

Triple Helix Model and Artificial Intelligence in Public Administration

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ABSTRACT

Although the Triple Helix model has been widely analysed in the context of innovation ecosystems, its contribution to fostering the adoption of artificial intelligence (AI) within public administration remains insufficiently explored. This study addresses this research gap by examining how interactions among universities, industry, and government facilitate AI integration into digital governance across selected EU countries.

Purposes: The main research objectives are to: (a) assess the digital maturity of the selected EU countries; (b) evaluate how Triple Helix interactions shape AI adoption in public administration; (c) analyse the interrelationships among the three actors within the context of AI governance; and (d) explore the connections between each country's AI strategy and its broader governance mechanisms.

Design/Methodology/Approach: The research combines both quantitative and qualitative methods, utilizing data from AI Watch, the European Commission, Eurostat, Oxford Insights, and the OECD.

Findings: The findings reveal significant disparities among the selected EU member states and identify critical factors that either facilitate or constrain AI integration within public administration, offering new insights into the evolving role of the Triple Helix model in the era of algorithmic governance.

Practical Implications: The results are particularly relevant for public sector decision-makers, researchers in governance and innovation studies, and policymakers seeking sustainable models for digital transformation and collaborative innovation.

Originality/Value: This research presents the first cross-national empirical study linking Triple Helix dynamics to AI-driven innovation in the public sector, incorporating a range of indicators. The originality of this research lies in its conceptual integration of the Triple Helix framework with the transformative capacities of artificial intelligence in reconfiguring public governance and innovation dynamics within a few EU countries.

Keywords: *Triple Helix model, artificial intelligence, public administration, innovation ecosystems, European Union, comparative analysis, digital transformation, digital governance.*

Model trojne vijačnice in umetna inteligenca v javni upravi

POVZETEK

Čeprav je model trojne vijačnice široko analiziran v kontekstu inovacijskih ekosistemov, je njegov prispevek k spodbujanju uvajanja umetne inteligence (UI) v javni upravi premalo raziskan. Ta študija zapolnjuje raziskovalno vrzel z analizo, kako interakcije med univerzami, industrijo in vlado pospešujejo vključevanje UI v digitalno upravljanje v izbranih državah EU.

Nameni: glavni raziskovalni cilji so: (a) oceniti digitalno zrelost izbranih držav EU; (b) ovrednotiti, kako interakcije v okviru trojne vijačnice oblikujejo sprejemanje UI v javni upravi; (c) analizirati medsebojna razmerja med tremi akterji v kontekstu upravljanja UI; ter (d) raziskati povezave med nacionalno strategijo za UI posamezne države in njenimi širšimi mehanizmi upravljanja.

Načrt/metodologija/pristop: raziskava združuje kvantitativne in kvalitativne metode ter uporablja podatke AI Watch, Evropske komisije, Eurostata, Oxford Insights in Organizacije za gospodarsko sodelovanje in razvoj (OECD).

Ugotovitve: rezultati razkrivajo pomembne razlike med izbranimi državami članicami EU in opredeljujejo ključne dejavnike, ki bodisi omogočajo bodisi omejujejo vključevanje UI v javno upravo, pri čemer ponujajo nove vpoglede v razvijajočo se vlogo modela trojne vijačnice v dobi algoritmičnega upravljanja.

Praktične implikacije: rezultati so posebej relevantni za odločevalce v javnem sektorju, raziskovalce s področja upravljanja in inovacijskih študij ter za oblikovalce politik, ki iščejo trajnostne modele za digitalno preobrazbo in sodelovalne inovacije.

Izvirnost/vrednost: gre za prvo čeznacionalno empirično študijo, ki povezuje dinamiko trojne vijačnice z inovacijami, ki jih poganja UI, v javnem sektorju ob upoštevanju niza kazalnikov. Izvirnost raziskave je v konceptualni integraciji okvira trojne vijačnice s preoblikovalnimi zmožnostmi umetne inteligence pri preoblikovanju javnega upravljanja in inovacijskih dinamik v nekaterih državah EU.

Ključne besede: *model trojne vijačnice, umetna inteligenca, javna uprava, inovacijski ekosistemi, Evropska unija, primerjalna analiza, digitalna preobrazba, digitalno upravljanje.*

JEL: O33, O38, R53, R58.

1 Introduction

In the era of the knowledge-based economy and intelligent artificial technologies, innovation is no longer the exclusive result of university research or private investments, but of a strategic interaction between several institutional actors. In recent years, the European Union has placed a strong emphasis on the ethical and strategic adoption of Artificial Intelligence (AI) across public sectors. According to the *European Commission's Coordinated Plan on Artificial Intelligence (2021)* and the *EU AI Act (2024)*, member states are encouraged to integrate AI to improve administrative efficiency, transparency, and citizen-centred services. However, the level of AI adoption remains uneven across member states, with significant disparities in digital readiness, data governance, and institutional capacities.

The Triple Helix model is increasingly recognized as both an explanatory and operational framework for analyzing collaborative innovation processes (Etzkowitz, 2003a, p. 298; Etzkowitz, 2003b, p. 305). Within the European Union, this approach has been embedded in various regional and national initiatives, supported by structural funds and programs such as Horizon Europe. Originally proposed by Etzkowitz and Leydesdorff (1995a, p.29), the Triple Helix model offers a conceptual and practical foundation for fostering innovation through dynamic and systemic interactions among universities, industry, and government. This article analyzes the application of the Triple Helix model in different European Union member states, with a focus on good practices, public policies, governance structures, and economic and social results in the context of the accelerated growth of the integration of digital technologies and artificial intelligence (Nyathani, 2023, p. 3). Case studies from EU Member States illustrate different stages of maturity of innovation ecosystems and offer relevant lessons for future European policies (Grilli and Pedota, 2024, p. 242). The Triple Helix model is becoming increasingly relevant in the context of the adoption of artificial intelligence (AI) technologies in public administration (Reis et al. 2019, p. 132). AI requires both academic expertise (universities and research institutes), applied technological solutions (industry, business), and institutional capacity for integration and regulation (government through central, regional, and local administrative authorities). Success stories from some European countries (Neumann et al., 2024, p. 121) are instructive in this regard. Estonia has developed and implemented the KrattAI project, in which the government collaborates with universities and the IT industry to create AI-based digital assistants for public administration. In Finland, the AI4Cities project brings together local authorities, universities, and companies to develop sustainable urban AI solutions. In France, the Paris-Saclay AI Hub project is an initiative where cutting-edge research, AI startups and public policies focused on digital ethics intersect.

