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Article

Digital Development Levels in the European Union: Measurement and Analysis

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Abstract

Digital transformation is a key driver of economic and social progress, and assessing its evolution is essential for guiding public policies. In the European Union (EU), until 2022 the European Commission published the quantitative values of the Digital Economy and Society Index (DESI); however, it is no longer being published, which makes it difficult to compare the digitalisation process between Member States. This study proposes a new composite index, the DESI-DP2, constructed using the distance P2 methodology (DP2), which provides a synthetic and up to date measurement of the digitalisation levels in the twenty-seven EU countries in 2025, both at an aggregate term and by dimensions. The results reveal notable stability in the ranking of countries, with Denmark, Finland, the Netherlands, and Sweden as persistent leaders, and Bulgaria and Romania among the most lagging countries. Moreover, although digitalisation is positively associated with human development, a high level of development alone is not sufficient to ensure strong digital performance. Finally, the study identifies a shift in the explanatory factors behind cross-country differences, from digital skills toward the digital transformation of the business sector, offering relevant insights for the design of public policies within the framework of the European Digital Decade.

Keywords: digital transformation; multidimensional measurement; P2 distance (DP2); Digital Economy and Society Index (DESI); digital skills

1. Introduction

The impact of Information and Communication Technologies (ICT) on the growth and development of countries has been addressed from various disciplines. In general, a positive effect is found (Ciacci et al., 2024; Criveanu, 2023; Magoutas et al., 2024), although the potential economic and social benefits of ICT may be constrained by difficulties in access and use, potentially leading to the exclusion of certain countries or groups. As noted by Hong et al. (2025, p. 2), digital technologies have a widespread impact, but not all citizens benefit equally, as certain groups may be excluded from their benefits. Moreover, despite the extensive literature on the development of the digital economy, the specific determinants influencing digitalisation levels across EU Member States are not yet thoroughly understood (Roszko-Wójtowicz et al., 2024).

It is now recognised that digitalisation is of great importance within the knowledge economy and society. Digital development constitutes a fundamental pillar for human welfare, business competitiveness, and environmental sustainability, issues that have been reflected in the extensive literature (Arvanitis & Loukis, 2009; Dedrick et al., 2003;

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Fernández-Portillo et al., 2020; Hong et al., 2025; Jorgenson, 2001; Roszko-Wójtowicz et al., 2024; Szajt et al., 2024; Török, 2024; Van Dijk et al., 2008). According to Denissova et al. (2025), measuring and promoting digital transformation constitutes a priority at an international level. Furthermore, in the case of less advanced economies, digitalisation can not only improve productivity and, therefore, economic growth, but also overcome certain historical constraints on development.

In this way, the digitalisation of the economy and society determines the pace of economic growth and the capacity to adapt new technologies to business and social processes; consequently, analysing the degree and pace of digitalisation in each country is essential for assessing its economic potential.

Within the EU context, a measure of the Member States' progress in their digital development (Vuorikari et al., 2022, p. 1), known as the Digital Economy and Society Index (DESI), was provided by the European Commission through annual DESI reports from 2014 to 2022. Since 2023, the DESI has been integrated into the Report on the State of the Digital Decade[1], making it possible to access information on updated indicators for the four dimensions: digital skills, digital infrastructure, digital transformation of businesses, and digitalisation of public services. However, since 2022 neither the scores for these dimensions nor those of the synthetic index (DESI) have been published; moreover, it is likely that these measures will not be provided in the future.

In any socioeconomic sphere, accurately measuring a phenomenon is essential for understanding it and designing effective ways to improve it. As highlighted by the Organisation for Economic Co-operation and Development (OECD, 2019, p. 3): "The demand for useful data and measurement tools relating to the ongoing and accelerating digital transformation is particularly acute due to the wide-ranging role that digitalisation and digital technologies play in economies and everyday lives".

Despite the limitations that aggregate indices may present, especially in the case of digitalisation, which is a phenomenon that has not yet been fully defined (Jin et al., 2023), the most common techniques consists of constructing a synthetic index that takes into account the different areas or dimensions of the socioeconomic phenomenon analysed (in this case, in order to estimate the level of digital development of Member States). In this regard, various synthetic measures are available, such as the New Economy Index produced by the Information Technology and Innovation Foundation (Atkinson & Nager, 2014) and the DESI, both overall and by dimensions, produced until 2022 (European Commission, 2022); alternatively, an indicator framework is provided, such as the Going Digital Toolkit (OECD, 2014) or the current DESI dashboard indicators (European Commission, 2025).

