

Laitou, Eleni; Gerogiannis, Vassilis C.; Savvas, Ilias K.

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Artificial Intelligence Adoption in the European Union

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Title: "Artificial Intelligence Adoption in the European Union"

Authors and Affiliations:

Dr. Eleni Laitsou¹, Prof. Vassilis C Gerogiannis¹, Prof. Ilias K. Savvas¹

¹Digital Systems Department, University of Thessaly, 41500 Larissa, Greece

laitsou@uth.gr, vgerogian@uth.gr, isavvas@uth.gr

Abstract

This paper investigates the macro-level determinants of Artificial Intelligence (AI) adoption among enterprises in the 27 member states of the European Union (EU-27) over the period 2021–2023. Drawing on data from the Digital Economy and Society Index (DESI) and Eurostat, the study employs a multiple linear regression model to assess the influence of four key variables: R&D expenditure, the share of large enterprises, the proportion of the population with above-average digital skills, and access to very high-capacity networks. All variables are log-transformed to enable elasticity-based interpretation. The findings indicate that all four factors are statistically significant and positively associated with AI adoption, with digital skills and VHCN coverage exhibiting the strongest effects. Notably, the inclusion of the share of large enterprises as an explanatory variable provides a novel contribution, underscoring the structural conditions that facilitate technology diffusion at scale. Complementary scatterplot analysis further illustrates these relationships and identifies outlier cases that deviate from general trends. The paper concludes by highlighting the importance of context-sensitive policy interventions that integrate infrastructure investment, skills development, and structural upgrading to support inclusive and effective AI adoption across the EU.

Keywords: Artificial Intelligence Adoption, European Union (EU-27), Digital Economy and Society Index (DESI), R&D, Digital Skills, Large Enterprises

I. Introduction

The widespread adoption of computer and information technology has profoundly altered contemporary life, shaping the quality and structure of everyday activities (Laitou et al., 2020b; Laitou and Xenakis, 2023; Laitou et al., 2025). Among these advancements, Artificial Intelligence (AI) stands out as a pivotal innovation with wide-ranging implications across multiple domains. While initially confined to academic discourse and experimental applications, AI has become embedded in the core functions of sectors such as healthcare, financial services, transportation, education, and public administration (Zorman et al., 2023), (Tang et al., 2022), (Dias and Torkamani, 2019). Its capacity to learn from data, automate decision-making, and augment human capabilities positions it as a cornerstone of the digital transformation era, influencing both internal enterprise operations and the broader socio-economic landscape (Wellsandt et al., 2022; Benbya et al., 2020; Lepenioti et al., 2020).

In the European Union, the adoption of AI is increasingly regarded as a strategic priority. To this end, the European Commission has introduced major policy frameworks, including the Coordinated Plan on AI and the AI Act (European Commission, 2024), which seek to promote technological innovation while safeguarding ethical standards, transparency, and inclusivity. In parallel, the Digital Decade policy agenda sets out ambitious targets, such as ensuring that by 2030, at least 75% of EU businesses adopt advanced digital tools, including AI systems (European Commission, 2021; Laitou et al., 2020a). These initiatives underscore the EU's broader ambition to reinforce its digital autonomy and enhance its global competitiveness in the evolving technological landscape. Although AI holds significant strategic importance, its adoption by enterprises across the EU-27 remains uneven. This variability is influenced by a range of structural and contextual conditions, such as the extent of digital infrastructure, levels of national investment in research and innovation, the share of large enterprises within the economy, and the digital skillset of the labor force. Given that the successful deployment of AI requires more than mere financial resources, it is essential to examine how these factors interact within each national context.

This research aims to empirically investigate the macro-level determinants influencing AI adoption among enterprises within the EU-27 during the period 2021 to 2023. Utilizing official datasets from the Digital Economy and Society Index (DESI) (European Commission, 2019) and Eurostat, the analysis focuses on four key independent variables: research and development (R&D) expenditure, the proportion of large enterprises in the economy, digital skills, and access to Very High-Capacity Networks (VHCN). The objective is to assess the relative impact of each factor on AI integration and to explore potential disparities and outlier cases among EU member states. Through this approach, the paper contributes to a deeper understanding of the structural conditions that facilitate the widespread adoption of AI technologies. Furthermore, it provides evidence-based guidance to support the formulation of targeted digital policy frameworks and the strategic direction of innovation-related investments across the European Union.

