Digital Intensity and Technology Adoption in European Enterprises: Comparative Analysis Using NRI and DESI 2023 Data

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SUMMARY

A number of targets aimed at promoting digital transformation have been set up within the framework of the 2020-2030 Digital Decade. An abundance of scientific research has shown the importance of digital technologies and the impact they have on the competitiveness of businesses. The objective of this study is to conduct a comparative analysis of the digital technology applications used by European Union enterprises in an effort to identify any potential linkages. This study primarily analyses the use of artificial intelligence (AI), cloud services, and Big Data, as well as the current level of digital intensity and skills. In addition, the research evaluates the extent to which the strategy document 2030 Digital Compass of the European Union, which delineated the goals pertaining to technology applications, has been achieved so far. The purpose of this assessment is to provide guidance for the subsequent seven years of the development stage. The evaluation is conducted with data acquired from the Network Readiness Index (NRI) and the Digital Economy and Society Index (DESI) for the year 2022.

Keywords: Big Data, digital economy, digital intensity, digital skills, cloud service, artificial intelligence
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INTRODUCTION

The classic form of digital divide, namely the lack of access to the Internet, as well as computers and smart devices, are almost nowhere to be found nowadays, while new gaps and challenges are emerging, such as data protection and cybersecurity (Bánhidi et al., 2023; Bruno et al., 2011). One of the largest industries, the global information and communication technology (hereinafter ICT) market is projected to reach €6 trillion in 2023. However, the position of the European Union (EU) in the global ecosystem could be significantly improved. The EU's share of the global ICT market revenue has fallen drastically over the past decade, from 21.8% in 2013 to 11.3% in 2022, while the US share has increased from 26.8% to 36%. Currently, the EU relies on foreign countries for digital products, services, infrastructure and intellectual property (European Commission, 2023a). The Digital Economy and Society Index (hereinafter DESI), an annual indicator measuring the development of the digital economy and society, measures EU Member States' progress towards a digital economy and society based on Eurostat data and specialist studies. The four main dimensions are Human Capital, Internet Access, Integration of Digital Technology and Digital Public Services, which are key measurement and benchmarking tools in the implementation of the European Commission's Digital Decade 2030 strategic programme. DESI helps countries to identify strengths and weaknesses in their digital ecosystems and informs strategic decision-

making to achieve a digitally advanced society. DESI can be seen as a measure of digital development. Several studies carry out analyses using the indicator to measure the overall progress of EU Member States on the path of digitalisation. Summarizing the studies, this indicator is applied in several approaches as it provides a comprehensive snapshot of a country's digital landscape and helps policymakers to assess their nation's digital readiness and competitiveness. In another approach, it is seen as a supporter of innovation and used as a quantitative framework for assessing the level of digitalisation of EU Member States, which plays a key role in fostering innovation and competitiveness by monitoring variables such as internet access, digital skills and the use of online services. In this approach, the index is a catalyst for innovation-led economic growth, providing the basis for evidence-based policy-making (Skare et al., 2023; Bruno et al., 2023). In summary, DESI is an EU policy assessment tool for monitoring the progress of the EU member states in digital transformation. The index covers many aspects of the digital economy and society and provides insights into areas requiring targeted interventions. It mainly contributes to policy decisions aimed at fostering digital innovation and ensuring a fair distribution of digital benefits. It is a critical tool for assessing digital inclusion and goes beyond economic aspects as it takes into account social and cultural factors when measuring digitalisation. DESI highlights the importance of digital accessibility, affordability and digital skills in promoting an inclusive digital society (Ghazy et al., 2022; Oloyede et al., 2023).

The index itself was established by the European Commission in 2014. It is a composite measurement containing 33 indicators, a benchmark for digital transformation. DESI reports always show the results of the previous year's data, i.e. DESI 2023 represents the results of 2022. DESI summarised Europe's digital performance indicators between 2014 and 2022 and analysed the relative progress of the member states based on their initial situation against the results of the last five years. In 2021, the European Commission amended the previous methodology and aligned it with its policy objectives, resulting in the reduction of the previous five key aspects to four and the recalculation of the results of previous years. In line with the Digital Decade Policy Programme, it was revised again in 2023 and has since been incorporated into the State of the Digital Decade 2030 report and is currently used to monitor progress towards the digital targets. 11 of the 2022 DESI indicators measure the objectives set in the Digital Decade (DESI, 2023). The revised data was published in October 2023 at the time of writing so the study includes analyses of the previous structure and that of the new data at the same time. On 9 March 2021, the European Commission presented the Digital Compass 2030: A European path to the Digital Decade, which sets out the vision, goals and main tools and areas for the digital transformation of Europe and the European Union. On 8 December 2022, the European Parliament and the Council adopted the Digital Decade Policy Programme (COM, 2022).The Digital Compass strategy focuses on four areas and sets the following objectives for the year 2030 (COM, 2023).

