = All platforms)
	Sales_web	0 = NO; 1 = YES
	Sales_marketplace	0 = NO; 1 = YES
	Sales_edi	0 = NO; 1 = YES
	ERP	0 = NO; 1 = YES
	CRM	0 = NO; 1 = YES
	Business_Intelligence	0 = NO; 1 = YES
	Datasharing_supplychain	0 = NO; 1 = YES
	Dataanalytics_sources	0 = None; 8 = All sources
Cloud_services	0 = None; 10 = All services	
Datasharing_invoice	0 = No; 1 = YES	

Control variables	Firm-size	= LN (Avg. number of employees in 2022)	Average number of employees and self-employed persons (persons employed), during 2022
	Industry	NACE_X 0-1	Main economic activity of the enterprise, during 2022 (previous slide)

RQ1: What types of digital technologies influence the adoption of AI?

Ordered Logistic Regression models were used to explore the influence of digital technologies and control variables (e.g. firm size, industry) on the intensity of AI technology (AI_tech) use.

	Model_1	Model_2	Model_3
Internet speed	0.390***	0.358***	0.185**
Website	-0.073**	-0.073**	-0.061***
Mobile_app	0.017	-0.056	-0.062
Socialmedia	0.684***	0.694***	0.527***
Sales_web	0.139	0.158	0.335
Sales_marketplace	-0.291	-0.263	-0.146
Sales_edu	0.205	0.193	0.451*
ERP	0.103	0.012	0.057
CRM	0.083	0.1	0.025
Business_Intelligence	0.977***	0.837***	0.678***
Datasharing_supplychain	0.304*	0.254	0.237
Dataanalytics_sources	0.035	0.037	0.056*
Cloud_services	0.227***	0.223***	0.190***
Datasharing_invoice	0.286*	0.266*	0.378**
Firm_size		0.237***	0.325***
Industry			YES
McFadden	0.1629	0.1674	0.1913
N	9,064	9,064	9,064

Regarding digital solutions, four items have a positive and significant influence on AI usage at the $p < 0.05$ level in all models:

- Internet speed (increases the probability of the company's AI usage by 18.5% in Model 3),
- Social media (52.7%),
- Business Intelligence (67.8%), and
- Cloud services (19%).

Website has a negative influence on AI use.

Our model has moderate explanatory power.

RQ2: To what extent do digital technologies and AI justify higher productivity?

Firm-level business performance is measured by productivity ((Total turnover in 2022 - Total expenses for goods and services in 2022) / Average number of occupied positions in 2022), and we used a winsorized (99/1) value in the OLS models.

AI cannot be related to firm productivity in any of the Models (2 to 4).

Sales with online marketplaces are associated with substantially lower productivity (-24509.6, $p < 0.001$).

Once industry effects are included (Model 4), the impact of firm size becomes non-significant (-496.5, $p = 0.712$).

	Model_1	Model_2	Model_3	Model_4
Intercept	83780.9***	84221.7***	104530.6***	81902.5***
Internet_speed	7411.5***	7295.9***	7713.5***	3839.0***
Website	3475.2***	3497.0***	3654.9***	3169.6***
Mobile_app	2240.8	2301.7	2993.9	-1988.1
Socialmedia	4838.1***	4642.0**	4627.6**	3013.3*
Sales_web	5548.1	5524.3	5125.3	-7105.8
Sales_marketplace	-29730.8***	-29638.1***	-30082.2***	-24509.6***
Sales_edu	20575.4***	20558.0***	21666.4***	27825.5***
ERP	19863.3***	20140.1***	21777.2***	18468.5***
CRM	10904.6**	10850.5**	10744.6**	9735.1**
Business_Intelligence	30470.9***	29980.2***	31675.2***	25501.8***
Datasharing_supplychain	3745.0	3549.7	3699.5	1991.5
Dataanalytics_sources	-57.7	-92.6	-112.3	-492.6
Cloud_services	5167.5***	5013.9***	5108.0***	4453.4***
Datasharing_invoice	-5400.4*	-5439.8*	-5240.4*	-5439.9*
AI_tech		3306.7	3724.2	2087.4
Firm_size			-5054.8***	-496.5
NACE_D				YES
F-statistic	0.0000	0.0000	0.0000	0.0000
Adjusted R-squared	0.0737	0.0738	0.0751	0.1453
N	9,064	9,064	9,064	9,064

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A fragmented view of the sample – three clusters