II. Literature Review

The adoption of Artificial Intelligence (AI) has been the subject of extensive academic research in recent years. Research efforts have focused on identifying enablers, barriers, and broader implications of AI integration. This review synthesizes key insights from recent literature to provide a comprehensive understanding of the factors influencing AI adoption.

Khanfar et al. (2024) offer a thorough bibliometric and content analysis of 91 studies on AI adoption, revealing four predominant themes: artificial intelligence, machine learning, the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT). Their findings highlight a sectoral concentration in the literature, with agriculture, robotics, and legal services receiving considerable attention, while sectors such as healthcare and higher education remain underexplored. This suggests a need for broader, cross-sectoral investigations to deepen understanding of AI adoption dynamics. Expanding on sector-specific analyses, Yang et al. (2024) examine AI adoption in professional service firms through the Technological–Organizational–Environmental (TOE) framework. Their case studies of three auditing firms identify six critical factors influencing adoption: technological affordances and constraints, AI readiness, innovation management, competition, and regulatory environment. The study uncovers significant heterogeneity, with larger firms

exhibiting greater scale and depth of AI adoption driven by operational advantages, albeit facing more complex regulatory challenges. Conversely, smaller firms demonstrate lower AI readiness, constraining their ability to overcome adoption barriers. Addressing organizational complexities, Tursunbayeva and Chalutz-Ben Gal (2024) propose a framework-based checklist grounded in the Technology-Organization-People (TOP) model. Designed for digital leaders, this tool facilitates assessment of technological capabilities, organizational preparedness, and human factors, promoting a multilevel approach that enhances planning and implementation of AI initiatives and supports successful digital transformation. Bedué and Fritzsche (2022) address the trust gap in AI adoption using a qualitative approach based on expert interviews and the extended valence framework. Their findings identify key trust-building factors, such as transparency, explainability, certification, and access to knowledge, as critical enablers of AI adoption. The study refines the trust dimensions of ability, integrity, and benevolence, highlighting how trust in AI differs from that in traditional technologies. These insights offer valuable guidance for decision-makers seeking to foster trust and promote broader uptake of AI solutions. Radhakrishnan and Chattopadhyay (2020) provide a systematic review of AI adoption studies, focusing on theoretical frameworks such as Diffusion of Innovation, TOE, and UTAUT. Their analysis identifies key facilitators and barriers at both individual and organizational levels. Individual factors include trust, security, social influence, and intrinsic motivation, while organizational determinants encompass technical competencies, strategic planning, top management support, and digital maturity. This comprehensive view underscores the multifaceted nature of AI adoption processes. Beyond adoption factors, Kuzior et al. (2019) emphasize AI's role in fostering sustainable organizational development. They introduce a combinatorial model leveraging neural networks to support intelligent decision-making in managing organizational change, highlighting AI's potential as a strategic asset for long-term growth beyond mere automation. Alsheibani et al. (2019) examine the factors influencing AI adoption in professional service firms using the Technological-Organizational-Environmental (TOE) framework and a qualitative case study of three auditing firms. They identify six key factors, including technological affordances and constraints, innovation management, AI readiness, competition, and regulation. The findings show significant variation across firms, with larger firms adopting AI more extensively but facing regulatory challenges, while smaller firms struggle due to limited readiness.

This study builds upon and extends the existing body of research by adopting a macro-level, cross-country perspective on the adoption of Artificial Intelligence (AI) within European Union member states. While prior studies have predominantly concentrated on organizational or sector-specific analyses using theoretical frameworks, the present research employs quantitative methods to empirically assess the key determinants of national AI readiness and adoption. Specifically, the analysis confirms the importance of investments in Research & Development, digital skills, share of large enterprises, and technological infrastructure, factors widely recognized in the literature as critical for successful AI integration.