The Triple Helix model has proven effective in stimulating innovation in EU countries with mature infrastructure and coherent public policies (Etzkowitz, 2008, p. 149). To replicate its success across the Union, it is necessary to adapt models to the regional context, strengthen institutional capacity, and encour-

age cross-sectoral collaboration. The future of European innovation depends on the ability of actors in the three spheres to act in an integrated and adaptive manner in a competitive global context (Parent-Rochelleau and Parker, 2022, p. 14). The EU supports these directions through initiatives such as the Green Deal, Horizon Europe and the EIT (European Institute of Innovation and Technology), promoting responsible and sustainable innovation. The Triple Helix model provides the institutional and cultural infrastructure necessary for the integration of AI in public administration. It is not a technological model, but it is becoming essential for the collaborative governance of emerging technologies, including artificial intelligence.

This study focuses on a few EU member states, Estonia, Finland, Germany, France, and Romania, as representative cases that reflect varying levels of AI maturity and digital governance. Estonia and Finland are recognized for their advanced e-government infrastructures, while Germany and France illustrate large-scale administrative systems adapting to AI regulation and ethical governance. Romania represents a developing context, highlighting structural and institutional barriers to AI adoption. The comparative selection included in this research enables a nuanced understanding of the Triple Helix dynamics across different levels of AI readiness within the EU. From this perspective, this research aims to identify, analyze, and categorize selected EU member states according to specific variables derived from the Triple Helix model, within the broader context of developing and integrating diverse AI applications in public interest services. Although the principles of the Triple Helix model are formally embedded in European innovation strategies, their practical implementation differs considerably across Member States. To standardize innovative performance and strengthen knowledge and technology ecosystems across the European Union, a differentiated but coherent approach is needed at the level of public policies. While the literature on AI in the public sector has expanded rapidly, most studies focus on technological capabilities, ethics, or citizen trust (e.g., Janssen et al., 2020; Zuiderwijk et al., 2022). However, limited attention has been given to the institutional and collaborative mechanisms that enable or constrain AI innovation in public administration — particularly through the *Triple Helix framework* (interaction between government, academia, and industry). This paper seeks to bridge this gap by examining the functioning of the Triple Helix model in the context of AI adoption within selected EU public administrations, as well as the structural conditions that enable effective governance and innovation. The analysis conducted provides a coherent foundation of data and insights on the selected EU countries, categorized according to specific variables of the Triple Helix model, in the broader context of the rapid expansion of artificial intelligence across administrative and related domains. In the EU literature, the role of AI in public administrations is rapidly growing, being the subject of interesting empirical and conceptual studies, which are selectively presented in the next section of the paper.

This paper contributes to the literature, offering both theoretical insights for innovation governance and practical implications for the implementation of the EU AI Act and related digital public policies.

This work is organized into four interrelated sections. The first section provides a comprehensive review of key concepts and scholarly studies on the Triple Helix model, emphasizing its relevance to the application of artificial intelligence in public administrations across EU member states. The second section details the research methodology, including the study's objectives, research questions, hypotheses, and principal variables, as well as the analytical framework employed to systematically investigate the topic. The third section presents the research findings alongside a correlative analysis, highlighting patterns and insights derived from the data. Finally, the fourth section offers the main conclusions and underscores the study's contributions to advancing knowledge in the field of public governance and AI implementation.

2 Literature Review About the Triple Helix Model in the EU Member States

The Triple Helix model, developed by Henry Etzkowitz and Loet Leydesdorff (2001, p. 24), conceptualizes the interactions between university, industry, and government as pillars of innovation in a knowledge-based economy and artificial intelligence. In the EU, the Quadruple/Quintuple Helix extensions have added the sphere of civil society and the environment, strengthening a systemic framework for digitalization and AI (Androniceanu and Georgescu, 2023; Androniceanu et al., 2022). Our research aims to analyze the synergy between the Triple Helix and AI in European public administration, as reflected in the specialized literature. Henry Etzkowitz and Loet Leydesdorff (2001, p. 24, 1995b, p. 115; 1999, p. 117) laid the foundations of the model in 1995, emphasizing the hybrid role of universities, regulated by market and governance dynamics. Leydesdorff (2009, p. 381) extends the model, emphasizing the new evolution in knowledge-based economies. Elias Carayannis and Campbell (2009, p. 221) formulated the Quadruple/Quintuple Helix, including civil society and the environment in the innovation process. Research on these topics continues at an accelerated pace in the context of the large-scale penetration of artificial intelligence tools in public administration in EU countries and in other areas that provide public services (Makridakis, 2017, p. 52). Thus, an intensification of interdisciplinary approaches is observed in research in the last decade. Other researchers explore AI for the public sector, emphasizing the essential role of cross-sectoral collaboration (university–industry–government), but also the managerial and technological challenges that accompany such initiatives. Straub, Morgan, Bright and Margetts (2022, p. 162) propose an integrated framework for government AI through multiple dimensions: operational fitness, epistemic alignment, and normative divergence. JRC (Joint Research Centre, 2024) identified and analyzed the adoption of AI in public administration through an analysis of 574 managers based on the following main dimensions: leadership, technical-ethical skills, and governance. There is a par-

ticular interest in analyzing the synergy of the main actors in the Triple Helix model with new applications of artificial intelligence that can greatly support the cooperation between the main actors of the Triple Helix model, as universities generate knowledge, companies develop AI solutions, and the government adopts/regulates everything needed in a Triple Helix structure. Michalec et al. (2024, p. 62) show that administrative centers led by mixed teams can reduce institutional barriers. Research within the JRC has highlighted the role of AI in facilitating data interoperability through ontologies and taxonomies in European public administration. AI GOV (Straub et al., 2022, p. 163) introduces procedural, structural, and relational practices at strategic and tactical levels, which can be coordinated through Triple Helix nodes.

JRC (2024) recommends developing ethical and legal skills in AI governance (Rodgers et al., 2024, p. 25). In 2023, Tangi and his team at JRC produced a large study demonstrating the added value of AI in interoperability, supported by government-university-industry collaboration. The European Commission, through the Futurium programme (European Commission, 2023) describes concrete uses such as AI assistants for employees (HR, procurement, reporting), highlighting investments in governance and innovation culture (Etzkowitz and Carvalho de Mello, 2004, p. 162). Consequently, there is a solid body of literature exploring the interaction between AI and public administration in the context of the Triple Helix model, from theoretical perspectives (Etkowitz and Leydesdorff, 1999, p. 118), to applied cases and EU frameworks (JRC, 2024). This convergence provides an integrated framework for innovation, governance and skills, but the challenge of transforming this potential into real impact on public services and democratic trust remains. The literature (Votto et al., 2021, p. 14; Etzkowitz and Klofsten, 2005, p. 246) contains detailed case study examples from various EU member states, illustrating how the Triple Helix model is applied in public administration, in the context of artificial intelligence (Kruger and Steyn, 2025, p. 28). For example, during the pandemic, in Spain, a group of experts coordinated by Pierra Riccio created a multi-disciplinary center using anonymized mobility data and public surveys for epidemiological predictions and resource allocation based on the Triple Helix model and AI applications (Riccio et al., 2022, p. 7). The Triple Helix model in Spain had as main actors the regional government, the University of Alicante and the telecom companies: Telefonica and Vodafone. Another example of the application of the Triple Helix Model is identified in Denmark in the municipality of Gladsaxe. AI applications used are the internal Chatbot "GladGPT" (ChatGPT-4), launched in 2023, for employee support. In 2017, the algorithm for detecting vulnerable families was discontinued due to transparency and bias issues. The Lüneburg district and the federal states in Germany have examples of implementing a variety of chatbots to reduce direct interaction between the administration and citizens, but the results are varied (Gill et al., 2024, p. 21; Strohmeier, 2020, p. 352). Other researchers emphasize the importance of AI strategies at the state (Bundesländer) level: competencies, regulations, and different approaches from one state to another. Other experimental examples are identified in the Czech Republic between the Ministry of the Interior and universities, using various AI ap-