1) **Digital skills development objectives:**
   - According to the strategy, at least 80% of the total adult population should have basic digital skills;
   - increase the employment rate of women in the ICT sector;
   - at least 20 million professionals to be employed.
2) **Digital transformation of businesses:**
   - *Technology deployment: 75% of EU companies should use cloud services, artificial intelligence or Big Data;*
   - Innovators: scale-up, strengthen and increase funding for innovative companies to double the number of unicorns, i.e. start-ups worth at least USD 1 billion, in the EU;
   - *Late adopters: in terms of digital intensity, more than 90% of small and medium-sized enterprises (SMEs) should reach at least basic level, at least 75% of EU enterprises should be based on cloud-based artificial intelligence and Big Data services; strengthening scale-ups.*
3) **Secure and sustainable digital infrastructure:**
   - Connectivity: everyone should have gigabit internet access;
   - Cutting-edge semiconductors: doubling the EU's share of global production;
   - Data-edge and cloud: 10,000 climate-neutral, highly secure edge nodes;
   - Computing: the first computer with quantum acceleration.
4) **Digitalisation of public services:**
   - Key public services: 100% online;
   - eHealth: 100% of citizens should have online access to their health data;
   - Digital identity: 100% of citizens should have access to a digital ID.

The Network Readiness Index (NRI) is a system of indicators designed to assess countries' digital development and examine the economic and social impacts of digitization. The Network Readiness Index is annually published by the Portulans Institute in Washington, D.C. NRI analyses data for 130 countries to help to compare and prioritise digital network readiness. The NRI's 60 indicators are grouped under a

total of four main pillars – technology, people, governance, impact – and 12 sub-pillars. The first pillar of NRI is Technology, which is also essential for laying the foundations of the network economy. This pillar comprises three sub-pillars (Access, Content and Future Technologies), which contribute equally to the assessment of the level of technological development. The second pillar (People) concerns the measurement of ICT use at three levels of analysis: Individuals, Companies and Governments. The third pillar of the NRI is Governance, which reflects the effectiveness of the systems underpinning activities within the network economy and also has three sub-pillars: Trust, Regulation and Inclusion. Finally, the fourth pillar measures the impact of digital technologies on society as a whole along three sub-pillars: the Economy, Quality of Life and the contribution to the Sustainable Development Goals (SDGs) (Bánhidi, Tokmergenova, et al., 2023).

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MATERIAL AND METHOD

The digital technology practices of EU businesses are presented using data from the Digital Economic and Social Index (DESI) and Network Rediness Index (NRI). DESI data consists of the DESI 2023 database (covering the period between 2014 and 2022), downloaded from the European Commission's website, while NRI data reflects the NRI 2022 database requested and received on the Portulans Institute website in Washington. The study uses the methodology of comparative analysis and correlation analysis. First, the relationship between the DESI 2022 dimensions was examined, then the technology applications of enterprises in each country were compared to each-other based on the latest DESI Digital Transformation dimension analysis data (Artificial Intelligence, Cloud and Big Data Usage) in 2023. Then similar data of the NRI index on future technological dimensions (Adoption of new technologies, Robot density, Investment in new technologies, Expenditure on

computer software) were compared. Digital intensity was also examined by comparing two DESI indicators.

To analyze the relationship between DESI factors, Pearson's correlation was chosen. The Pearson correlation coefficient quantifies the strength and direction of the linear relationship between two continuous variables. It evaluates how well a change in one variable can be predicted by a change in another.

The formula for calculating the Pearson correlation (r) between the variables X and Y is as follows:

$$r=\sum i=1n(Xi-X)2\sum i=1n(Yi-Y)2\sum i=1n(Xi-X)(Yi-Y)$$

Where:

- r is the coefficient of the Pearson correlation;
- Xi and Yi are values of data points with the same index;
- X *and* Y *are the averages of the variables* X *and* Y,
- n is the sample size.