The key questions driving this research are: What factors significantly influence AI adoption among enterprises in the EU-27? How do research and development (R&D) expenditure, the proportion of large enterprises, digital skills, and access to Very High Capacity Networks (VHCN) contribute to this process? Understanding these relationships is essential for developing effective policies and strategies to accelerate the adoption of AI and leverage its benefits for economic growth and societal development. Consequently, this research offers evidence-based and measurable directions for policymakers aiming to accelerate AI development and adoption at both national and European levels.

III. Methodology

This study adopts a quantitative research design to investigate the determinants of Artificial Intelligence (AI) adoption among enterprises in the 27 member states of the European Union (EU-27) for the period 2021–2023. Data was sourced from the Digital Economy and Society Index (DESI) and Eurostat, covering enterprises with 10 or more employees.

The dependent variable is the percentage of enterprises adopting AI technologies, as defined by the DESI. This metric quantifies the percentage of enterprises (with 10 or more employees) utilizing artificial intelligence technologies across all manufacturing and service sectors, excluding financial services. The independent variables are: (1) RD (Research and Development): Gross expenditure on R&D as a percentage of GDP. This variable reflects the level of investment in innovation and its potential to drive technological advancements. (2) NON_SME (Proportion of Large Enterprises): The percentage of enterprises with 250 or more employees. This variable serves as a proxy for the structural composition of the business sector, capturing the extent to which a national economy is characterized by firms with sufficient scale and capacity to adopt advanced technologies such as AI. (3) DIG_SKILLS (Digital Skills Above Average): The percentage of the population with above-average digital skills. This factor captures the readiness of human capital to engage with and support AI technologies. (4) VHCN (Very High-Capacity Networks): The percentage of households with access to very high-capacity broadband networks, representing the technological infrastructure necessary for AI deployment.

Dependent variable	Independent variables	TIME PERIOD	COUNTRIES
AI	RD, NON_SME, DIG_SKILLS, VHCN	2021-2023	27 EUROPEAN

All variables were log-transformed to enable interpretation of regression coefficients as elasticities. The multiple linear regression model is specified as:

$$\ln(AI) = \beta_0 + \beta_1 \ln(NON_SME) + \beta_2 \ln(RD) + \beta_3 \ln(DIG_SKILLS) + \beta_4 \ln(VHCN) + \epsilon$$

Diagnostic tests (VIF, R², F-tests, t-tests) were conducted to ensure model validity, and all analyses were performed using Minitab Statistical Software version 21.

To complement the regression analysis and offer additional empirical insights, a series of scatterplots was constructed to visually explore the bivariate relationships between AI adoption and each of the four independent variables. These visual representations enable the identification of general trends, clustering patterns, and outlier cases across EU member states. Moreover, the scatterplots highlight countries that deviate from the expected patterns and need closer examination.

IV. Results and discussion

Regression analysis results

The regression output is summarized below:

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-2,620	0,723	-3,62	0,001	
InRD	0,501	0,123	4,07	0,000	1,80
InDIG_SKILLS	0,642	0,121	5,32	0,000	1,68
InVHCN	0,657	0,160	4,10	0,000	1,27
InNON_SME	0,2405	0,0895	2,69	0,009	1,17

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,358697	68,04%	66,35%	61,89%

All independent variables are statistically significant and positively associated with AI adoption, confirming their role as key enablers of digital transformation. The final model explains approximately 68% of the variation in AI adoption across EU countries ($R^2 = 0.680$), indicating substantial explanatory power and model robustness.

Specifically, VHCN ($\beta_4 = 0.657$, $p < 0.001$): The elasticity of very high-capacity network coverage is the highest among all predictors. A 1% increase in access to VHCN corresponds to a 0.66% rise in AI adoption, underscoring the foundational importance of digital infrastructure. R&D ($\beta_2 = 0.501$, $p < 0.001$): A 1% increase in national R&D expenditure as a share of GDP is associated with a 0.50% increase in AI adoption. This highlights the strategic role of investment in innovation and knowledge creation in enabling AI integration at scale. DIG_SKILLS ($\beta_3 = 0.642$, $p = 0.001$): A 1% increase in the proportion of individuals with above-average digital skills leads to a 0.64% increase in AI adoption. This result reinforces the need for upskilling and continuous digital education as a cornerstone of digital transformation. NON_SME ($\beta_1 = 0.2405$, $p = 0.009$): A 1% increase in the proportion of large enterprises corresponds to a 0.24% increase in AI adoption. This result highlights the importance of business structure in driving technological transformation. Larger firms tend to possess more internal resources, technical expertise, and strategic capability, which collectively enhance their ability to adopt and scale AI solutions.