plications for the analysis of databases from population registers, security, and e-government. In Poland, there is a high Government AI Readiness Index (62.5%), with a progressive growth trend until 2027. The Triple Helix model consists of collaborations between the state, research institutions, and private companies specialized in ICT, focusing on chatbots, predictive analysis, and smart cities. Applied research and successful implementations of the Triple Helix model also exist in Norway in the municipality of Trondheim, where a study was conducted in approximately 200 public institutions, and 19 interviews were organized. The study analyzed the early adoption of AI, with risks of discrimination and political pressure. In Italy, the PRISMA project was carried out (2016): an interoperable cloud platform for citizen engagement (Catania and Siracusa municipalities) - Triple Helix models between local governments, universities, and the IT industry. AIDA is an AI system based on deep learning for crime prevention and collaboration between academia, police, and the public sector. In Belgium and Latvia, AI innovations in administration based on the Triple Helix model were carried out. In Belgium, several experimental research studies were conducted, and projects were implemented. One of the successful research areas was Knowledge management with generative AI (smart regulation). Another was Job matching (Jobnet). As can be seen, the Triple Helix Model in the context generated by AI in public administration in the public sector in EU countries is confirmed, but the risks of discrimination and cultural barriers represent major challenges (Ranga and Etzkowitz, 2013, p. 247). Theoretical frameworks (Nosratabadi et al., 2019, p. 18; Rodgers et al., 2024, p. 27.) and studies from different countries (Estonia, Italy, Germany, Spain, etc.) show that success comes from ethical policies, human involvement, and adaptive organizational culture, but also from massive investments in infrastructure and in the training of human resources and citizens culture (Lorincova et al., 2024, p. 19; Michalec, 2024, p. 64). Dvorský (2025, p. 98) emphasizes the importance of using AI in risk management. Expert recommendations include piloted approaches, rigorous training, and transparency and accountability mechanisms (Stachová et al., 2024). AI transforms HR in the public sector – from recruitment, performance appraisal, to professional development and planning, emphasizing the efficiency and personalization of new models, but warns of the risks of bias, transparency, and confidentiality (Mwita and Kitole, 2025). Nosratabadi et al., 2022, p. 23) present a systematic approach (“Employee Lifecycle Management”), highlighting the use of algorithms (Random Forest, SVM, Neural Networks) at all stages of the employee life cycle – recruitment, retention, and off-boarding. Rodgers et al. (2023) address “ethical decision-making” in HR, emphasizing the integration of responsible AI to eliminate bias. The Springer (2025) study from Tanzania shows that the success of AI implementation in HR requires technological infrastructure and organizational capital. The study draws attention to organizational culture and the fact that AI acceptance requires managerial involvement, cultural alignment and dedicated task forces.

Through the #KrattAI initiative, Estonia is developing virtual robots to guide staff and citizens. The “job matching” system has been extended to public HR, suggesting positions in line with users’ profiles. The Jobnet system uses

machine learning to match candidates to open positions in public administration (Garg et al., 2022, p. 607). A JRC comparative study conducted in Italy and Germany (N=1411) shows that human supervision does not prevent discrimination in AI decisions. A “fair AI” can reduce gender bias, but remains influenced by the prejudices of the assessor. Discrimination remains a problem: even algorithms designed for fairness can be influenced by the actions of human assessors (Meshram, 2023, p. 329; Androniceanu, M., 2024, p. 91; Androniceanu, M., 2025, p. 110). Rigid or bureaucratic institutional culture reduces AI adoption. Solutions: task force, “skunk works” require training and early involvement of institutional leadership (Malin et al., 2023, p. 8). Adopting AI requires clear rules, transparency, and trained personnel who can override automated decisions, as recommended by various researchers (Alaa, 2023, p. 348; De Alwis et al., 2022, p.190; Rahman and Audin, 2020, p. 259). Relevant empirical studies to discover the implications of the Triple Helix model and AI applications are identified in the literature (Wirtz, 2018, p. 609). Some of the relevant ones are presented below. In Sweden, an empirical analysis was carried out in public administration with HR analytics. The research that was carried out was based on national, regional, and local data obtained through semi-structured interviews for 51 respondents, all middle-level managers in the Swedish public sector. As the results presented in the paper “Reasons for HR analytics adoption in public sector organisations” show, organisations currently use only descriptive HR analytics (dashboards, reports), but intend to evolve towards predictive analytics. The identified determining factors were: internal pressure for efficiency, the need to quantify HR indicators, and data availability (Androniceanu, 2025, p. 82; Androniceanu, 2024, p. 110).

The main challenges are: limited technological capacity, lack of skills, and conservative organisational culture. The research showed that success depends on data infrastructure, technical skills, and strategic direction, including the qualitative involvement of HR and non-HR actors. The main advantages and challenges of the penetration of artificial intelligence in human resource management in public institutions, identified by Mwita and Kitole in the work published in 2025, are presented in Table 1.

The findings reported by Mwita and Kitole (2025, p. 12) highlight the potential risks of decision-making errors associated with the use of automated artificial intelligence systems in human resource management within public institutions, as illustrated in Figure 1.