Table 1

Correlation of DESI 2022 and its individual dimensions

	DESI	Human capital	Internet access	Integration of digital technologies	Digital public services
DESI	1				
Human capital	0,91	1			
Internet access	0,72	0,57	1		
Integration of digital technologies	0,88	0,82	0,52	1	
Digital public services	0,90	0,75	0,49	0,70	1

Source: Own calculation based on DESI (2023)

Human capital, digital technology integration and digital public services have a particularly strong positive correlation with DESI, indicating that they play a key role in reducing a country's digital lag. It is also worth noting that although internet access is slightly lower compared to human capital, digital technology integration and digital public services, it is an essential factor in promoting skills, technological integration and digital services. A strong positive correlation of 0.91 between DESI and Human capital indicates a strong relationship, which means as a country's human capital improves, the overall digital economy and society index tends to increase significantly. Human capital includes factors such as digital skills, education and adaptability of the workforce to digital technologies. Human capital displays strong positive correlations with the integration of digital technologies (0.82) and digital public services (0.75) too. A high level of Human capital seems closely associated with better-integrated digital technologies and advanced digital public services. This suggests that enterprises with a well-educated workforce tend to adopt and utilize digital technologies more effectively, leading to more sophisticated digital public services. Promoting education and skill development among the population could contribute to a more tech-savvy workforce, consequently positively impacting the digitalization of services. Internet access exhibits moderate positive correlations with the Integration of digital technologies (0.52) and Digital public services (0.49). Areas with higher internet access tend to demonstrate more significant integration of digital technologies and better-developed digital public services. Ensuring broader internet access could be pivotal in enhancing the implementation and utilization of digital technologies across various sectors. Improved internet accessibility might be linked to the provision of better digital public services, emphasizing the importance of bridging the digital divide for more comprehensive digitalization. The Integration of digital technologies and Digital public services also shows a strong positive correlation (0.70). Enterprises effectively integrating digital technologies often tend to offer well-developed digital public services. It appears that the successful integration of digital technologies makes a substantial contribution to the availability and progress of digital public services. This highlights the connection that exists between the integration of technology and the supply of services. These findings can guide policymakers to focus on improving these key areas to enhance overall digital development.

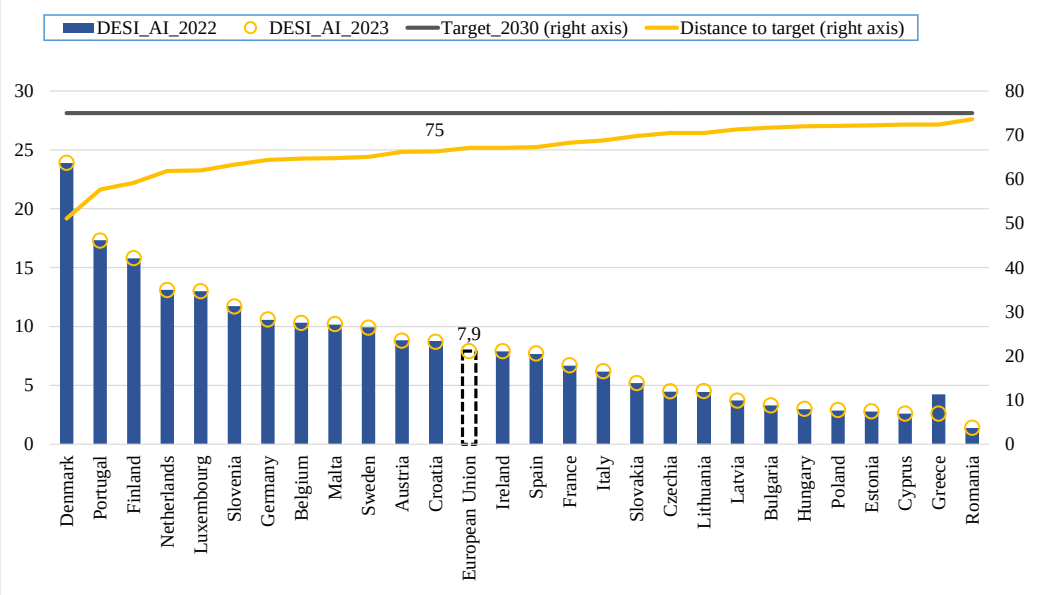
Digital Divide in Technology Applications for Businesses in the European Union

The first State of the Digital Decade report, published on 27 September 2023, provides a comprehensive picture of progress towards achieving digital transformation. The report takes stock of the EU's progress towards a successful digital transformation of people, businesses and the environment by 2030 (European Commission, 2023a). The report highlights the need to accelerate and deepen joint efforts, including policy measures and investment in digital technologies, skills and infrastructure, which are critical geopolitical, social, economic and environmental factors.