These findings align with existing literature, which points to the interplay of technological infrastructure, human capital, innovation capacity, and organizational scale as critical for successful AI integration. The use of logarithmic transformation also reveals the proportional effect of each factor, offering a more detailed understanding of their relative importance. Overall, the results suggest that a balanced and synergistic policy approach, supporting R&D,

upgrading broadband infrastructure, enhancing digital skills, and strengthening enterprise capacity, is essential for accelerating the diffusion of AI technologies in the European context. Policymakers must address these areas holistically to create an environment conducive to AI integration.

Scatterplots analysis

The following scatterplots visually demonstrate the relationships between AI adoption and the four main independent variables in 2023: R&D expenditure, the proportion of large enterprises, digital skills, and VHCN coverage. In most cases, they reveal a generally strong positive association between each independent variable and AI adoption across EU member states. This supports the regression findings, which identify these parameters as statistically significant determinants of AI integration. However, several countries deviate from these trends, constituting cases that require deeper investigation into the specific national factors that drive their AI adoption.

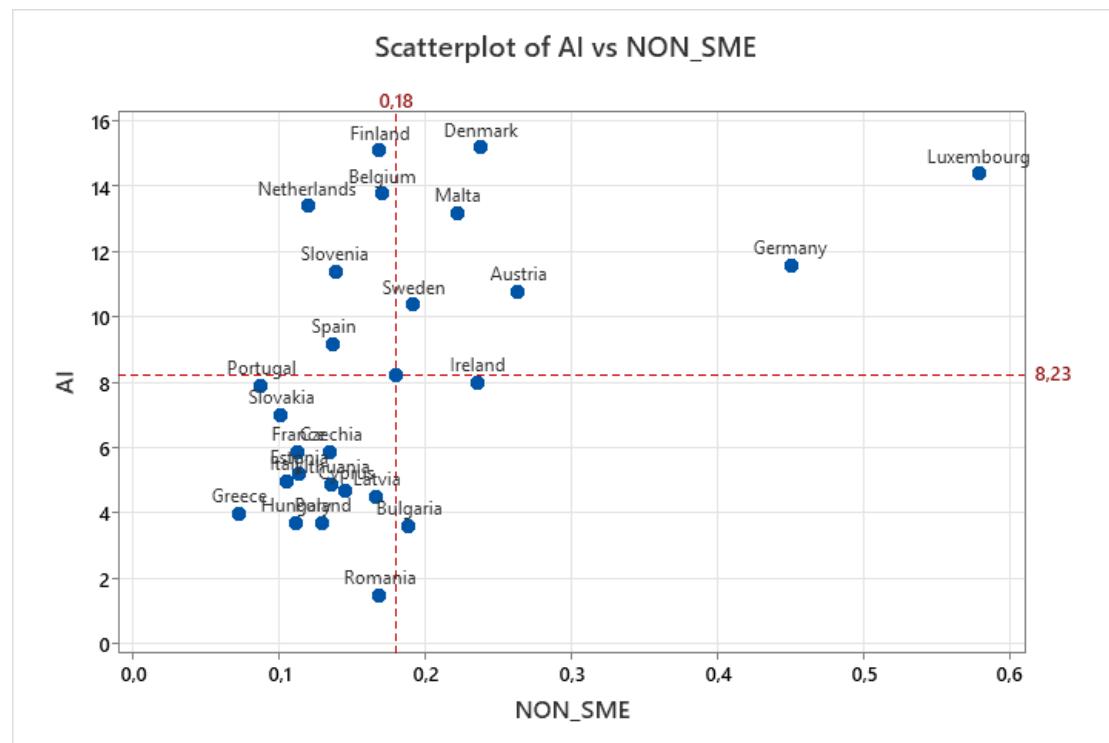


Figure 1 AI adoption vs Large (NON_SME) Enterprises

