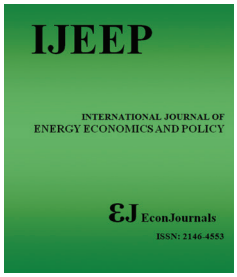

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Driving Technological Efficiency in European Healthcare: The Role of Digital Innovation Across EU

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ABSTRACT

Digital innovation reshapes healthcare, offering new solutions to enhance operational efficiency and sustainability. This study explores how emerging technologies, including Artificial Intelligence (AI), Internet of Things (IoT), and Digital Twin models, are being leveraged to optimize efficiency within any public and private facilities across the European Union (EU). Given the EU's ambitious sustainability targets, the healthcare sector presents a critical area for intervention. This research examines the extent of digital adoption in healthcare through a comparative analysis of the 27 EU member states. Results indicate significant regional disparities, with Northern European countries showing advanced digital integration compared to their Southern and Eastern counterparts. Findings highlight the potential of digital technologies to contribute meaningfully to technology efficiency while underscoring barriers such as infrastructure gaps and regulatory challenges. This paper provides insights into strategies for sustainable healthcare transformation, addressing both technological and policy implications for achieving efficient healthcare systems across diverse European contexts.

Keywords: Digital Innovation, Efficiency, Healthcare, European Union, Sustainability, Internet of Things
JEL Classifications: I18, O33, Q40, Q55

1. INTRODUCTION

The rapid advancement of digital technologies has transformed numerous sectors, ushering in a new era of operational efficiency, data-driven decision-making, and optimised resource use (Ciarli et al., 2021). Healthcare, a traditionally conservative and highly regulated field, has gradually embraced this digital transformation in response to growing pressures for improved patient outcomes, cost reduction, and sustainable practices. Innovations such as Artificial Intelligence (AI), the Internet of Things (IoT), and Digital Twin technology are no longer confined to high-tech industries but have found a pivotal role in healthcare (Ghatti et al., 2023; Peshkova et al., 2023), offering unprecedented opportunities to enhance service delivery, streamline operations, and improve efficiency. Within the European Union (EU), integrating digital solutions in healthcare has taken on strategic importance, particularly considering the EU's sustainability goals and its commitment to reducing carbon emissions under the European Green Deal. By adopting innovative technologies, healthcare institutions can optimise building management systems and implement predictive maintenance, directly contributing to their sustainability objectives (Lv et al., 2023; van Dinter et al., 2022).

The promise of digital technologies for technology efficiency lies in their ability to provide real-time insights and predictive analytics. Digital Twin models, which create virtual replicas of physical systems, can simulate different operational scenarios to identify the most efficient approaches before implementing them. These innovations empower healthcare administrators to make informed decisions that align with financial imperatives and environmental responsibilities (Marino et al., 2023a). Despite the clear benefits, the adoption of digital technologies is uneven across the EU's 27 member states. Factors such as digital infrastructure, regulatory support, and investment capacity vary

widely, leading to a fragmented landscape. Northern European countries, for example, generally show higher levels of digital adoption, supported by advanced technological frameworks and proactive government policies. In contrast, Southern and Eastern European regions face challenges, including limited access to digital infrastructure, financial constraints, and technical expertise, which can impede the widespread implementation of digital technologies in healthcare (Wang et al., 2023).

This study investigates the role of digital innovation in promoting technology efficiency across healthcare institutions in the EU, aiming to identify key drivers, barriers, and variations in adoption (Marino and Capone, 2024). By analysing digital integration in healthcare settings across diverse EU countries, this research offers valuable insights into the potential and limitations of digital transformation to achieve sustainable practices in European healthcare.

2. LITERATURE REVIEW

The healthcare sector is under increasing pressure to adopt sustainable practices due to economic and environmental concerns. Recent literature highlights that technological innovations can transform healthcare facilities (Marino et al., 2023). Digital solutions, such as the integration of Artificial Intelligence (AI), the Internet of Things (IoT), and Digital Twin technology, are now recognized as essential components for optimizing technology efficiency (Croatti et al., 2020). These innovations allow healthcare institutions to adopt predictive maintenance, optimize heating, ventilation, and air conditioning (HVAC) systems, and monitor real-time equipment performance (Sharma and Alshatshati, 2024).

Studies have shown that hospitals use AI to reduce their expenditure by up to 20% through dynamic adjustments and fault detection in HVAC systems (Marino et al., 2024). Digital Twin technology enables healthcare facilities to create virtual replicas of physical assets, allowing for continuous monitoring and testing of saving strategies in a risk-free environment (Vallée, 2023). This real-time simulation assists hospital managers in identifying inefficiencies and implementing corrective measures before they substantially waste resources (Yu et al., 2022).