The indicators on digitalisation of enterprises that are part of DESI 2023 fall into three categories: 1) measuring the digital intensity level of SMEs, 2) digitalisation of enterprises and 3) e-commerce. The study analyses the following indicators that make up the objectives of the Digital Decade: SMEs with at least basic digital intensity and the percentage of companies using Big Data, cloud computing and artificial intelligence. The strategy document identified the following strategic steps related to the areas examined. To create the necessary preconditions for the development and uptake of AI, room has to be made for the proliferation of AI in the EU where excellence flourishes from laboratory to market. A necessary requirement is to ensure that AI works for people and benefits society and build strategic leadership in high-impact sectors. Cloud computing is crucial for emerging technologies such as artificial intelligence, Big Data and digital ledger technologies, as well as many industrial and entertainment applications. In order to reap the full economic benefits of the data economy, the cloud has the potential to be game-changer, requiring at least twice as many European businesses to start using advanced cloud computing by 2030, which is particularly important for SMEs. Advanced cloud services enable businesses to build a truly sustainable and competitive advantage with this technology. Businesses are increasingly realising that business transformation and performance depend on better use of data. The estimated share of the impact of the data economy on GDP in the EU27 increased from 3.7% in 2021 to 3.9% in 2022. According to the latest estimates, the EU27 data economy is expected to remain slightly below the €1 trillion threshold in 2023 and reach a compound annual growth rate of 5.5% in 2025-2030. SMEs account for 98% of all data-using companies in the European Union. In 2022, the EU data economy reached the €500 billion threshold and showed an annual growth rate of 8.7% in 2021. As a result of positive trends in the EU data economy as a whole, the number of companies using data in the EU7 increased to more than 579 000 companies in 2022. It is estimated that data-using companies will account for more than 905 000 companies by 2030 (COM, 2023; Micheletti et al., 2023).

OUTCOMES

Member States and the Commission have agreed to ensure that by 2030 more than 75% of EU businesses use artificial intelligence technologies, Big Data or the cloud. Support for artificial intelligence solutions plays a prominent role in the digital economy. Based on DESI 2022 data (Figure 1), only 7.9% of EU businesses use AI technology, i.e. one in 12 companies have adopted AI technology.

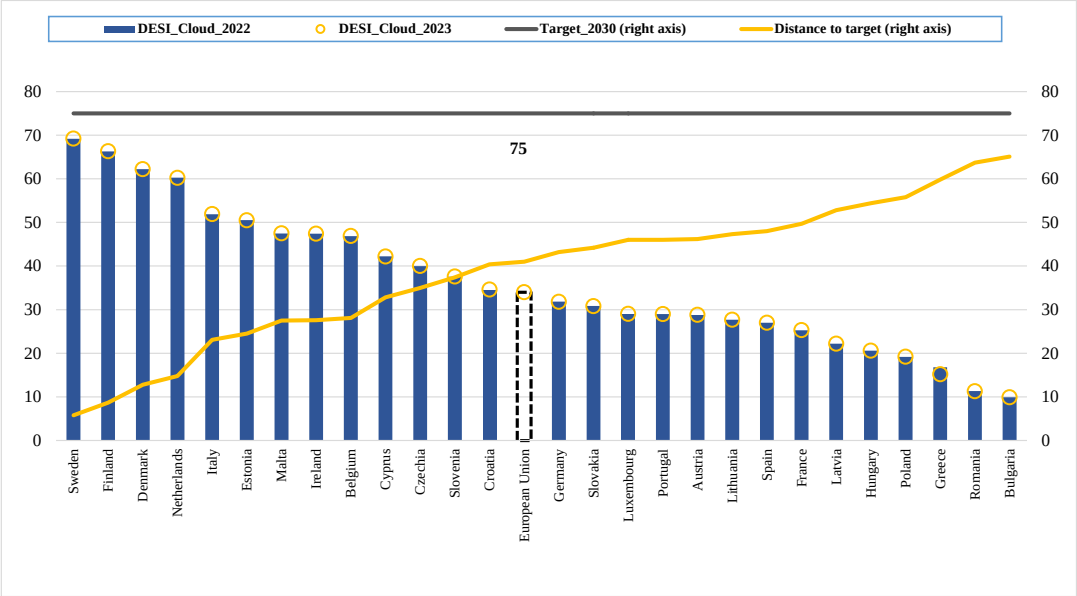


Source: Own editing based on DESI (2023)

Figure 1. Use of artificial intelligence (% of enterprises)

According to the results, a year earlier, in 2021, there were more countries where making use of artificial intelligence was higher than in the case of others. Denmark currently has the highest take-up rate at 24%, followed by Portugal (17%) and Finland (16%). In seven countries it ranges from 10% to 13% (Netherlands, Luxembourg, Slovenia, Germany, Belgium, Malta and Sweden) and from 5% to 10% in seven other countries. The use of artificial intelligence is less than 5% in the following surveyed countries: The Czech Republic, Lithuania, Latvia, Bulgaria, Hungary, Poland, Estonia. Greece, Cyprus and Romania. The take-up rate appears to vary widely between Member States, ranging from 1% to 24%. The difference between SMEs and large companies is striking, as four times as many large companies use AI technologies as SMEs. In addition, twice as many medium-sized businesses use AI as small businesses. If we look at the sector overview, the ICT sector is clearly well ahead in the use of AI technologies: 25% of businesses use AI, followed by the publishing sector with 18%. Other sectors, such as real estate and manufacturing, are lagging behind with only 7% of businesses using AI. The transport, warehousing and construction sectors are the least likely to use such technologies. To change the current low level, all national AI strategies set out policy measures to increase and support it.