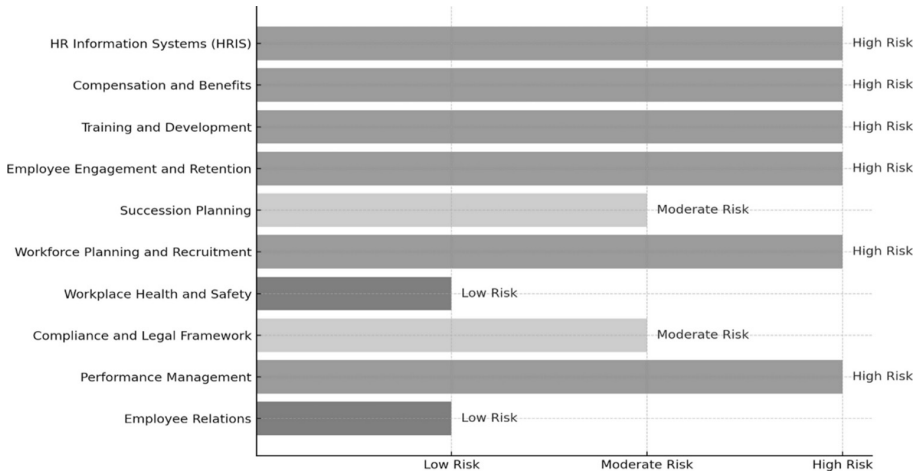
Table 1: Potential benefits and challenges of artificial intelligence in human resource management in public institutions

HRM Component	AI Benefits	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Workforce Planning and Recruitment	AI automates candidate screening to identify the best fit efficiently	87 (40%)	65 (30%)	43 (20%)	17 (8%)	5 (2%)
	AI enhances onboarding with personalized training modules for new hires	85 (39%)	67 (31%)	42 (19%)	18 (8%)	5 (2%)
Performance Management	AI generates actionable insights through continuous performance tracking	78 (36%)	70 (32%)	43 (20%)	19 (9%)	7 (3%)
	AI improves feedback accuracy with unbiased data analysis	80 (37%)	68 (31%)	44 (20%)	18 (8%)	7 (3%)
Training and Development	AI customizes employee training to address individual skill gaps	81 (37%)	74 (34%)	41 (19%)	15 (7%)	6 (3%)
	AI identifies future skill requirements for strategic upskilling	83 (38%)	70 (32%)	43 (20%)	15 (7%)	6 (3%)
Compensation and Benefits	AI uses predictive analytics to design competitive salary structures	83 (38%)	72 (33%)	39 (18%)	17 (8%)	6 (3%)
	AI simplifies benefit administration by automating complex processes	80 (37%)	73 (34%)	41 (19%)	17 (8%)	6 (3%)
Employee Relations	AI monitors employee sentiment to detect early signs of dissatisfaction	74 (34%)	69 (32%)	50 (23%)	19 (9%)	5 (2%)
	AI recommends proactive conflict resolution strategies	76 (35%)	67 (31%)	51 (24%)	18 (8%)	5 (2%)
Compliance and Legal Framework	AI ensures adherence to regulatory changes with real-time alerts	76 (35%)	73 (34%)	42 (19%)	20 (9%)	6 (3%)
	AI reduces human errors in compliance documentation and auditing	78 (36%)	71 (33%)	43 (20%)	19 (9%)	6 (3%)

HRM Component	AI Benefits	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Workplace Health and Safety	AI tracks workplace conditions to predict and prevent safety risks	79 (36%)	68 (31%)	44 (20%)	19 (9%)	7 (3%)
	AI facilitates wellness programs by monitoring employee health metrics	81 (37%)	69 (32%)	43 (20%)	17 (8%)	7 (3%)
HR Information Systems (HRIS)	AI streamlines data management and automates repetitive tasks in HR	85 (39%)	71 (33%)	41 (19%)	14 (6%)	6 (3%)
	AI provides predictive analytics for strategic workforce planning	82 (38%)	72 (33%)	42 (19%)	15 (7%)	6 (3%)
Succession Planning	AI identifies potential leaders through performance data analysis	84 (39%)	69 (32%)	44 (20%)	16 (7%)	4 (2%)
	AI maps career pathways to ensure seamless succession transitions	83 (38%)	68 (31%)	45 (21%)	17 (8%)	4 (2%)
Employee Engagement and Retention	AI predicts attrition risks by analysing engagement trends	82 (38%)	72 (33%)	43 (20%)	16 (7%)	4 (2%)
	AI designs personalized retention strategies using employee data insights	83 (38%)	71 (33%)	44 (20%)	15 (7%)	4 (2%)

Source: Mwita, K. M. and Kitole, F. A. (2025). Potential benefits and challenges of artificial intelligence in human resource management in public institutions. *Discover Global Society*, 3(35), pp. 1–19.

Figure 1: Risks Associated with AI in Human Resource Management



Source: Mwita, K. M., Kitole, F. A. (2025). Potential benefits and challenges of artificial intelligence in human resource management in public institutions. *Discover Global Society*, 3(35), pp. 1–19.

Another example of relevant empirical research conducted in the Swedish public administration is about AI systems integrated in the Swedish Public Employment Service (PES). The study was conducted in 2024 and the main results were published in the same year (Berman et al., 2024, p. 9). The theoretical framework of the research was based on Institutional Theory, Resource-Based View, and Ambidexterity. Case analysis was used as the method, with an emphasis on transparency, interpretability and stakeholder involvement. The results show that AI is effective in supporting decisions (assessment of assistance applicants), but transparency and stakeholder participation are suboptimal, which requires constant audits. Another study was conducted in 2021 in Germany by Kern and his team (Kern et al., 2021). The study was conducted on the German employment service, and the analysis of administrative data for profiling the unemployed. The methodology consisted of a comparative evaluation of predictive models with a focus on accuracy and equity. The results of the study highlighted the existence of performing models, but differentiated in the classification of policies, which can generate inequities, requiring a rigorous audit before the implementation of the system. Interesting experimental research was conducted in the Netherlands (Alon Barkat and Busuioc, 2021, p. 539) on the interaction between human resources and AI in public administration. Extended and diversified results were published three years later (Alon-Barkat and Busuioc, 2023, p. 157). The methods used were controlled psychological experiments with public decision-makers. The Triple Helix model provides a solid theoretical framework for understanding AI-based public innovation ecosystems in public administration. However, to translate the potential into real outcomes – such as improved decisions and citizen trust – robust research, cross-sectoral skills, and transparent and accountable governance are needed. The research underlying this paper con-

tributes to a classification of the selected EU countries and to an analysis of the state of implementation of the three pillars of the Triple Helix model in EU governance processes, in the context of artificial intelligence.

In summary, the existing literature demonstrates that the integration of the Triple Helix model with artificial intelligence in public administration remains an emerging yet up-and-coming field. While substantial progress has been made in conceptualizing collaborative frameworks among government, academia, and industry, empirical evidence on effective implementation and long-term outcomes is still limited. Cross-country analyses, particularly within the EU, reveal varying levels of maturity in AI governance and innovation ecosystems. Consequently, further research is needed to explore how the Triple Helix model can foster responsible, transparent, and ethically grounded AI adoption in public governance, contributing to both administrative efficiency and democratic accountability.