Additionally, the literature emphasizes the role of regulatory frameworks and governmental incentives in promoting adopting efficient technologies within healthcare (Marino et al., 2022). European Union policies, for example, provide guidelines and incentives for healthcare institutions to incorporate sustainable practices. The Digital Economy and Society Index (DESI) measures digital adoption and has revealed a correlation between higher digital integration and efficiency gains across EU healthcare systems (Marino et al., 2021).

Specifically, before introducing the types of drivers chosen, the following question was asked:

- RQ1: What role had the introduction of Artificial Intelligence in the Healthcare Area across EU?

This review suggests that digital innovations in healthcare, support broader sustainability goals (Sheikh et al., 2021; Manickam et al., 2022). However, it also identifies challenges, including high initial costs, the need for technical expertise, and issues related to data privacy, as potential barriers to widespread adoption. After analysing the literature, we proceeded with the methodology below to fully respond to our RQ in accordance with the research objectives.

3. METHODOLOGY

This study employs an algorithmic formula to analyse digital innovation in healthcare, with a specific focus on the adoption and impact of Artificial Intelligence (AI) in the European context; recognising the foundational aspects outlined in the Introduction and Literature Review, the research evaluates the Digital Innovation Score (DIS) as an indicator encompassing both the healthcare sector and broader national contexts.

To address our Research Question (RQ), we selected the Digital Economy and Society Index (DESI, 2024) due to its comprehensive coverage of digital adoption metrics across multiple sectors, including healthcare. Using the 2023 DESI Dataset, the study integrates variables from healthcare and broader national dimensions to determine whether AI adoption is sector-specific or indicative of a country's overall digital maturity. This dual-level analysis ensures a nuanced understanding of the interplay between healthcare-focused AI initiatives and broader technological trends within nations.

The DIS was constructed by adapting DESI's methodology, incorporating weighted dimensions and sub-dimensions relevant to the healthcare sector and national AI adoption. The study leveraged a context-specific weighting system to align with this analysis's unique requirements while maintaining comparability with DESI's parameters. The study offers a robust framework to evaluate AI-driven digital innovation in healthcare and its implications for national digital ecosystems. The research adopted a similar methodological approach to DESI's parameters (DESI, 2024; Methodological notes, 2024). In Table 1, we have listed the indicators and sub-indicators used by DESI that best help answer our research question, giving a broad scope for implementing innovative technologies such as AI and digital healthcare. The Digitalization of Public Services, used in the driver "Adoption Rate", allows us to Measure the adoption of digital technologies in public and health services. With the same driver but with the sub-driver "Access to eHealth Records", we could measure the clinical impact of digital solutions on patients' health, for example, through data access and evaluate it in the driver "Impact of Health Outcomes". As for the driver, "Technological Sophistication" was chosen to evaluate the use of AI or Cloud or Data Analytics and the implementation of AI since it reflects the level of advanced technology, including IoT and AI skills. For the "System Integration" driver, using the sub-driver "e-Government users" provides us with a framework for accessing digital services intended for the public, in this case, also those focused on healthcare and connectivity. Finally, the "Regulatory Compliance" in Measuring compliance with regulations such as GDPR and other security regulations was evaluated with the sub-index "Transparency of service delivery, design and personal data" of the DPS.

Table 1: DESI indicators table for drivers

Driver	DESI indicators	Sub-indicators	Description
Adoption rate (AR)	• Digitalization of Public Services	• DPS for Citizens • DPS for Businesses	Measures the adoption of digital technologies in public and health services.
Impact on health outcomes (HO)	• Digitalization of Public Services	• Access to eHealth Records	Measure the clinical impact of digital solutions on patients' health, for example through access to data.
Technological sophistication (TS)	• Digital Transformation for Businesses	• AI or Cloud or Data Analytics • Artificial Intelligence	Reflects the level of advanced technology, including IoT and AI skills.
System integration (SI)	• Digitalization of Public Services	• e-Government users	Assess integration with healthcare systems and provider connectivity.
Regulatory compliance (RC)	• Digitalization of Public Services	• Transparency of service delivery, design and personal data	Measure compliance with regulations such as GDPR and other security regulations.

Source: DESI 2024 (Data 2023), own elaboration

A weighting system by dimensions and sub-dimensions, akin to DESI's methodology, was applied with minor adjustments to suit this study's context. It must ensure balance and meaningful aggregation of diverse dimensions contributing to the Digital Innovation Score (DIS). The rationale approach for the weights highlights how drivers like w_5 (weight 0.3) are assigned higher weights to reflect their critical influence, likely representing foundational or impactful aspects such as national AI Policies or advanced technology infrastructure. Moreover, drivers like w_4 (weights 0.15) received lower weights, suggesting a secondary supporting role in the overall DIS calculation.

The sum of weights is normalized to 1, ensuring compatibility and interpretability across different contexts. This technique aligns with practices recommended in indices like DESI.