Cloud computing is now considered a core technology. Its availability today far exceeds file storage and email, which are still the most common cloud application scenarios for European companies today. Figure 2 shows the proportion of companies using cloud services. It can be seen that, on average, only one in three companies in the European Union uses cloud computing services. Companies in the Nordic countries are at the forefront of adopting cloud services. In Sweden, Finland, Denmark and the Netherlands, more than 60% of businesses purchased such services. Italy and Estonia follow with more than 50%. However, the gap between the best and the low performers remains wide with Bulgaria and Romania scoring below 15%. There are significant differences (up to 62 percentage points) between businesses of different sizes and between different types of cloud services used. Cloud adoption by enterprises (60%) is almost double than that of SMEs (33%) in 2021.



Source: Own editing based on (DESI, 2023)

Figure 2. Cloud computing usage (% of enterprises)

The three global cloud providers, Amazon Web Services, Microsoft Azure and Google Cloud account for two-thirds of the European cloud market. If we look at cloud use by sector, two-thirds of ICT companies have already purchased such a service. The least cloud-consuming sectors are construction, transport and manufacturing. Businesses across the EU and across sectors are constantly adapting to new technologies for collecting, storing and analysing data. Big Data, i.e. managing Big Data, can be a key and competitive advantage for businesses. Big Data is complex, comes in different formats and forms, and many factors determine their usability and turn them into real competitive advantages. According to the DESI survey (Figure 3), 14% of companies carried out Big Data analysis in 2020 (no more recent data is available).

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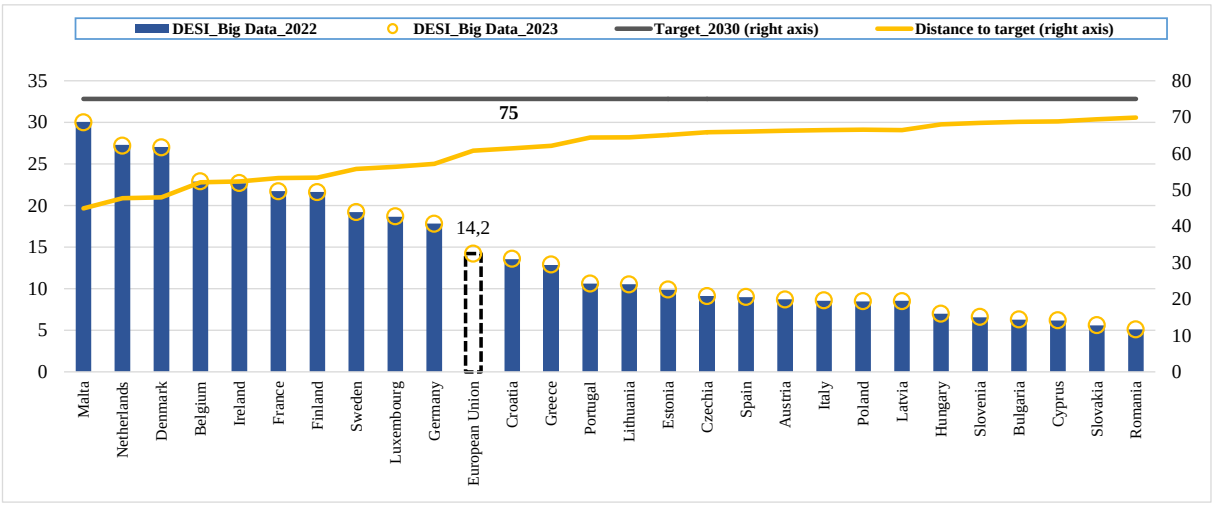
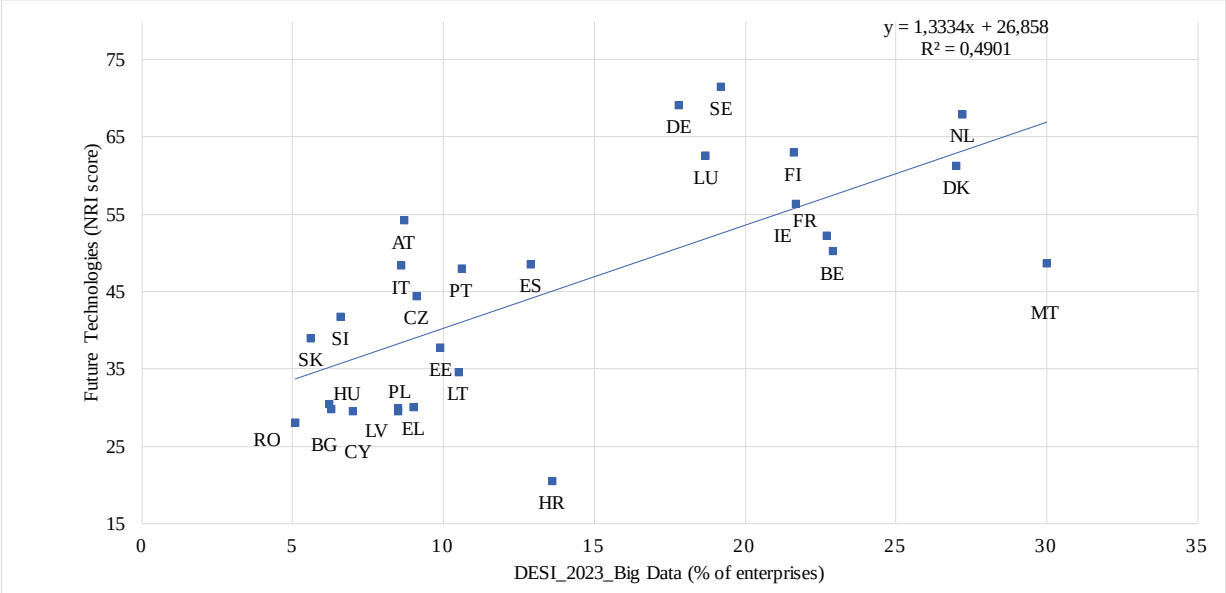