3 Research Methodology

According to the specialized literature, the variables for the Triple Helix model are specific to the three main actors: the academic environment providing knowledge, research and innovation, the business environment (industry) providing smart solutions and technologies in the context of public-private partnerships and the government/public administration, which develops public policies, provides total or partial financing and is the beneficiary of research and innovation. This study adopts a comparative, mixed-method research design to explore the relationship between Artificial Intelligence (AI) adoption in public administration and the Triple Helix model of innovation across selected EU member states. The study focuses on a few EU member states. This design enables comparative insights rather than exhaustive coverage, aligning with the study's aim to analyze structural and institutional determinants of AI adoption in public administration. This purposive sampling enables a comparative analysis of the Triple Helix dynamics and institutional factors influencing AI adoption in different administrative and policy environments, rather than aiming for exhaustive coverage of all EU states. The study employs a purposive sampling approach. A few EU countries were selected to reflect a diversity of AI maturity levels, administrative capacities, and geographical contexts within the European Union. The selection was based on three main criteria: (1) diversity in AI maturity and digital governance levels; (2) institutional and geographical representation of both Western/Northern and Central/Eastern Europe; and (3) availability and comparability of data from official EU and OECD databases. This balanced selection allows for cross-country comparison of institutional drivers and constraints affecting AI adoption in public administration.

Quantitative indicators were compiled, corresponding to the implementation of the *EU Coordinated Plan on Artificial Intelligence (2021 Review)* and the *Digital Europe Programme*. Data were obtained from Eurostat, the OECD, and the European Commission's Digital Economy and Society Index (DESI) and Oxford

Insights. To ensure cross-country comparability, all variables were normalized using min–max scaling (0–1 range). Missing data (less than 5% of the total) were addressed through linear interpolation based on available time series. The empirical analysis proceeds in descriptive statistics and Pearson correlation coefficients were used to identify preliminary associations between AI adoption and the Triple Helix dimensions. All variables were standardized (z-scores), and multicollinearity was tested using the Variance Inflation Factor ($VIF < 3$). Model assumptions regarding normality, homoscedasticity, and independence were verified before interpretation. This transparent methodological framework ensures replicability and provides a robust foundation for interpreting the institutional mechanisms underlying AI adoption in selected EU public administrations through the lens of the Triple Helix model.

Within the framework of this research, the following aspects are analyzed: (1) the degree of digital maturity of the selected EU states; (2) the intensity of the Triple Helix model; (3) the proportion of ICT graduates and the degree of integration of AI in public administration; (4) collaborative framework between university, industry and government and the AI integration in public administration; (5) ITC infrastructure supporting the TH model and the integration of AI in public administration (6) the national AI and governance strategy.

The objectives of the research are: (1) to analyse the degree of digital maturity of the states included in the pilot study; (2) to identify the impact of the Triple Helix Model (university-industry-government collaboration) on the assimilation and integration of AI in public administration; (3) to identify the main correlations between the three actors in the context of artificial intelligence; (4) to discover the main correlations between the TH maturity and the ICT infrastructure; (5) to find out the relations between the AI national strategies, government strategies and the degree of AI implementation in the public administration of the selected EU state.

The main questions answered by the research are: (1) What is the relationship between the intensity of the Triple Helix collaboration and the degree of digitalization and integration of AI in public administration? (2) Are there significant differences between the selected EU states in terms of implementing AI strategies in the public sector? (3) Is there a collaborative frame for supporting innovation and AI integration? How do the national AI strategies of the selected EU countries influence the success of AI implementation in administration?

The main research hypotheses (H) are the following:

- H1. A country's digital maturity level (DESI) mediates the relationship between the Triple Helix and the success of AI implementation in public administration.
- H2. Countries with strong Triple Helix (TH) have a higher intensity of UIG (universities, innovation, and government) collaborations.
- H3. Countries with higher proportions of ICT graduates tend to report greater levels of AI adoption.

- H4. A well-developed collaborative framework between universities, industry, and government is closely associated with increased innovation activity and AI integration.
- H5. There is a positive correlation between TH maturity, innovation activity and infrastructure.
- H6. Even if states have an artificial intelligence strategy for public administration, the real impact is different.

The main quantitative variables used in the first stage of the research are: (1) Number of AI projects in public administration; (2) DESI index – digital public services; (3) Percentage of civil servants trained in AI; (4) Percentage of AI integration in public administration; (5) Existence of a public AI strategy; (6) Triple Helix maturity level. A special category of subsidiary research variables was added to uncover the relationships between the national AI strategies of the selected countries and their governance. This subcategory of variables includes: the level of integration of AI in the governance process; public investments and partnerships with private sector organizations for the implementation of AI applications in the governance process; and the degree of adoption and integration of AI in the public sector.

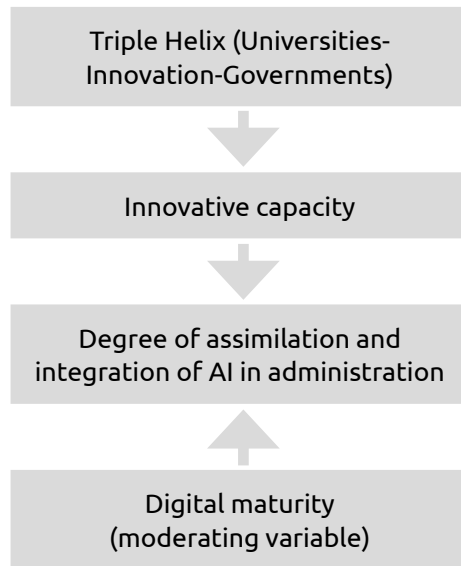
The main research variables used for the comparative analysis are presented in Table 2.

Table 2: The main research variables

Research variables	Type	Measurement level
Number of AI projects in the administration, public-private partnership	Quantitative	Absolute (number)
Index – services publicly available digital	Quantitative	Index (0-100)
Percent officially trained in AI	Quantitative	Percent
Percentage of integration of AI in public administration	Quantitative	Percent
The existence of a public AI strategy	Qualitative	Nominal (Yes/No)
Triple Helix Maturity Level	Qualitative	Ordinal (low/medium/high)

The research model is represented in Figure 2.

Figure 2: The correlational research model



Source: authors.

4 Discussions of the Research Results

The first parameter analyzed is the digital maturity of the selected EU states, which is measured with DESI. This index includes four relevant sub-dimensions: (1) human capital, which measures the digital skills of the population, including the number of IT specialists and the degree of internet use; (2) connectivity, which measures digital infrastructure, such as broadband network coverage and internet speed; (3) Digital technology integration, which measures how companies integrate digital technologies into their activities, including e-commerce; and (4) Digital public services, which measures the degree of digitalization of public services, such as e-government.

The analysis combines descriptive statistics and correlation analysis to examine the relationship between AI adoption in public administration and the three dimensions of the Triple Helix model. Correlation coefficients were first used to identify bivariate relationships among the indicators. Based on the data presented in Table 3, the Pearson correlation between DESI, the global DESI indicator for the year 2024, and the Government AI Readiness Index (Oxford Insights, 2024) for a few EU countries was determined.