This paper aims to offer a synthetic measure of the digitalisation process, to cover the absence of the DESI and to be able to compare the level of digital development of the 27 EU Member States, by applying the DP2 distance methodology; it is an alternative index to the DESI produced until 2022. Furthermore, the construction of a synthetic index based on various indicators grouped into several dimensions will make it possible to identify the variables that most influence the level of digitalisation of countries and therefore provide guidance on the most appropriate measures for digital development.

Building on these premises, this paper poses the following research question: Does the DP2 methodology make it possible to obtain an indicator that approximates the DESI and can be used to analyse the evolution and the differences between countries?

To address this question, the following objectives are defined:

(a) To compare the results obtained by applying the DP2 methodology with those derived from the DESI in 2022 and to assess whether it can serve as a substitute indicator.
(b) To compare the situation of DESI-DP2 in 2022 and 2025 in the EU countries.

(c) To identify the importance of the different dimensions in explaining the inequalities in the digitalisation level of EU countries.

The remainder of this paper is organised as follows. Section 2 describes the research methodology, including the analytical framework and the construction of the DESI-DP2. Subsequently, Section 3 presents the empirical results, describing the position of the 27 EU Member States in 2022, its evolution, and the identification of the main determining factors of the differences between them. Finally, Section 4 concludes the study by summarising the main findings, highlighting the contributions to the literature and suggesting future research lines.

2. Methodology

Adequately measuring the digitalisation process is essential for understanding it better and for designing effective policies (OECD, 2014). Therefore, in the case of the digital economy and society, new data and measurement tools are required, given their growing role in daily life and the rapid pace of change being experienced. As some authors point out, digital transformation is developing at such a rapid pace that the measurement instruments of the digital economy must be adapted continuously. Along these lines, Olczyk and Kuc-Czarnecka (2022) have attempted to seek better measures of the level of digital development of EU Member States, altering the methodology applied in the DESI and using sensitivity-based analysis. They conclude that the DESI would improve by reducing the set of variables and modifying the weighting scheme. In this context, when working with synthetic indicators grouped into several dimensions, various problems may arise, including interdependence between the indicators, the choice of a specific weighting for each indicator within a specific dimension, and the aggregation of each component or dimension into the synthetic index. In this sense, Bánhidi et al. (2020, p. 44) point out that the various dimensions of the DESI are not isolated from one another but rather are interconnected areas, as also indicated by the European Commission (2022, p. 4): "developments in the digital economy and society cannot be achieved through isolated improvements in particular areas but through concerted improvement in all areas". Despite these limitations, aggregate indices allow for temporal and cross-sectional comparisons, providing a global perspective that could not otherwise be obtained.

One of the techniques that makes it possible to construct composite indices is the DP2 methodology, based on the distance (in this case, of the digitalisation level) between each country and the "worst possible scenario", which is assigned a value of zero. According to Zarzosa-Espina (2009, p. 401), the DP2 measure "is capable of being applied to other concepts more or less related to social welfare and has demonstrated its suitability in numerous studies for resolving issues not adequately resolved by other methodologies". This methodology, proposed by Pena-Trapero in 1977, has been widely used in the analysis of multidimensional socioeconomic phenomena, such as wellbeing and quality of life. More recently, it has been applied to the public dimension of digitalisation in Italy (Traversa & Ivaldi, 2024) and to the concept of digital sustainability, which emphasises the responsible and sustainable use of ICT (Ciacci et al., 2024). For their part, Nayak and Mishra (2012, p. 3) consider that the use of DP2 has increased following the publication of certain works in a widely spoken language such as English. They conclude that there is no consensus on the best composite index, since such indices are based on ordinal measures used for classification.