Source: Own editing based on (DESI, 2023)

Figure 3. Share of companies performing Big Data analysis (%)

In Malta, almost a third of businesses have already analysed Big Data. The Netherlands and Denmark follow closely behind with 27%. At the other end of the spectrum are companies in Romania, Slovakia, Cyprus and Bulgaria where only 5-6% have analysed such data. There are significant differences according to the size of enterprises, while one-third of large companies accept Big Data analysis, one in five medium-sized companies and one in 10 in the case of small businesses are ready to carry out such analysis. On a sectoral basis, companies in travel agencies, tour operator reservation services and related activities, publishing activities and ICT are more likely to analyse Big Data. Big Data adoption is expected to be slow at first but then accelerate over time, which is likely due to very small companies that have less incentive to adopt Big Data technologies.

The three technology applications analyzed above were compared with NRI data (Based on the total scores given to Future technologies such as Robot density, Investment in new technologies, Expenditure on computer software, a correlation analysis was performed between the individual factors. Analyzing the three technologies, no strong correlation can be detected in either case, the strongest connection was seen in the case of Big Data (Figure 4). Countries with higher NRI - Future technologies are also likely to use Big Data more actively.



Source: Own editing based on (NRI, 2022, DESI, 2023)

Figure 4. Big Data use in relation to future technologies

Countries can be divided into three groups. The first group includes countries such as Belgium, Denmark, Finland, France, Ireland, Luxembourg, Malta, the Netherlands and Sweden, which have high Big Data and NRI values, suggesting that these countries are leaders in technological development and data use. The second group includes Austria, Germany, Spain, Italy and Portugal, where Future Technology values are high but the use of Big Data is lower. The third group with the largest digital divide includes Bulgaria, Croatia, Cyprus, the Czech Republic, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Slovakia, where both Big Data and Future Technology values are low.

Correlation analysis (Table 2) was used to compare the sub-pillars of future technologies (Adoption of new technologies, Robot density, Investment in new technologies, Expenditure on computer software). Correlation between adoption of new technologies and AI is 0.60, indicating that the increase in adoption of new technologies goes hand in hand with the growth of AI. If we look at the correlation between Robot density, Investment in new technologies, and AI, they are in a moderately positive relationship so with the increase of that factor, AI will also grow. The correlation matrix also shows that there is a moderate positive relationship between Big Data and New Technology Takeover, Robot Density, Investments in New Technologies, and AI. So these factors could potentially affect the growth of Big Data. The adoption of new technologies, robot density, investment in new technologies, the promotion of AI and Big Data can all contribute to increasing the value of cloud use, as there is a moderate positive relationship between the factors.