The scatterplot (Figure 1) of AI adoption (Y-axis) against the share of large enterprises (X-axis) across EU member states in 2023 reveals distinct patterns and outlier cases that enrich our understanding of the macro-level determinants of AI diffusion. It visually confirms the positive association between the share of large enterprises and AI adoption among EU member states. Most notably, countries such as Germany and Luxembourg, with a high proportion of large enterprises, also report high AI adoption rates. In contrast, Ireland, despite its relatively high share of large enterprises, lags behind in AI adoption, likely due to the unique structure of its

economy and the globalized nature of its multinational corporations. Conversely, countries like Finland and Slovenia achieve high AI adoption with a lower share of large enterprises, underscoring the importance of effective national strategies and support for SMEs.

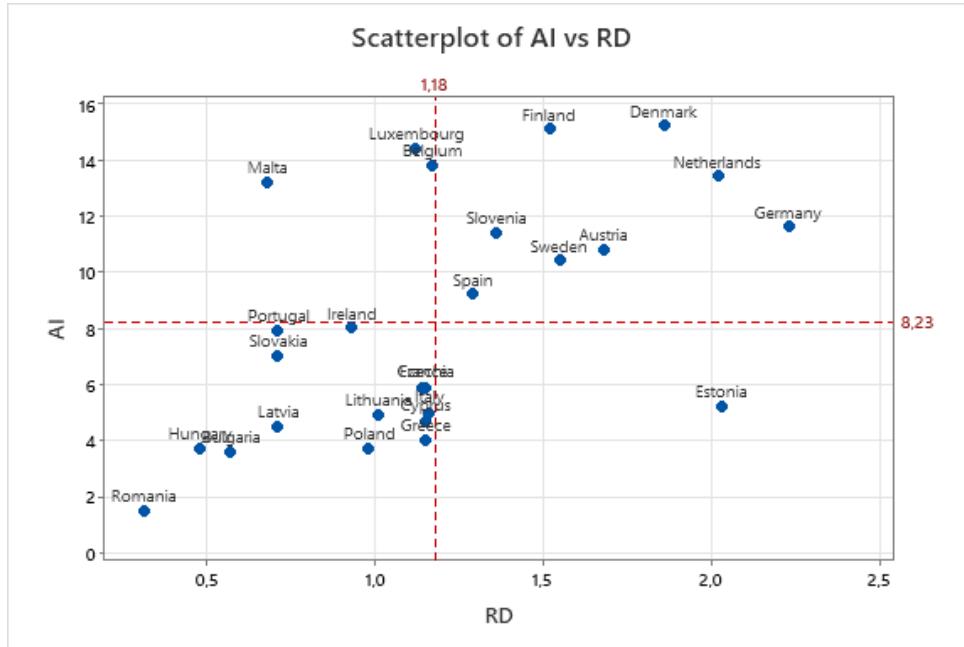


Figure 2 AI adoption vs R&D expenditure

The scatterplot of AI adoption versus R&D expenditure (Figure 2) confirms a strong positive association across EU member states, with most countries clustering along an upward trend. Notably, innovation leaders such as Finland, Denmark, the Netherlands, Germany, Austria and Sweden combine above-average R&D investment with high AI adoption, underscoring the strategic role of research intensity in fostering digital transformation. However, several outlier cases emerge. For example, Estonia exhibits high R&D expenditure but below-average AI adoption, suggesting the presence of additional barriers beyond innovation investment. Conversely, countries like Luxembourg and Belgium achieve high AI adoption despite moderate R&D intensity, likely reflecting the influence of other enabling factors such as digital infrastructure, policy frameworks, or the presence of multinational enterprises. These findings highlight that while R&D investment is a critical driver, its impact on AI adoption is mediated by broader contextual and structural factors.