The DIS Ranking is organised according to three tolerance levels, Low, Moderate and High, to categorise (ranking) and was statistically derived to ensure an equitable classification:

- Low (≤ 0.4) indicates limited progress, reflecting underperformance across weighted drivers
- Moderate ($>0.4 \cup \leq 0.7$) captures transitionary states, indicating medium-level adoption
- High (>0.7) represents optimal digital innovation and robust AI integration.

We have shown them in Table 2 to define how innovative a country is in technological innovation rather than the European Average, not only for the healthcare sector.

After that, for each healthcare entity, we had calculated a digital innovation score (DIS) using the following formula (1):

$$DIS = (w_1 \times AR) + (w_2 \times TS) + (w_3 \times SI) + (w_4 \times RC) + (w_5 \times HO) \quad (1)$$

Where w1, w2, w3, w4, w5 are the weights for each metric.

From the data extracted from individual drivers, it was possible to interface them with indicators within the DESI and assess how strong their impact on technological innovation in health. At the same time, it was possible to define for each driver a specific scenario for each European country, in addition to the European average.

Table 2: Assigned weight and DIS rank

Weights	w1	w2	w3	w4	w5
	0.2	0.25	0.2	0.15	0.3
DIS rank	Low (≤ 0.4)	Moderate ($>0.4 \cup \leq 0.7$)			High (>07)

Source: Own elaboration

4. RESULTS

To present the results on the impact of AI implementation in public and private sectors, we analysed the data focusing on the choose drivers.

4.1. Adoption Rate (AR)

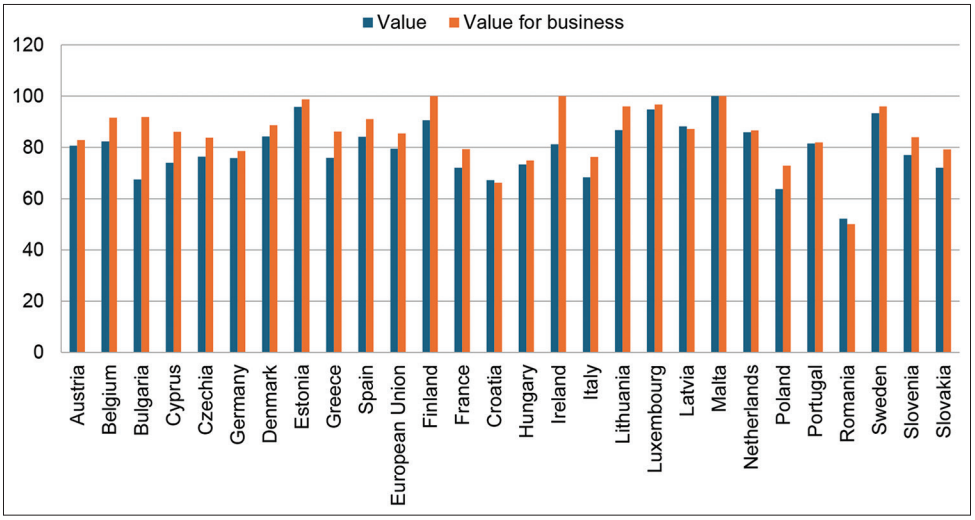
In Figure 1, we can recognize that Nordic countries such as Denmark and Finland show high scores for citizen services and business, confirming their digital leadership. These countries are known for their high level of adoption of digital technology, advanced infrastructure, and substantial investment in public digitisation. While maintaining high values, Sweden shows a negligible difference between services for citizens and businesses. Germany and France show average high scores, especially for business services. However, in Germany, there is a slight disparity in services for citizens, which could indicate a more excellent orientation towards businesses. Austria and Belgium maintain more balanced and high scores for both services, indicating good digital integration.

Estonia is emerging as a digital leader in the region, with high scores for citizens and businesses, reflecting a strong drive for digital innovation. In contrast, Poland and the Czech Republic show lower values, particularly for services to citizens, indicating a greater emphasis on business digitalisation than public services to citizens. These countries tend to have relatively lower scores for citizens and businesses, especially Romania and Bulgaria. This reflects a lower digitisation of public services, probably linked to infrastructure challenges, lower investment and delays in adopting advanced technologies. Italy and Greece show average services for businesses, but services for citizens remain lower, signalling a polarisation in the more business-oriented digitisation.