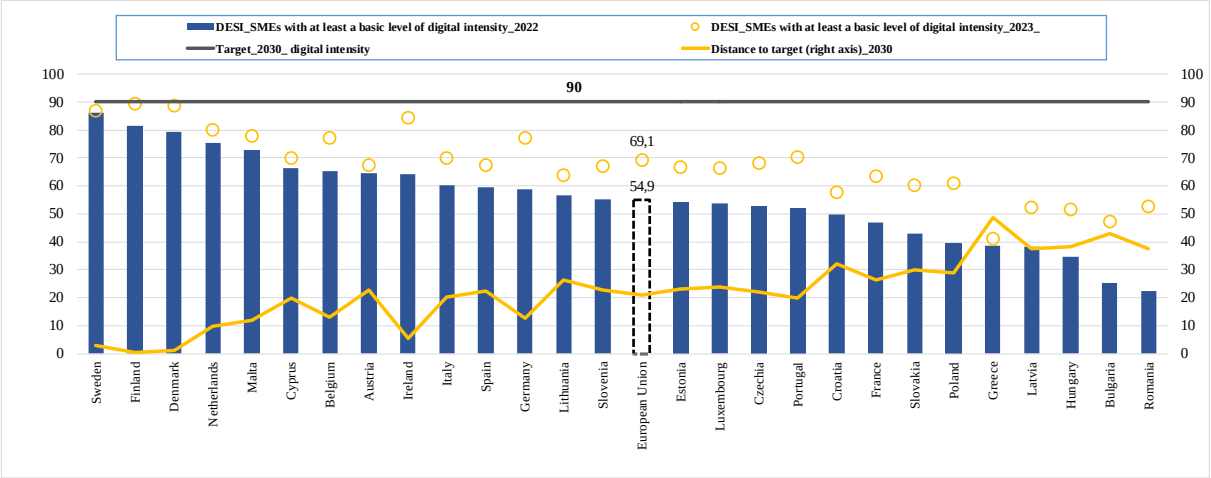
Table 2

Relationship between DESI and NRI indicators

	Adoption of new technologies	Robot density	Investing in new technologies	Expenditure on computer software	AI	Big Data	Cloud
Adoption of new technologies							
Robot density	0,57						
Investing in new technologies	0,94	0,48					
Expenditure on computer software	0,37	0,45	0,28				
AI	0,60	0,48	0,55	0,39			
Big Data	0,65	0,43	0,66	0,49	0,63		
Cloud	0,60	0,48	0,58	0,33	0,57	0,61	

Source: Own calculation based on DESI (2023) and NRI (2022)

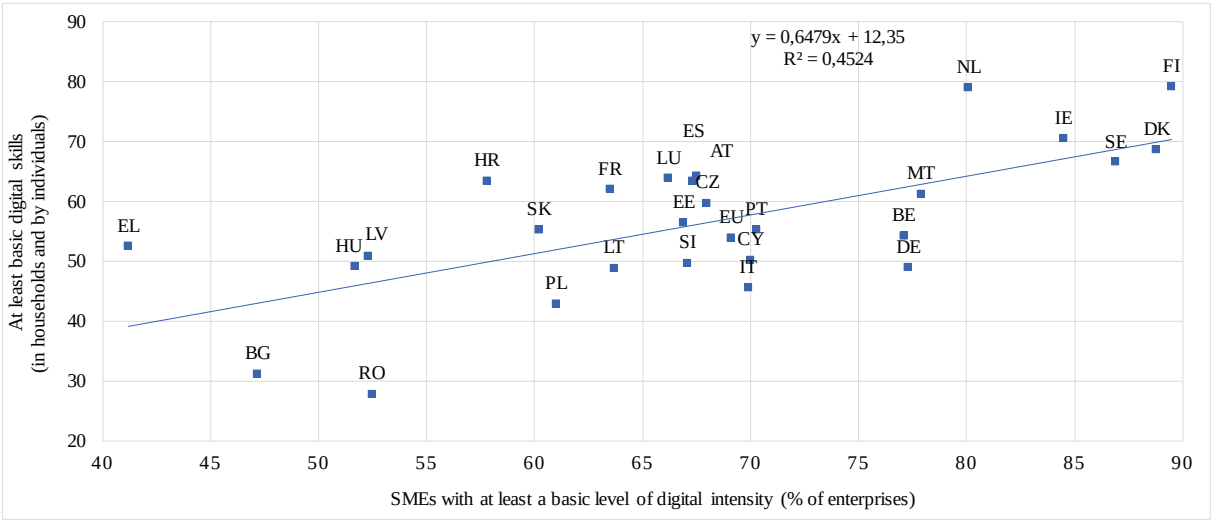
Looking at some more potential relationships, the digital intensity of businesses was examined. Figure 5 shows the proportion of SMEs with basic digital intensity. In four Nordic countries (Finland, Denmark, Sweden and Ireland), at least 80% of SMEs have reached at least basic digital intensity while in Greece and Bulgaria this level is below 50%.