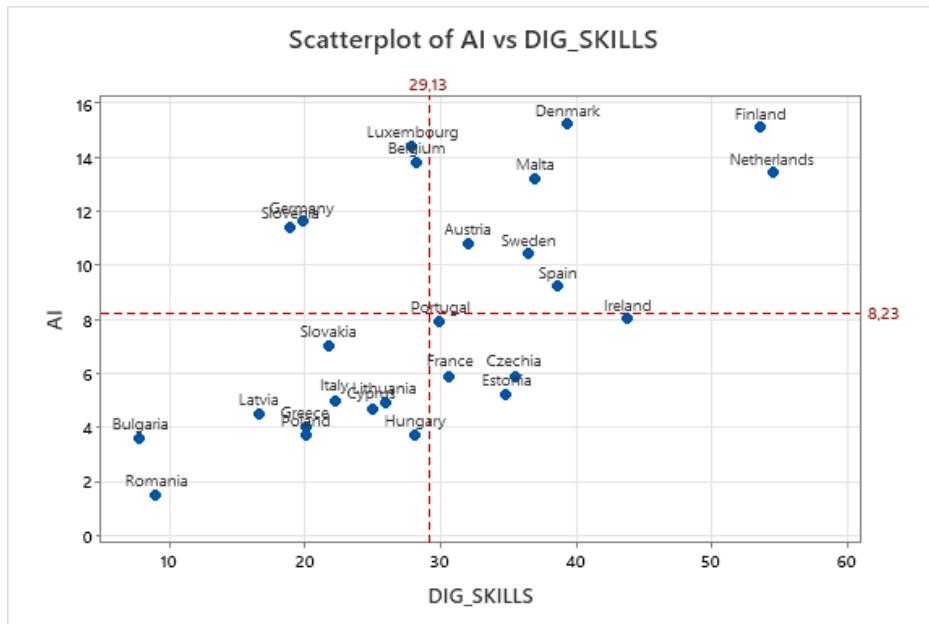


Figure 3 AI adoption vs Digital Skills (above average)

While the scatterplot (Figure 3) demonstrates a strong positive association between the share of the population with above-average digital skills and AI adoption across EU member states, several countries deviate from this general trend, providing valuable insights into the complexity of national contexts. For example, Ireland stands out as an outlier, exhibiting relatively high digital skills but only moderate AI adoption, possibly reflecting the structural characteristics of its economy. Conversely, Germany and Luxembourg achieve high levels of AI adoption despite only moderately exceeding the EU average in digital skills, suggesting that other factors may compensate for skill gaps. Czechia and Estonia represent interesting cases as well: both countries report digital skills above the EU average but display only moderate levels of AI adoption. This may indicate the presence of additional barriers that constrain the diffusion of AI technologies. At the lower end of the spectrum, Bulgaria and Romania consistently report both low digital skills and low AI adoption, reinforcing the importance of targeted investment in human capital.