4.2. Impact on Health Outcomes (HO)

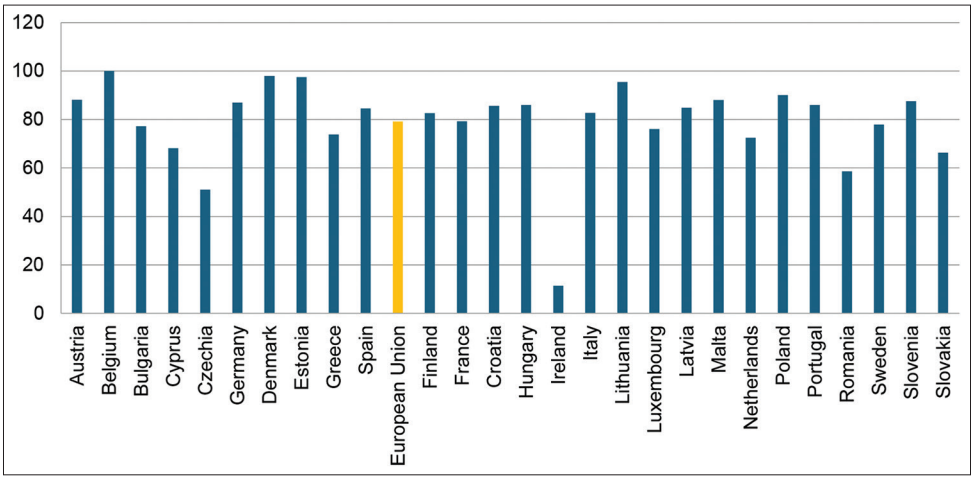
Figure 2, depicting access to e-health records across European countries, highlights notable disparities in digital health service accessibility. Countries in Northern and Western Europe, such as Denmark, Finland, and Estonia, exhibit high access levels,

Figure 1: Digital public services for citizens and business



Source: DESI 2024 (Data 2023). Own elaboration

Figure 2: Access to e-health records



Source DESI 2024 (Data 2023). Own elaboration

with scores nearing or surpassing 80%. This suggests a mature e-health infrastructure and a strong emphasis on digital health integration, often supported by robust governmental policies, investment in health technology, and an existing culture of digital literacy. Finland and Estonia have been pioneers in digital health, implementing interoperable systems that allow seamless access to electronic health records (EHRs) across healthcare providers. This leadership in digital health is consistent with their high ranking in digital innovation and technological sophistication across other domains.

In contrast, countries in Southern and Eastern Europe, such as Bulgaria, Romania, and Cyprus, show lower scores for access to e-health records, indicating a gap in digital health accessibility and infrastructure. Bulgaria and Romania, with access levels well below the European average, reflect structural challenges such as limited funding, lower levels of digital literacy, and less mature healthcare IT infrastructures. This digital divide can be attributed to historical disparities in economic resources, differences in public sector investment, and varying readiness levels to implement advanced digital solutions. For instance, the healthcare systems in many Eastern and Southern European countries often face more significant resource constraints, leading to slower adoption of comprehensive EHR systems and limited interoperability between healthcare providers.

Furthermore, the score variance may also stem from differing regulatory and privacy frameworks. Countries with stringent data protection and security standards, like those in Northern Europe, have managed to implement these standards alongside accessible e-health services, balancing privacy with usability. Conversely, some countries with lower scores may still grapple with regulatory frameworks that hinder rapid digital adoption or lack the infrastructure to support secure, nationwide access to EHRs.

4.3. Technological Sophistication (TS)

The chart in Figure 3 reveals significant variation in AI adoption across European countries, with a marked concentration of higher adoption rates in Northern and Western Europe. Finland, Denmark, and Sweden exhibit some of the highest levels of AI adoption, aligning with their overall leadership in digital literacy, digital

public services, and e-health access. This trend highlights the strong integration of advanced technologies in these regions, where supportive digital infrastructures, high levels of digital literacy, and proactive government policies foster a conducive environment for AI integration. Northern European countries have historically invested heavily in technology and innovation, enabling them to become frontrunners in adopting cutting-edge solutions such as AI.

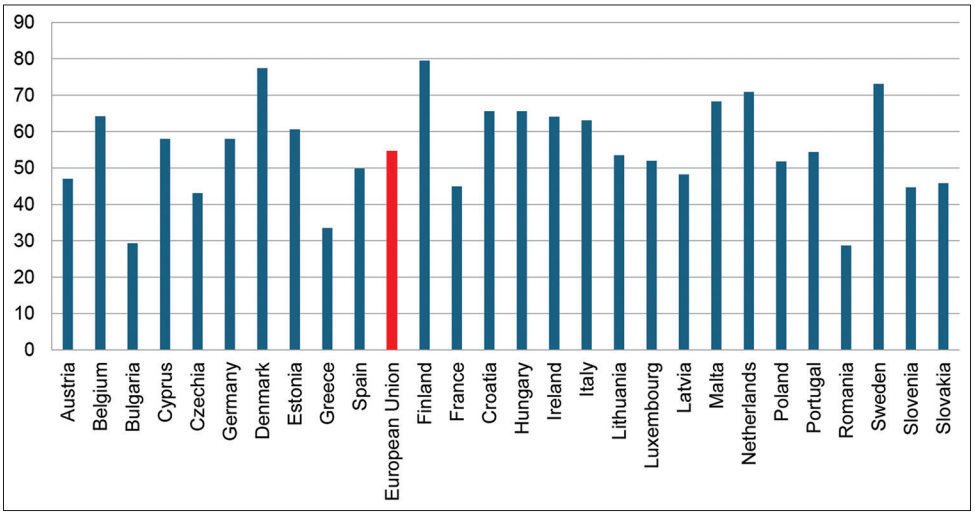
In contrast, countries in Southern and Eastern Europe, including Bulgaria, Romania, and Slovakia, generally show lower levels of AI adoption. This disparity reflects broader regional differences in digital readiness, as these countries often lag in digital public service provision. Economic and structural factors, such as lower levels of investment in technology infrastructure and limited access to digital education, further contribute to this gap. The lower adoption rates in these regions may also stem from a lack of regulatory support and fewer incentives for businesses to invest in AI technologies, resulting in a slower pace of digital transformation.