Somarriba-Arechavala and Pena-Trapero (2009a, p. 383; 2009b, pp. 130–131) emphasise that a key advantage of the DP2 indicator is its ability to resolve issues affecting synthetic indicators, such as the application of arbitrary weightings or redundant data. Furthermore, it allows weights with economic interpretation to be obtained and enables comparisons over

time and space, as it is a cardinal measure, which makes it preferable to other methodologies, such as Principal Component Analysis or Data Envelopment Analysis. Regarding the first issue, Zarzosa-Espina (1996, p. 161) notes that in this methodology, "the weight of the partial indicators is determined scientifically, not arbitrarily". As for the second issue, data redundancy is avoided because only the new and useful information incorporated by each variable is retained (Somarriba-Arechavala & Zarzosa-Espina, 2019). Consequently, dimensions are not assigned identical weightings, unlike in the DESI.

Drawing on the works of Zarzosa-Espina and Somarriba-Arechavala (2013) and Somarriba-Arechavala et al. (2015), who summarise the characteristics and advantages of the P2 distance method, it is worth highlighting that this approach yields a robust synthetic measure with multiple desirable statistical properties[2] of the socioeconomic phenomenon analysed and identifies the dimensions with greater explanatory power regarding differences between countries. Relevant information is therefore obtained regarding the specific public policies that may be most effective in achieving certain goals. On the other hand, the work by Abellán-Salinas et al. (2026) provides a review of the DP2 methodology, comparing it with other recent techniques, including one derived from the application of machine-learning algorithms, highlighting both its limitations and strengths; an issue that lies beyond the scope of the objectives addressed here.

In this paper, based on the thirty-three DESI indicators for 2022 (and thirty-six for 2025) and applying the DP2 methodology, the aggregate index (DESI-DP2) was constructed for both years, as were the indices for their four dimensions (Appendix A). Table 1 summarises its four dimensions and its nine or ten sub-dimensions. As can be seen, there is considerable similarity between them and the number of sub-dimensions for skills and businesses has remained constant, whereas for infrastructure they have been reduced from four to two, and for public services one has been added to the single one previously considered.

Table 1. DESI. Dimensions and sub-dimensions, 2022 and 2025.

2022		2025	
Dimensions	**Sub-Dimensions**	**Dimensions**	**Sub-Dimensions**
Human capital	Internet user skills Advanced skills and development	Digital skills	Internet user skills Advanced skills and development
Connectivity	Fixed broadband take-up Fixed broadband coverage Mobile broadband Broadband prices	Digital infrastructure	Fixed broadband Mobile broadband
Integration of digital technology	Digital intensity Digital technologies for businesses e-Commerce	Digital transformation of businesses	Digital intensity Digital technologies for businesses e-Commerce
Digital public services	e-Government	Digitalisation of public services	e-Government e-Health

Source: Appendix A.

As the database is continuously being updated, the information used refers to the year of publication, which generally tends to be from the previous year since that is the latest data available at that moment. A detailed description of the various DESI indicators and how to access the data can be found in Obelovska et al. (2025), who use it to analyse the level of two specific dimensions: digital skills and network infrastructure in EU Member States.

As previously indicated, the DP2 distance methodology is utilised, yielding a non-compensatory index based on a linear regression model (Ciacci et al., 2024). The DESI-DP2

index measures the distance of each country from a reference value, which is the minimum obtained by the 27 EU Member States. The formulae used are specified below, including a table reflecting the levels considered for each partial indicator and the DESI-DP2 indicator. The dimensions are calculated from the sub-dimensions, while the sub-dimensions are obtained from the indicators included in each of them.

First step: Calculation of the Fréchet distance (FD) (1) and the DP2 indicator (2) for each sub-dimension k and country i:

$$FD_k^i = \sum_{j=1}^{n} \frac{\left(x_j^i - x_j^{mín}\right)}{\sigma_j} = \sum_{j=1}^{n} \frac{d_j^i}{\sigma_j} \quad (1)$$

x_j^i: value of indicator or variable j for country i.

j = 1, . . ., n (each sub-dimension k has n indicators).

$d_j^i = \left(x_j^i - x_j^{mín}\right)$: Distance between the value of an indicator j for country i and the minimum value recorded for that indicator j.

$$DP2_k^i = \sum_{j=1}^{n} \frac{d_j^i\left(1 - \overline{R}^2_{j,\, j-1,j-2,\ldots,1}\right)}{\sigma_j} \quad (2)$$

$DP2_k^i$: partial digitalisation indicator for country i and sub-dimension k.

Second step: Calculation of the partial indicators (IP) for each dimension.