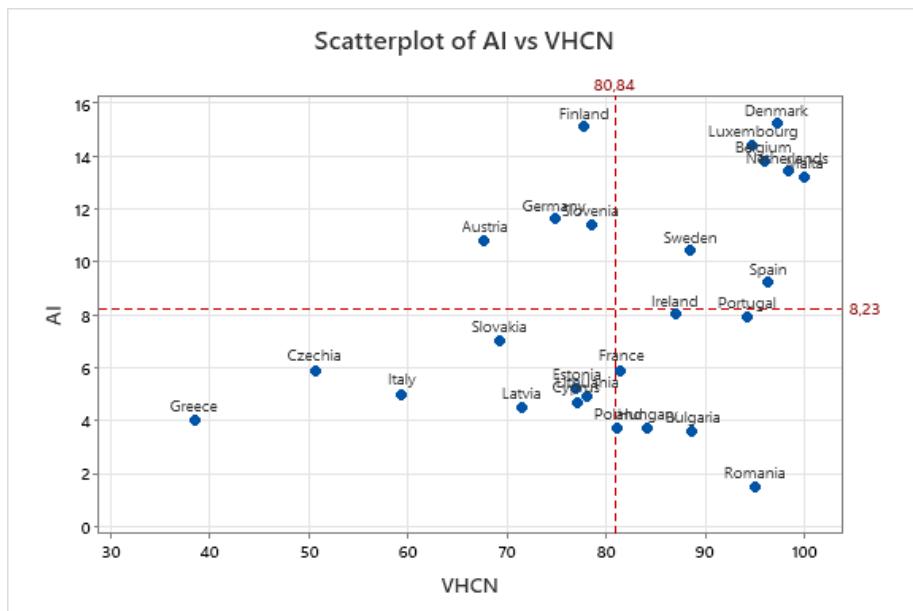


Figure 4 AI adoption vs VHCN

The scatterplot (Figure 4) examining the relationship between AI adoption and the coverage of Very High-Capacity Networks (VHCN) also demonstrates a pronounced positive correlation. Member states that have prioritized investments in advanced broadband infrastructure, such as Denmark, Luxembourg, and the Netherlands, stand out for their high levels of AI adoption among enterprises. Robust digital infrastructure is essential for enabling the deployment of AI applications that require high-speed, reliable connectivity and the processing of large volumes of data in real time. In contrast, countries with limited VHCN coverage, including Greece and Italy, display considerably lower rates of AI adoption. These findings reinforce the conclusion that infrastructure readiness is a fundamental enabler of AI-driven innovation. Addressing disparities in VHCN coverage should thus remain a central focus of digital policy agendas to ensure inclusive and widespread AI integration across the EU. It is also worth noting the presence of outliers. For example, Romania appears to have one of the highest VHCN coverage rates but one of the lowest levels of AI adoption, suggesting that infrastructure alone is not sufficient. Conversely, countries like Austria and Germany exhibit relatively high AI adoption despite having VHCN coverage levels below the EU average, potentially reflecting stronger institutional capacity or innovation ecosystems.

This study provides important insights into the macro-level factors influencing AI adoption across EU-27 member states. However, several limitations should be acknowledged. The analysis is based on aggregated data from official sources (DESI, Eurostat), which may not fully capture differences within countries or between economic sectors. Moreover, the dataset includes only enterprises with 10 or more employees, thus excluding micro-enterprises that represent a large share of the European business landscape and may have different adoption patterns. Finally, while the selected variables are grounded in the literature, other relevant factors—such as regulatory frameworks, industry-specific policies, or cultural attitudes—were not included in the model. These limitations suggest that the findings should be interpreted with caution and highlight the need for longer time series, more detailed, and sector-specific research in the future.

V. Conclusions

This study provides empirical evidence on the macro-level factors shaping the adoption of Artificial Intelligence (AI) among enterprises in the EU-27, drawing on data from 2021 to 2023. The regression analysis revealed that R&D expenditure, the share of large enterprises, digital skills, and very high-capacity network (VHCN) coverage are all statistically significant and positively associated with national AI adoption rates. Among these, access to VHCN and digital skills exhibited the strongest elasticities, underscoring the foundational role of infrastructure and human capital in enabling technological transformation. Moreover, the positive association between R&D expenditure and AI adoption emphasizes the critical role of innovation investment in fostering technological readiness. The inclusion of the proportion of large enterprises as a predictor offers a novel perspective, highlighting the influence of business structure and organizational capacity on AI diffusion. Larger firms are more likely to possess the internal resources, technical capabilities, and strategic foresight necessary to implement and scale advanced digital solutions. Complementary scatterplot analysis further supported the regression findings and allowed for the identification of outlier cases, whose AI adoption trajectories deviate from expected patterns. These divergences emphasize the need for more context-sensitive policy frameworks that account for national structural specificities and sectoral dynamics.

Overall, the findings contribute to the academic discourse by extending the literature beyond firm-level determinants and emphasizing the importance of national-level structural conditions in shaping AI adoption. For policymakers, the results underline the need for an integrated digital strategy that simultaneously enhances digital infrastructure, strengthens innovation ecosystems, supports workforce upskilling, and encourages AI diffusion among both large firms and SMEs.

Future research could expand this approach by incorporating longer time series designs, sector-specific analyses, or additional indicators such as institutional quality and regulatory environment. Such extensions would further illuminate the complex interplay between technological capacity, economic structure, and digital policy in driving AI adoption across Europe.

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