The geographic polarization observed in AI adoption parallels patterns seen in other digital indicators. Western and Northern European nations have emerged as leaders in digital transformation, leveraging strong digital foundations to incorporate AI into various sectors, including healthcare and business. Meanwhile, Southern and Eastern Europe play a follower role, constrained by infrastructural limitations and skill gaps hindering AI adoption. To bridge this divide, targeted investment in digital skills training, infrastructure, and policy support will be essential for accelerating AI adoption in less advanced regions. These efforts could enable a more balanced digital ecosystem across Europe, fostering widespread access to the benefits of AI technology.

4.4. Regulatory Compliance (RC)

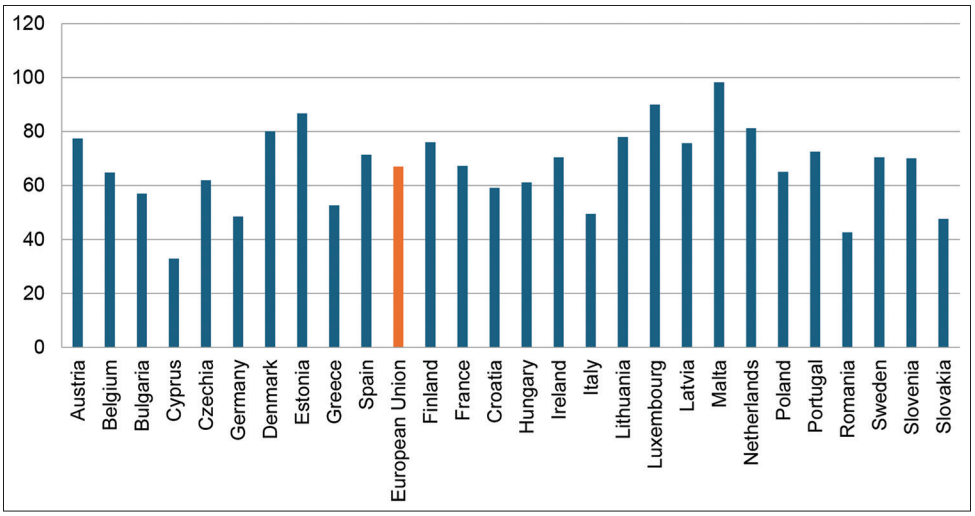
The chart, represented in Figure 4, on transparency of service delivery, design, and personal data demonstrates notable variation across European countries, with higher scores predominantly in Northern and some Western European nations. Estonia, Denmark, and Finland are leading in transparency, reflecting their

Figure 3: Artificial Intelligence adoption



Source DESI 2024 (from Data 2023). Own elaboration

Figure 4: Transparency of service delivery, design and personal data



Source: DESI 2024 (Data 2023). Own elaboration

longstanding commitments to digital governance and citizen-centric data policies. These countries prioritise transparency as a foundation for building public trust in digital services, supported by robust regulatory frameworks emphasising data protection and open government initiatives. This is consistent with their broader digital maturity, which has enabled advanced e-governance and public service delivery.

In contrast, several Southern and Eastern European countries exhibit relatively lower transparency scores, including Bulgaria, Greece, and Romania. This pattern aligns with previous findings on AI adoption, suggesting that digital governance practices are generally less developed in these regions. Factors such as limited investment in digital infrastructure, lower levels of digital literacy, and regulatory environments that may not prioritise data transparency contribute to this divide. These nations may face challenges in achieving the same level of transparency due to resource constraints, bureaucratic inefficiencies, or slower adaptation to evolving data protection norms.