<i>Number of firms</i>		9064	508	1864	6692
			Digital sales	Data analytics and cloud	Basics
Variable	Min	Max	Avg_cluster1	Avg_cluster2	Avg_cluster3
internet_speed	1	5	3,579	3,613	3,328
website	0	8	3,573	2,777	1,273
mobile_app	0	1	0,211	0,206	0,051
socialmedia	0	3	1,469	1,349	0,501
sales_web	0	1	0,787	0,219	0,059
sales_marketplace	0	1	1	0	0,001
sales_edi	0	1	0,26	0,185	0,016
ERP	0	1	0,557	0,921	0,158
CRM	0	1	0,348	0,649	0,023
BusinessIntelligence	0	1	0,333	0,591	0,009
datasharing_supplychain	0	1	0,339	0,492	0,036
dataanalytics_sources	0	8	2,195	3,08	0,301
cloud_services	0	10	2,508	3,689	0,562
useAI	0	1	0,063	0,093	0,013
AI_tech	0	7	0,205	0,282	0,037

Digital technologies → adaption of AI

RQ1: What types of digital technologies influence the adoption of AI? +: internet speed, social media, business intelligence, cloud; -: website

RQ1: What types of digital technologies influence the adoption of AI?

- It depends on your actual "maturity" (preferences) – focused strategies for more advanced firms.
- No negative influence of any technology.

	9064	508	1864	6692
	Sample	Digital sales	Data analytics and cloud	Basics
internet_speed	YES		YES	YES
website	NEGATIVE			
mobile_app				
socialmedia	YES		YES	YES
sales_web				YES
sales_edi				YES
ERP				YES
CRM				
BusinessIntelligence	YES		YES	
datasharing_supplychain				
dataanalytics_sources		YES		
cloud_services	YES	YES	YES	YES
datasharing_einvoice				YES

Digital technologies and AI → productivity

RQ2: To what extent do digital technologies and AI justify higher productivity? Many digital technologies have positive influence on productivity, but AI has no influence on it.

RQ2: To what extent do digital technologies and AI justify higher productivity?

- *It depends on your actual "maturity" (preferences) – focused strategies for more advanced firms.*
- *No negative influence of any technology.*

	9064	508	1864	6692
	Sample	Digital sales	Data analytics and cloud	Basics
internet_speed	YES			YES
website	YES	YES		YES
mobile_app				
socialmedia	YES			
sales_web				
sales_edi	YES			YES
ERP	YES		YES	YES
CRM	YES			
BusinessIntelligence	YES		YES	YES
datasharing_supplychain				
dataanalytics_sources				
cloud_services	YES		YES	YES
datasharing_einvoice				
AI_tech				YES

Conclusions, limitations and future research

The overall picture is less favourable than expected. Firms are experimenting but must find ways to use it effectively. There is no 'one-strategy-fits-all' approach.

RQ1: The use of digital technologies positively influences AI usage, however, in a selective and context-dependent way.

RQ2: Only the digitally least developed firms can exploit AI's productivity implications.

One can define a core set of digital technologies contributing to AI usage and productivity simultaneously:

- Basics: ERP and cloud
- Data analytics and cloud: BI and cloud
- Digital sales: no pathway

Differences in productivity across firms are better explained by sectoral affiliation and digital adoption than by firm size. At the same time, AI usage is significantly influenced by firm size.

Time-lag analysis – to learn about the cause-and-effect link, and potential implications

Operational measures – inventory turnover

To examine the impact of context on the results, in our future research, we aim to incorporate Denmark, the leading country in digitalisation in the EU27.

Funding

This work was supported by the project entitled

“Strengthening the digitalization of businesses in Eastern Europe – a micro and macro-level approach”

funded by the **European Union – NextGenerationEU** project and the **Romanian Government**,

under the National Recovery and Resilience Plan for Romania,

contract no. 760036/23.05.2023, cod PNRR-C9-I8-CF 198/28.11.2022,

through the Romanian Ministry of Research, Innovation and Digitalization, within Component 9, Investment I8.



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Thank you for your attention!