Source: Own editing based on DESI (2023)

Figure 5. Basic digital intensity (% of enterprises)

While in recent years the proportion of businesses with at least basic digital intensity has averaged around 50%, it jumped to 69% at EU level in 2022. This is a positive development that could signal the beginning of an upward change in the trend. However, the digital intensity indicator fluctuates from year to year, as the components of the indicator (questions asked from businesses) alternate every two years. In addition, countries are still far from reaching the target of 90% of SMEs having basic digital intensity by 2030, as indicated by the line in Figure 5. Currently, only a few countries have made significant progress, which can be seen from the distance between circles and columns. Large companies are more likely to adopt new technologies. For example, electronic information sharing through enterprise resource planning software (ERP) is much more common in large enterprises than in SMEs. Social media is used by more than twice as many large companies as SMEs, while the latter also make limited use of e-commerce and online sales opportunities. They should also take advantage of many other technological opportunities, such as cloud services, AI or Big Data analysis. There are common factors that play a critical role in enabling and boosting the uptake of cloud services, Big Data, and artificial intelligence, such as the availability of staff with advanced digital skills. Almost one in two European citizens lacks the basic digital skills needed to access opportunities online. Digital skills are measured by Eurostat's index, which refers to the five digital competences of the EU Digital Competence Framework (DigComp): Information and data literacy skills, Communication and collaboration skills, Digital content creation skills, Security skills and Problem-solving skills. All competences are assessed from a digital perspective. At least to achieve basic digital skills, people need to know how to carry out at least one activity related to each digital competence. According to DESI data, only 54% of adults in the European Union had at least basic skills in 2021, which is still far from the target of 80% by 2030. The differences between countries are sharp (Figure 6). The Netherlands and Finland are close to achieving this goal, where 79% of adults had at least basic digital skills. However, eight Member States still have at least basic digital skills below 50%, including Bulgaria, Romania, Poland and Italy, Lithuania, Hungary, Germany and Slovenia (European Commission, 2023b).



Source: Own editing based on NRI (2022) and DESI (2023)

Figure 6. Basic digital intensity in relation to digital skills

CONCLUSION

Digitalisation in Europe is sub-optimal. The European Union's Digital Decade 2020-2030 policy programme has set numerous objectives for promoting digital transformation. The analysis of digital technology applications in European Union enterprises, based on data from the 2022 Digital Economy and Society Index and the Network Readiness Index, reveals important correlations. The study highlights that only 54% of adults in the European Union had at least basic digital skills in 2021, which is still far from the target of 80% by 2030. Furthermore, the analysis shows correlations between the Adoption of new technologies, Robot density, Investment in new technologies, Expenditure on computer software, AI, Big Data, and cloud adoption. These correlations provide more precise evaluation on the present situation of digital technology implementations in firms of the European Union. The uptake of digital technologies by businesses remains uneven, varies depending on the technology concerned and varies significantly between Member States and economic sectors. The use of Big Data and AI will fall significantly short of the objectives set. The use of cloud computing services has grown significantly in recent years, reaching 34% of EU businesses in 2022. The uptake of Big Data analytics and artificial intelligence technologies remains significantly more limited, with only 14% and 8% of businesses using them, respectively. Achieving the goals of the Digital Decade will require significant efforts by member states through comprehensive and integrated policies to reduce the lack of specific skills, increase technical expertise and diminish the barriers to use more AI, Big Data and Cloud technologies. The integration of basic or advanced digital technologies would require developing knowledge related to digital technologies, developing digital skills and increasing technical expertise, especially among employees. A large amount of research confirms that the ability to extract information from data using advanced data analysis techniques will be fundamental to the competitiveness of any economy. Cloud computing is also at the heart of the data economy to keep businesses competitive against their international competitors. Using advanced big data analysis by 75% across sectors would allow European companies to keep pace with the growth of data use globally and take full advantage of new ways of exploring and interpreting data using artificial intelligence. For example, it is recommended for businesses to grow Big Data effectively to extend data sources, including enterprise systems, user activities, and IoT devices. Efficient optimisation of data processing and storage is essential to manage growing amounts of data, which requires the use of modern Big Data technologies and data storage solutions. Although these solutions appear to be excellent, the inquiry remains as to how. While the presence of technology is undeniably significant, the proficiency of its operators may be even more determining. "Increase appropriate competence and training" would rank among the most essential key phrases. Consequently, a more in-depth mapping of digital abilities will be the further direction for this research in the future.

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