The observed polarisation in transparency reflects broader regional disparities in digital governance. Strong institutional frameworks, cultural emphasis on trust in public institutions, and proactive public policies on digitalisation underpin Northern Europe's leadership in transparency. Countries with lower transparency scores may require targeted interventions, including regulatory reforms, investment in digital skills, and the modernisation sector infrastructure, to enhance their digital transparency. Addressing these disparities will be essential for fostering a unified approach to data protection and trust in digital services across Europe, ultimately ensuring equitable access to transparent digital governance for all European citizens.

4.5. System Integration (SI)

The data on e-government usage across European countries (Figure 5) reveals a clear trend, with Northern and Western European nations achieving high engagement levels in digital government services. Countries like Estonia, Denmark, and Finland show exceptionally high e-government usage rates, aligning with their long-standing investments in digital infrastructure and e-government policies. Estonia stands out as a pioneer in digital government solutions, fostering a culture of digital adoption among its citizens. This commitment to e-government is further supported by high digital literacy rates and a robust policy framework emphasizing accessibility and user-centric service design.

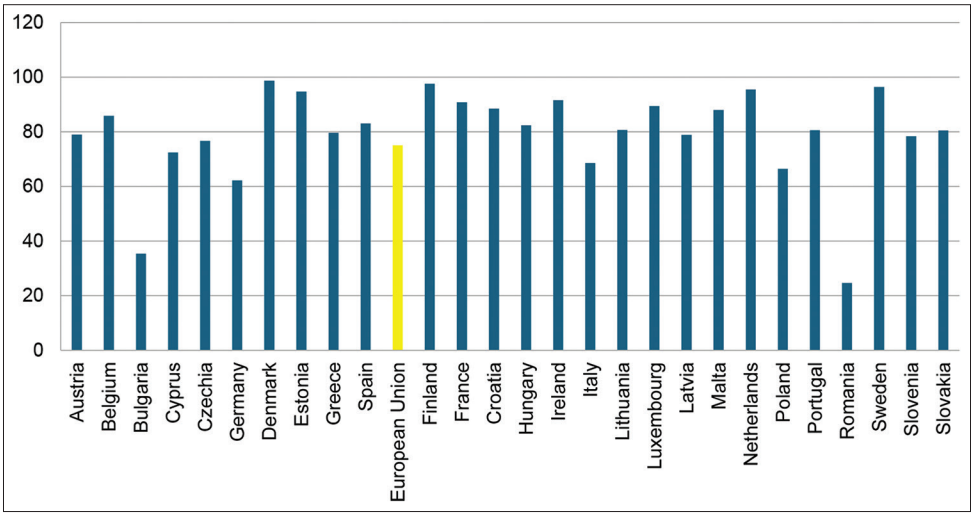
In contrast, Southern and Eastern European nations, such as Bulgaria, Romania, and Greece, exhibit relatively lower e-government usage rates. This discrepancy can be attributed to several factors, including a slower pace of digital transformation and limited public investment in digital infrastructure among the population. For instance, Romania and Bulgaria, which rank lower in AI adoption, also lag in e-government usage. This suggests a correlation between digital literacy and adopting digital public services. Additionally, these regions may face challenges related to public trust and data transparency, essential for encouraging e-government adoption.

This regional polarization highlights a broader digital divide within Europe, where Northern and Western European countries lead in both the adoption and sophistication of e-government services, while Southern and Eastern European nations continue to lag. To address this gap, efforts should focus on increasing digital literacy, enhancing digital infrastructure, and fostering trust in digital services in underperforming regions. By promoting equitable access to e-government services, Europe can work towards a more cohesive digital landscape that benefits all citizens equally, irrespective of their geographical location. This alignment is essential for the European Union's broader digital transformation goals, which seek to ensure that all member states can equally participate in and benefit from digital advancements.

In Table 3, we verify the data taken by DESI and evaluate according to the Drivers chosen for reference by the algorithm, with relative weights recalled in Table 2 to provide a clear view of the operation.

Table 4 shows that 12 of the 27 countries have a moderate DIS value, and the remaining 15 have a high DIS value, providing a