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Aalborg, Denmark



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Appendix

INDUSTRIAL

	Internet_speed	<u>1-5</u>	What is the maximum contracted download speed of the fastest fixed internet connection of your enterprise?
	Website	<u>0 = None; All features - 8</u>	Does the website have any of the following? a) Description of goods or services, price information b) Online ordering or reservation or booking, e.g. shopping cart c) Possibility for visitors to customise or design online goods or services d) Tracking or status of orders placed e) Personalised content on the website for regular/recurrent visitors f) A chat service for customer support (a chatbot, virtual agent or a person replying to customers) g) Advertisement of open job positions or online job application h) Content available in at least two languages
	Mobile_app	<u>0 = No; 1 = Yes</u>	Does your enterprise have a mobile app for clients (e.g. for loyalty program, e-commerce, customer support)?
	socialmedia	<u>0 = None; 3 = All platforms)</u>	Does your enterprise use any of the following social media? a) Social networks (e.g. Facebook, LinkedIn, Xing, Viadeo, Yammer) b) Enterprise's blog or microblogs (e.g. Twitter) c) Multimedia content sharing websites or apps (e.g. YouTube, Flickr, SlideShare, Instagram, Pinterest, Snapchat)
	Sales_web	<u>0 = NO; 1 = YES</u>	During 2022, did your enterprise have web sales of goods or services on your enterprise's websites or apps?
	Sales_marketplace	<u>0 = NO; 1 = YES</u>	During 2022, did your enterprise have web sales of goods or services on e-commerce marketplace websites or apps used by several enterprises for trading goods or services?
	Sales_edl	<u>0 = NO; 1 = YES</u>	During 2022, did your enterprise have EDI-type sales of goods or services?
	ERP	<u>0 = NO; 1 = YES</u>	Does your enterprise use the following business software? a) Enterprise Resource Planning (ERP) software
	CRM	<u>0 = NO; 1 = YES</u>	Does your enterprise use the following business software? b) Customer Relationship Management (CRM) software
	Business_Intelligence	<u>0 = NO; 1 = YES</u>	Does your enterprise use the following business software? Business Intelligence (BI) software
	Datasharing_supplychain	<u>0 = NO; 1 = YES</u>	Does your enterprise share data electronically with suppliers or customers within the supply chain (e.g. via websites or apps, EDI systems, real-time sensors or tracking)?
	Dataanalytics_sources	<u>0 = None; 8 = All sources</u>	Does your enterprise perform data analytics on data from the following sources? a) transaction records such as sale details, payments records b) customer purchasing information, location, preferences, customer reviews, searches c) social media, incl. from your enterprise's own social media profiles d) web data (e.g. search engine trends, web scraping* data) e) location data from the use of portable devices or vehicles f) smart devices or sensors (e.g. Machine to Machine (M2M) communications, sensors installed in machinery) g) government authorities' open data h) satellite data
	Cloud_services	<u>0 = None; 10 = All services</u>	Does your enterprise buy any of the following cloud computing services used over the internet? a) E-mail b) Office software c) Finance or accounting software applications d) Enterprise Resource Planning (ERP) software applications e) Customer Relationship Management (CRM) software applications f) Security software applications g) Hosting the enterprise's database(s) h) Storage of files i) Computing power to run the enterprise's own software j) Computing platform providing a hosted environment for application development, testing or deployment
	Datasharing_invoice	<u>0 = No; 1 = YES</u>	In 2022, did your enterprise send any of the following types of invoices: a) Invoices in electronic form, in a standard structure suitable for automated processing (e-invoices)?

	Model_1	Model_2	Model_3
Internet_speed	0.390***	0.358***	0.185**
Website	-0.073**	-0.073**	-0.061***
Mobile_app	0.017	-0.056	-0.062
Socialmedia	0.684***	0.694***	0.527***
Sales_web	0.139	0.158	0.335
Sales_marketplace	-0.291	-0.263	-0.146
Sales_edu	0.205	0.193	0.451*
ERP	0.103	0.012	0.057
CRM	0.083	0.1	0.025
Business_Intelligence	0.977***	0.837***	0.678***
Datasharing_supplychain	0.304*	0.254	0.237
Dataanalytics_sources	0.035	0.037	0.056*
Cloud_services	0.227***	0.223***	0.190***
Datasharing_invoice	0.286*	0.266*	0.378**
Firm_size		0.237***	0.325***
NACE_D			0.551
NACE_E			-0.008
NACE_F			-0.381
NACE_G			-0.067
NACE_H			0.07
NACE_I			-0.758*
NACE_J			2.091***
NACE_M			3.446***
NACE_N			0.398
McFadden	0.1629	0.1674	0.1913
N	9,064	9,064	9,064

	Model_1	Model_2	Model_3	Model_4
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Sales_edt	20575.4***	20558.0***	21666.4***	27825.5***
ERP	19863.3***	20140.1***	21777.2***	18468.5***
CRM	10904.6**	10850.5**	10744.6**	9735.1**
Business_Intelligence	30470.9***	29980.2***	31675.2***	25501.8***
Datasharing_supplychain	3745.0	3549.7	3699.5	1991.5
Dataanalytics_sources	-57.7	-92.6	-112.3	-492.6
Cloud_services	5167.5***	5013.9***	5108.0***	4453.4***
Datasharing_einvoice	-5400.4*	-5439.8*	-5240.4*	-5439.9*
AI_tech		3306.7	3724.2	2087.4
Firmsize			-5054.8***	-496.5
NACE_D				261540.2***
NACE_E				-3385.1
NACE_F				10697.8**
NACE_G				68373.6***
NACE_H				27497.2***
NACE_I				-11054.2
NACE_J				75177.9***
NACE_M				41763.8***
NACE_N				-24689.7***
F-statistic	0.0000	0.0000	0.0000	0.0000
Adjusted R-squared	0.0737	0.0738	0.0751	0.1453
N	9,064	9,064	9,064	9,064