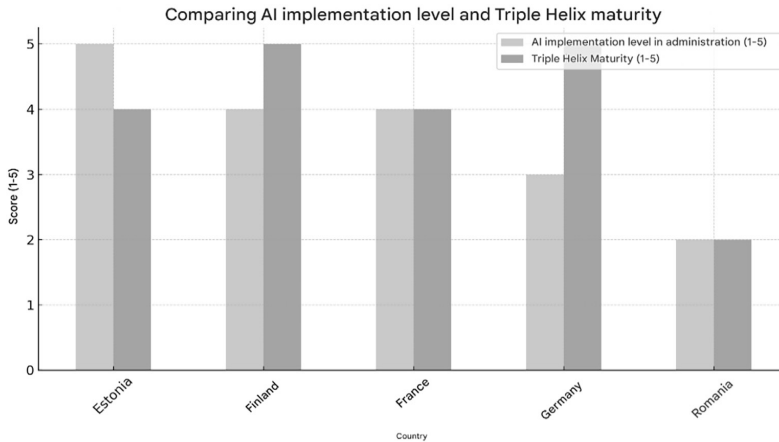
Table 3: DESI and the AI Score of the selected EU member states

Country	Score DESI (%)	Score AI (%)
Estonia	91.0	72.0
Finland	89.0	70.0
France	86.0	68.0
Germany	85.0	65.0
Romania	65.0	50.0

Sources: European Union, 2022 and Oxford Insights, 2023

The Pearson correlation coefficient calculation between DESI (European Union, 2022) and AI scores for the five countries is 0.98, indicating a very strong and positive correlation between these indicators. The correlation coefficient of 0.98 suggests that countries with higher DESI scores also tend to have higher AI scores, indicating a strong link between overall digitalization and the use of AI technologies. Estonia stands out with high scores on both DESI and AI, being a successful example of integrating digital technologies and AI. Romania has lower scores on both indicators, suggesting the need for more effective investments and public policies in the field of digitalization and AI development. The comparative analysis reinforces the fact that digital maturity (DESI) and AI in public administration are fundamental in mediating the effects of the Triple Helix on the assimilation and integration of AI in the public sector. The results show a clear positive correlation: countries with a higher DESI index have a significantly higher AI adoption. These results confirm hypothesis 1. Countries with solid ecosystems in these areas position themselves at the forefront of the EU, and the others have major potential if they invest strategically. Countries with a low DESI (Romania) have weak AI adoption. The bar chart in Figure 3 illustrates a comparative analysis of the level of AI implementation in public administration and the maturity of the Triple Helix model—representing university-industry-government collaboration—across five European countries: Estonia, Finland, France, Germany, and Romania. The data reveal notable differences in how these two dimensions correlate within each national context. Estonia emerges as a frontrunner in terms of AI implementation, achieving the highest possible score, while its Triple Helix maturity is slightly lower (4). This suggests that the country’s advanced digital governance infrastructure and strong political commitment to innovation may compensate for a moderately developed collaborative ecosystem.

Figure 3: The relationships between the AI implementation and the Triple Helix maturity



Source: authors.

In contrast, Finland and Germany display a reverse trend: both countries have achieved maximum maturity in their Triple Helix systems (5), but their AI implementation in administration remains at 4. This may indicate that despite robust collaboration among universities, industries, and governments, translating such systemic strengths into administrative AI adoption requires additional strategic alignment or regulatory innovation. France demonstrates equilibrium, with identical scores (4) for both AI implementation and Triple Helix maturity, reflecting a balanced relationship between ecosystem collaboration and technological integration. Romania, however, lags significantly behind, scoring only 2 in both categories. This parallel low performance highlights systemic weaknesses in both administrative innovation and collaborative capacity, suggesting that foundational reforms are necessary to foster both ecosystem maturity and technological uptake.

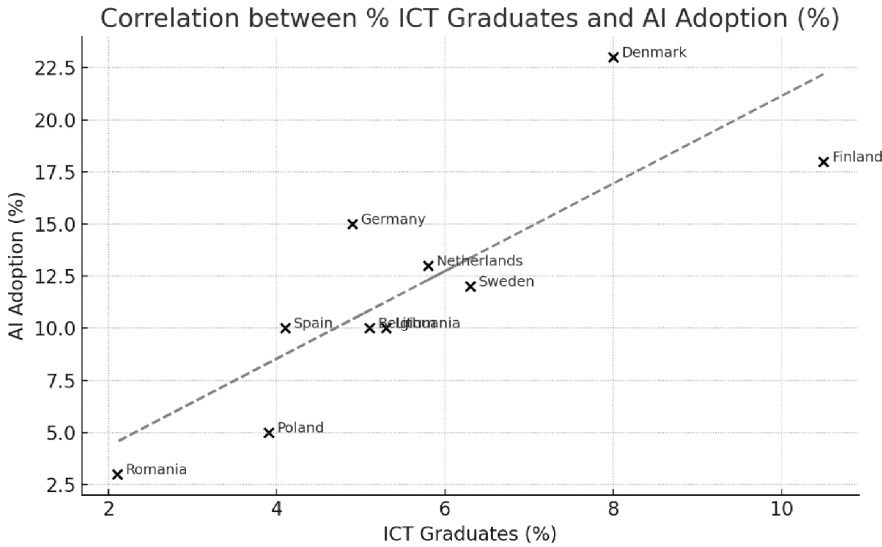
Overall, the comparison highlights a complex interplay between AI adoption and the maturity of collaborative ecosystems. While a high level of Triple Helix maturity appears conducive to technological implementation in some countries, it does not guarantee rapid AI integration in public administration. Conversely, Estonia's performance suggests that strong political will and a digital-first strategy can accelerate AI implementation even when ecosystem maturity is relatively moderate. These findings underscore the need for nuanced policy approaches tailored to each country's unique innovation landscape.

The second parameter is the Triple Helix (TH) intensity – proxies. It is determined based on ICT graduates and partnerships between public institutions and private sector organizations. At the level of the EU and according to DESI, Estonia leads in % ICT graduates (~11%) by 2022, while Italy, Belgium, and Cyprus have a process of less than 3%. The DESI-DII comparison shows that Germany, Finland, and the Netherlands have consolidated multi-sector ecosystems. We find out that countries with strong TH (e.g., Finland, the Nether-

lands, Germany) have a higher intensity of UIG (universities, innovation, and government) collaborations. These results partially confirm Hypothesis 2.

The graph in Figure 4 (% ICT graduates vs. AI adoption) confirms a moderate correlation: more ICT graduates usually mean a higher capacity to implement AI. However, there are exceptions (Spain has high AI adoption even with an average ICT percentage).

Figure 4: The correlation between the ICT graduates and the AI implementation within the sampled member states



Source: authors.

The scatterplot illustrates the correlation between the percentage of ICT graduates and the level of AI adoption across selected European countries. A positive relationship is evident, as indicated by the upward-sloping trendline: countries with higher proportions of ICT graduates tend to report greater levels of AI adoption. These results confirm hypothesis 3.