Figure 5: e-Government users



Source: DESI 2024 (From data 2023). Own elaboration

Table 3: Collected data

Country	Adoption rate (AR)	Technological sophistication (TS)	System integration (SI)	Regulatory compliance (RC)	Impact on health outcomes (HO)
Austria	0,65	0,7	0,6	0,8	0,55
Belgium	0,75	0,65	0,58	0,78	0,6
Bulgaria	0,5	0,55	0,45	0,7	0,4
Cyprus	0,6	0,6	0,5	0,65	0,45
Czechia	0,65	0,62	0,6	0,7	0,52
Germany	0,78	0,8	0,7	0,85	0,65
Denmark	0,82	0,83	0,72	0,9	0,7
Estonia	0,68	0,75	0,65	0,82	0,6
Greece	0,58	0,6	0,52	0,7	0,5
Spain	0,7	0,7	0,65	0,78	0,55
Finland	0,85	0,8	0,75	0,82	0,78
France	0,74	0,72	0,67	0,79	0,6
Croatia	0,75	0,76	0,68	0,81	0,62
Hungary	0,7	0,73	0,66	0,78	0,6
Ireland	0,77	0,78	0,7	0,84	0,63
Italy	0,75	0,68	0,6	0,7	0,5
Lithuania	0,7	0,65	0,6	0,75	0,52
Luxembourg	0,78	0,72	0,68	0,82	0,6
Latvia	0,7	0,64	0,58	0,7	0,52
Malta	0,7	0,6	0,55	0,73	0,53
The Netherlands	0,8	0,82	0,72	0,85	0,65
Poland	0,6	0,58	0,52	0,68	0,48
Portugal	0,68	0,7	0,62	0,74	0,54
Romania	0,5	0,55	0,47	0,65	0,42
Sweden	0,8	0,82	0,7	0,87	0,68
Slovenia	0,68	0,66	0,6	0,72	0,55
Slovakia	0,62	0,62	0,55	0,7	0,5

Source: Own elaboration

Table 4: Thresholds for innovation tiers

Country	DIS	Rank
Austria	0,71	High
Belgium	0,73	High
Bulgaria	0,55	Moderate
Cyprus	0,60	Moderate
Czechia	0,67	Moderate
Germany	0,82	High
Denmark	0,86	High
Estonia	0,76	High
Greece	0,63	Moderate
Spain	0,73	High
Finland	0,88	High
France	0,76	High
Croatia	0,78	High
Hungary	0,75	High
Ireland	0,80	High
Italy	0,70	Moderate
Lithuania	0,69	Moderate
Luxembourg	0,78	High
Latvia	0,68	Moderate
Malta	0,67	Moderate
The Netherlands	0,83	High
Poland	0,62	Moderate
Portugal	0,71	High
Romania	0,56	Moderate
Sweden	0,84	High
Slovenia	0,69	Moderate
Slovakia	0,64	Moderate

Source: Own elaboration

reading of the degree of technological innovation very present in much of the European continent. Specifically, the countries were organized into leadership and follower groups according to DIS score and geographical position (North, South, East, Over Europe), which, in turn, retrieved the following classification (Table 5).

- Leadership: Countries with a high score in the DIS ranking are mainly located in Northern and Western Europe, representing a strong adoption and integration of digital technologies in healthcare. Eastern Europe shows some leading countries like Estonia, Croatia and Hungary, which achieve high scores compared to others in the region.
- Followers: Moderate countries are most concentrated in Eastern and South-Eastern Europe. These countries, such as Bulgaria, Romania and Poland, show average technology adoption and could benefit from partnership strategies with leading countries to accelerate their progress.

This classification suggests that northern and western European regions are driving digital innovation in healthcare, while other regions can use cooperation programmes to bridge the gap.

5. DISCUSSION

The analysis of AI adoption, transparency in service delivery, and e-government usage across European countries reveal significant disparities, with patterns of regional polarisation. Northern and Western European countries generally outperform their Southern and Eastern counterparts across all these indicators, underscoring a broader digital divide within the European Union. A combination of historical investments in digital infrastructure, government

Table 5: Leadership and follower in Europe

Region	Leadership	Follower
Northern Europe	Denmark (0.86), Finland (0.88), Sweden (0.84), Ireland (0.80), Netherlands (0.83)	None
Western Europe	Germany (0.82), Austria (0.71), Belgium (0.73), France (0.76), Luxembourg (0.78), Spain (0.73), Portugal (0.71)	None
Eastern Europe	Estonia (0.76), Croatia (0.78), Hungary (0.75)	Czech Republic (0,67), Lithuania (0,69), Poland (0,62), Slovakia (0,64), Slovenia (0,69), Latvia (0,68)
Southern Europe	Italy (0.70), Malta (0.67), Greece (0.63)	Cyprus (0.60)
South-East Europe	None	Bulgaria (0.55), Romania (0.56)

Source: Own elaboration

policies, and public trust in digital solutions likely influences this divergence.

Countries like Finland, Denmark, and Estonia consistently rank top across all four categories, reflecting a robust foundation of digital literacy, a high rate of AI adoption, and widespread utilisation of e-government services. These nations have invested significantly in digital infrastructure and implemented policies prioritising transparency, security, and user-centred design in their digital public services. This proactive approach has fostered a culture of digital adoption, further reinforced by the population's high levels of digital skills. The Nordic and Baltic countries demonstrate how a comprehensive and coordinated digital strategy can create an environment conducive to advanced digital engagement among citizens and organisations.

On the other hand, Southern and Eastern European countries, such as Bulgaria, Romania, Greece, and Cyprus, frequently exhibit lower scores in AI adoption and e-government usage. The limited uptake of digital services in these regions may stem from weaker digital literacy rates, constrained public investment in technology, and persistent issues with digital infrastructure. Furthermore, societal factors, such as lower public trust in digital governance and data transparency, appear to exacerbate these regions' challenges in achieving higher levels of digital engagement. This lack of trust may discourage citizens from fully participating in e-government services, perpetuating a cycle of underutilisation and limited demand for digital improvements.

The data on transparency in service delivery illustrates how perceptions of openness and security are integral to fostering digital adoption. Northern European nations' emphasis on transparency has likely contributed to higher public trust, facilitating wider acceptance of AI and e-government initiatives. Conversely, the lower transparency scores observed in some Southern and Eastern European countries suggest that insufficient attention to data protection and service design may hinder the expansion of digital services, affecting citizens' willingness to adopt these technologies.

The Digital Innovation Score (DIS) provides a nuanced assessment of technological adoption across European countries, revealing significant disparities that align with the findings on digital skills, AI adoption, and transparency in service delivery. Countries such as Finland (0.88), Denmark (0.86), and Sweden (0.84) lead the rankings, reflecting advanced digital infrastructures, comprehensive e-Government usage, and high levels of public trust in AI technologies. These nations exemplify how historical investments and robust policies foster leadership in digital innovation, particularly in healthcare.

Conversely, Bulgaria (0.55), Romania (0.56), and Poland (0.62) fall into the moderate tier, consistent with lower adoption rates, underdeveloped infrastructures, and limited digital skills. The alignment between DIS and these sub-indicators suggests that national technological sophistication influences sector-specific outcomes like healthcare AI adoption. Interestingly, Italy (0.70), with its moderate DIS, highlights a gap between potential and realization. While showing promise in adoption and integration, systemic barriers such as public trust and infrastructure remain constraints. In contrast, Estonia (0.76), despite similar regional challenges, performs above average due to targeted strategies in transparency and digital service deployment.

The regional classification into Leadership (Northern and Western Europe) and Follower (Eastern and Southern Europe) groups highlights EU polarisation. Policies aimed at enhancing digital literacy, investing in infrastructure, and fostering international cooperation could address these disparities, enabling lagging countries to bridge the gap and unlock the full potential of digital transformation in healthcare.

6. CONCLUSION

The research provides a comprehensive tool to evaluate European digital health innovations, highlighting compliance with EU policies, identifying adoption trends, and surfacing key challenges and opportunities. Through iterative testing and expert feedback, this approach yields quantitative and qualitative insights, enabling policymakers and healthcare providers to better align digital health strategies with European regulatory and societal needs. This polarisation is consistent with the data already examined, which shows the Nordic and Western European countries as leaders in digital innovation, while the South-East European countries are more often followers. The main factors behind this divergence include the availability of economic resources, the population's digital literacy level and policies supporting digitisation, which are often stronger in the economies of Northern and Western Europe.

This geographic polarisation in access to e-health records reflects broader patterns observed in European digital innovation and adoption rates. Northern and Western European countries consistently lead in digital health advancements and serve as benchmarks for digital healthcare integration. On the other

hand, Southern and Eastern European nations often act as followers, adopting innovations at a slower pace due to financial, infrastructural, and regulatory limitations. These findings suggest that targeted policies and investments in digital health infrastructure could help bridge the digital divide and enable more equitable access to e-health records across Europe.

In conclusion, this analysis underscores Europe's considerable digital divide, reflecting regional strengths and persistent challenges. Northern and Western European countries, notably the Nordic and Baltic nations, exhibit a high level of digital maturity, evidenced by their advanced digital skills, high rates of AI adoption, transparency in service design, and substantial e-government usage. These outcomes highlight the positive impacts of sustained investment in digital infrastructure, effective government policies, and a strong public trust and transparency culture.

In contrast, Southern and Eastern European countries face notable obstacles to their digital development. Limited digital skills, lower public trust, and underdeveloped digital infrastructure in these regions contribute to their relatively low scores in AI adoption and e-government engagement. These challenges, compounded by societal and policy factors, perpetuate a digital gap that requires targeted intervention.

For the European Union, achieving digital cohesion demands a balanced approach that recognises the diverse circumstances of its member states. To foster digital inclusivity, the EU should prioritise policies that enhance digital literacy, improve infrastructure, and promote data security and transparency across all regions. Additionally, providing tailored support and resources to Southern and Eastern European countries can accelerate their digital transformation and strengthen their integration into the EU's digital economy. Bridging this digital divide is crucial for ensuring equitable access to digital resources and services, enhancing regional competitiveness, and fostering social cohesion within the EU. A digitally unified Europe is better positioned to adapt to future technological advancements, address global challenges, and uphold its inclusivity, innovation, and resilience values. Through strategic, region-specific support and collaboration, the EU can work towards a more digitally balanced and prosperous future for all its citizens.

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