Finland and Denmark stand out as clear leaders. Finland, with over 10% ICT graduates, achieves an AI adoption rate of approximately 18%, while Denmark surpasses 22% AI adoption with around 8% ICT graduates. These outliers suggest that while a strong ICT educational base is critical, other factors such as innovation policies, RandD investment, and digital infrastructure also play significant roles in facilitating AI integration.

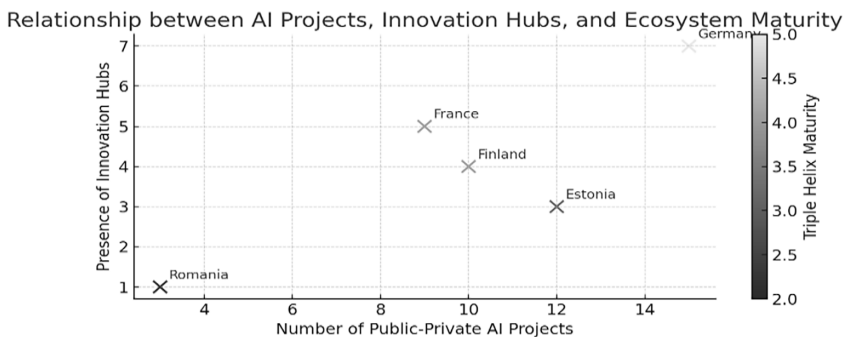
In contrast, Romania and Poland are positioned in the lower left quadrant of the chart, reflecting both a limited percentage of ICT graduates (below 4%) and low AI adoption rates (below 5%). This clustering suggests structural challenges in developing a skilled workforce and integrating advanced technologies.

Germany's performance is noteworthy: with a relatively moderate proportion of ICT graduates (about 5%), it achieves a comparatively high AI adoption rate (~15%). This deviation from the trendline indicates the potential influence of non-educational factors such as industrial capacity, public-private partnerships, and strong innovation ecosystems.

Overall, while the data support the hypothesis of a positive correlation between ICT education and AI uptake, the dispersion of data points around the trendline implies that ICT graduate rates alone are insufficient predictors of AI adoption. A comprehensive approach encompassing education, policy, infrastructure, and ecosystem development is likely necessary to drive AI integration at scale.

The third parameter is the degree of assimilation and integration of AI in public administrations in selected EU countries. According to AIWatch data (JRC, 2022, p. 126), in most EU countries, AI is used for multi-sector collaborations, governance processes, and interoperability. High levels of integration and use of AI applications in the public sector are in Denmark (24%), Portugal (17%), Finland (16%), in contrast to Romania/Poland/Hungary (~3%). These results indicate a strong correlation between digital maturity, the intensity of Triple Helix collaborations, and AI integration. The scatterplot presented in Figure 5 illustrates the relationship between the number of public-private AI projects, the presence of innovation hubs, and the maturity of the innovation ecosystem, measured through the Triple Helix model within a few selected EU countries.

Figure 5: The main relationships between the research variables



Source: authors.

Germany emerges as the most advanced ecosystem, with the highest number of AI projects (15), the strongest presence of innovation hubs (7), and the highest Triple Helix maturity (5). This suggests that a well-developed collaborative framework between universities, industry, and government is closely associated with increased innovation activity and AI integration. These results conform to Hypothesis 4.

Countries with clear artificial intelligence strategies in the public sector have higher adherence to government AI projects and significant budget allocations. France and Finland occupy intermediate positions, with a moderate number of AI projects (9–10) and innovation hubs (4–5), alongside relatively high ecosystem maturity (4–5). Estonia, despite having a comparable number of AI projects (12), demonstrates a lower presence of innovation hubs (3), which may limit the diffusion and scaling of innovation outcomes beyond specific sectors. Romania is an outlier, characterized by the lowest values on all three dimensions: minimal public-private AI projects (3), limited presence of innovation hubs (1), and low ecosystem maturity (2). This underscores significant structural gaps that could hinder its capacity to leverage AI for socio-economic development. Overall, the data suggest a positive correlation between Triple Helix maturity and both innovation activity and infrastructure. These results conform to Hypothesis 5.

The fourth parameter analyzed is national AI strategies and governance. For this purpose, in Table 4, relevant data for the 6 countries were collected based on the most recent official reports and EU sources (AI Watch, Oxford Insights, European Commission and OECD).

Table 4: The key research variable for measuring the relationship between AI governmental strategy and governance

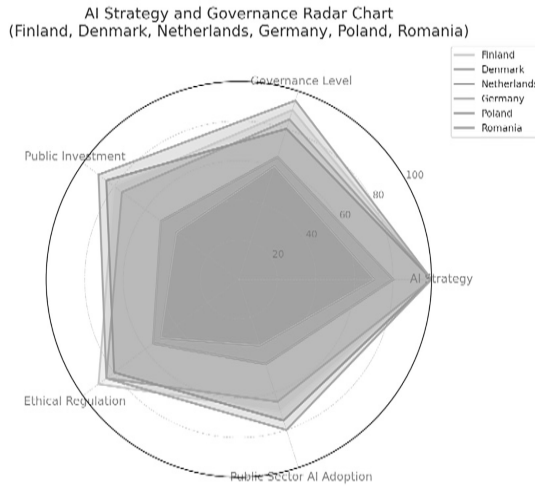
Country	AI Strategy (Y/N)	Governance Level	Public Investment (€/capita)	Ethical Regulation	Public Sector AI Adoption and Integration
Finland	100	90	80	90	70
Denmark	100	85	75	85	65
Netherlands	100	80	85	80	75
Germany	100	95	90	85	80
Poland	80	65	50	55	45
Romania	70	60	40	50	35

Notes: Values are normalized based on recent reporting and estimates to allow for clear comparisons.

Sources: European Commission, 2022a,b; Oxford Insights, 2022 and OECD, 2022

Analysis of AI Strategies and Governance in selected EU countries is presented in Figure 6 based on a representative research variable. This radar chart provides a comparative overview of six EU member states—Finland, Denmark, the Netherlands, Germany, Poland, and Romania—regarding their Artificial Intelligence (AI) strategies and governance.

Figure 6: The relationship between AI Strategy and governance



Source: authors.

The chart visualizes five key indicators: the existence of a national AI strategy, governance level, public investment per capita, ethical regulation, and AI adoption within the public sector. The key findings are presented and analyzed below. Finland, Denmark, the Netherlands, and Germany show a strong presence of national AI strategies (all scored 100), reflecting early and comprehensive government commitment to AI development. These countries also score highly in governance and ethical regulation, indicating robust institutional frameworks and alignment with EU ethical guidelines. Germany leads in public investment per capita, followed closely by the Netherlands and Finland, suggesting prioritization of AI research and infrastructure. Poland and Romania exhibit considerably lower investment levels, highlighting disparities in resource allocation within the EU. While ethical regulations are generally strong in northern and western countries, Poland and Romania lag behind. This gap may affect the responsible deployment of AI systems and trust in public AI applications. Similarly, public sector adoption rates are significantly lower in Poland and Romania, potentially due to infrastructural or legislative limitations. The differences underscore the need for targeted support and harmonization efforts by the EU to bridge gaps in AI governance and investment. These results prove hypothesis 6, meaning that all analysed states have AI strategies, but the impact on public administration is different. Enhanced collaboration could foster equitable AI advancements across member states, reducing digital divides. EU countries such as Germany, Finland, France, Italy, and Spain have AI strategies that include the use of AI in public services. Finland already has a working group to adapt national legislation to the AI Act. Tables 4, 5, and 6 contain comparisons between the main EU countries included in the research.

Table 5. Comparative approach of the selected EU states from the research parameters perspective

Country	DESI (2022)	ICT graduates %	Public sector AI strategies	Observations
Finland	69.6	high (~>10%)	Yes (legal working group)	digital champion, robust TH
Denmark	69.3	high	Yes	AI in e- government + governance
Netherlands	67.4	high	Yes	Advanced digital ecosystem
Germany	52.9	medium-high	Yes	AI standardization, active TH
Poland	40.6	reduced (~3.5%)	Yes	Average digital shelter, modest TH
Romania	30.6	low (<3%)	Yes	DIGITIZATION weak, fragile TH

Source: authors.

Table no. 5 presents a comparative analysis of the main indicators that reflect the main components considered in this research.

Based on the results of this research, 3 typologies of approaches to the Triple Helix model in the context of artificial intelligence can be identified. These are:

- Leaders: Scandinavia – Finland, Denmark – TH, DESI, solid AI strategies → high AI integration.
- Followers: Germany, Netherlands, France – moderate AI integration, but with infrastructure and strategies ready.
- Challenged: Poland, Romania – although they have AI strategies, modest digitalization, and innovation ecosystems reduce the impact of AI in administration.

For policymakers, this study highlights the importance of multi-sectoral collaboration in implementing the EU AI Act; for scholars, it proposes a conceptual framework linking AI governance to the Triple Helix innovation model. The adoption of artificial intelligence (AI) in public administration presents both significant opportunities and challenges for governance. From a policy perspective, AI can enhance efficiency, streamline decision-making processes, and improve service delivery. However, successful implementation requires robust data governance frameworks, clear regulatory guidelines, and active collaboration between government, industry, and academia, consistent with the Triple Helix model. Comparative insights from Estonia, Finland, France, Germany, and Romania highlight diverse approaches: Estonia and

Finland exemplify advanced digital governance infrastructures, while Germany and France emphasize stringent data protection and ethical oversight. Romania, still developing its digital governance capabilities, can benefit from adopting best practices from these countries. Ultimately, responsible AI integration in public governance demands a balance between technological innovation, ethical standards, and public accountability to foster trust and equitable service delivery.

Table 6. The main research comparative indicators

Country	DESI (2022)	% ICT graduates (2022)	Adoption and integration AI (%)	AI strategies in public admin.	Observation
Finland	69.6	~11 (high)	16		Mature ecosystem
Denmark	69.3	~8	24		Government AI leader
Netherlands	67.4	~7	~12		Stable, TH collaborations
Sweden	65.2	~6	~12		Advanced TH, AI e-government
Germany	52.9	~5	~10		Industrial complex
Belgium	50.3	~3	~10		Medium TH
Spain	60.8	~5	~15		Good digital public services
Poland	40.5	~4	~5		Digital on the rise
Romania	30.6	~2	<5		Low digital
Lithuania	52.7	~5	~5		Average digital maturity

Note: AI adoption values in the public sector are estimated from AI-Watch data on companies.

Source: authors.

4.1 Limitations and Further Research

The study has several limitations that should be acknowledged. First, the sample is limited to almost ten European Union countries, which, while selected to provide regional and institutional diversity, may reduce the generalizability of the findings across the broader EU or other global contexts. Second, the analysis is based on data from 2018–2023, a period that captures recent developments in AI adoption and digital governance but may not reflect longer-term trends or policy shifts occurring outside this timeframe.

Future research could address these limitations by expanding the sample to include additional EU member states or non-European countries, enhancing the comparative perspective and robustness of findings. Longitudinal studies covering longer timeframes could also provide insights into the evolution of

AI adoption and the impact of governance innovations over time. Additionally, future work could explore more granular or sector-specific analyses, examining the effects of AI adoption on particular public administration functions or policy areas.

5 Conclusions

This study investigates the relationship between the Triple Helix model (university–industry–government collaboration) and the assimilation of artificial intelligence (AI) in public administration across selected European Union (EU) member states. The findings highlight distinct cluster patterns among selected EU countries, reflecting varying degrees of Triple Helix collaboration, digital maturity, and AI integration in public administration. The study offers valuable insights into how multi-actor ecosystems can accelerate AI-driven public sector innovation, and it proposes policy recommendations to strengthen cross-sector collaboration for digital governance. This study advances the understanding of how university–industry–government collaboration (Triple Helix) shapes the assimilation of artificial intelligence (AI) within public administration across EU member states. The empirical findings confirm that countries with higher levels of Triple Helix intensity exhibit significantly greater integration of AI applications in public governance processes. The analysis also highlights the mediating effect of digital maturity (measured by DESI) in amplifying the benefits of collaborative innovation ecosystems.

The comparative correlation analysis reveals structural disparities across EU countries, with a clear divide between digitally mature states fostering cross-sectoral innovation and lagging countries constrained by weak institutional capacities, limited public-private partnerships, and insufficient ethical governance frameworks.

Theoretically, the study contributes to extending the Triple Helix model to the domain of AI-driven public sector innovation, offering a novel perspective on how collaborative ecosystems accelerate digital transformation. Practically, the findings suggest that policymakers should strengthen multi-actor governance mechanisms, integrate ethical AI frameworks into digital strategies, and invest in public sector capabilities to leverage AI for citizen-centric innovation.

This study underscores the transformative potential of integrating the Triple Helix Model with Artificial Intelligence to advance innovation, efficiency, and responsiveness in public administration. By aligning the collaborative capacities of academia, industry, and government with data-driven decision-making and intelligent systems, public institutions can transition toward more adaptive and evidence-based governance models. The research contributes to the theoretical enrichment of innovation governance and provides practical implications for policymakers aiming to harness AI responsibly within the public sector.

This paper emphasizes the added value and originality of combining the Triple Helix model with Artificial Intelligence as a framework for reimagining

innovation and governance in public administration. Conceptually, the study advances the field by linking collaborative innovation theory with emerging models of AI governance, providing a fresh perspective on how knowledge co-creation among academia, industry, and government can be strengthened through the use of intelligent technologies.

From a practical standpoint, the findings provide actionable insights for policymakers and institutional leaders seeking to foster data-driven, transparent, and citizen-oriented governance. Overall, the research enriches the academic discourse on digital transformation in the public sector and opens new directions for empirical investigation into the long-term societal impacts of AI-enabled collaboration.

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