Once the distance indicators for each sub-dimension have been obtained, they are aggregated using the aforementioned formulae to generate the dimension-specific distance indicators. In this case, the indicators or variables are replaced by the distance values for each sub-dimension.

Third step: Calculation of the DESI-DP2 from the IPs obtained in the second step

$$\text{DESI} - \text{DP2} = \sum_{d=1}^{4} \frac{\left(IP_d^i - IP_d^{min}\right)\left(1 - \overline{R}^2_{d,\, d-1,d-2,\ldots,1}\right)}{\sigma_d} \quad (3)$$

IP_d^{min}: Minimum value recorded for each partial indicator.

Fourth step: Calculation of the differentiating power of each dimension explained by each sub-dimension and of the DESI-DP2 explained by each dimension.

$$CD_d^{Iva} = \frac{2}{m(m-1)} \sum_{i,z=1\ (z>i)}^{m} \left| \frac{DF_d^z - DF_d^i}{\overline{DF}_d} \right| \quad (4)$$

CD: Ivanovic discrimination coefficient.

m: number of countries; DF_d^i: Fréchet distance of dimension d, country i.

$\overline{DF}_d$: Mean FD value corresponding to dimension d for the 27 EU Member States.

$$\alpha_d = \frac{CD_d^{Iva}\left(1 - \overline{R}^2_{d,d-1,d-2,\ldots,1}\right)}{\sum_{d=1}^{4} CD_d^{Iva}\left(1 - \overline{R}^2_{d,d-1,d-2,\ldots,1}\right)} \cdot 100 \quad (5)$$

α: Relative individual information coefficient for each dimension d, defined by Zarzosa-Espina in 1996 (Zarzosa-Espina & Somarriba-Arechavala, 2013, p. 14).

In this way, the DESI-DP2 provides a synthetic measure of the level of digitalisation achieved by EU countries, extracting the information actually contributed by each indicator, without redundancies and without the need to specify arbitrary weights. Moreover, the technique employed not only makes it possible to compare the consistency of our

index with respect to the DESI produced by the European Commission, but it also goes further by identifying the dimensions that contribute most to explaining the differences in digitalisation levels among EU countries.

3. Results

3.1. The DESI-DP2 as an Approximation to the DESI for Assessing the Overall Level of Digitalisation

First, Table 2 shows that the relative levels of digitalisation are very similar when using the DESI and the DESI-DP2, which is confirmed by the high correlation (cross-sectional across countries) between both indicators (Figure 1), such that most countries occupy very similar positions. Thus, the countries achieving the best results with both methodologies are Denmark, Finland, the Netherlands, Sweden, and Ireland. The level of digital development in Malta, Spain, and Luxembourg is also noteworthy. At the opposite end, the lowest positions are held by Slovakia, Poland, Greece, Bulgaria, and Romania.

Table 2. DESI and DESI-DP2 in the 27 EU Member States, 2022.

		2022			
Code	**Countries**	**DESI**	**Order**	**DESI-DP2**	**Order**
FI	Finland	69.6	1	8.6	5
DK	Denmark	69.3	2	10.0	1
NL	Netherlands	67.4	3	9.1	3
SE	Sweden	65.2	4	8.6	4
IE	Ireland	62.7	5	9.1	2
MT	Malta	60.9	6	7.1	7
ES	Spain	60.8	7	6.8	8
LU	Luxembourg	58.9	8	7.5	6
EE	Estonia	56.5	9	6.1	9
AT	Austria	54.7	10	5.5	10
SI	Slovenia	53.4	11	4.4	17
FR	France	53.3	12	5.5	11
DE	Germany	52.9	13	4.7	16
LT	Lithuania	52.7	14	3.8	20
PT	Portugal	50.8	15	5.2	13
BE	Belgium	50.3	16	5.3	12
LV	Latvia	49.7	17	4.1	19
IT	Italy	49.3	18	2.9	22
CZ	Czechia	49.1	19	4.3	18
CY	Cyprus	48.4	20	4.8	14
HR	Croatia	47.5	21	4.8	15
HU	Hungary	43.8	22	3.7	21
SK	Slovakia	43.4	23	2.5	24
PL	Poland	40.5	24	1.4	25
EL	Greece	38.9	25	2.6	23
BG	Bulgaria	37.7	26	0.8	26
RO	Romania	30.6	27	0.0	27

Source: compiled by the authors.

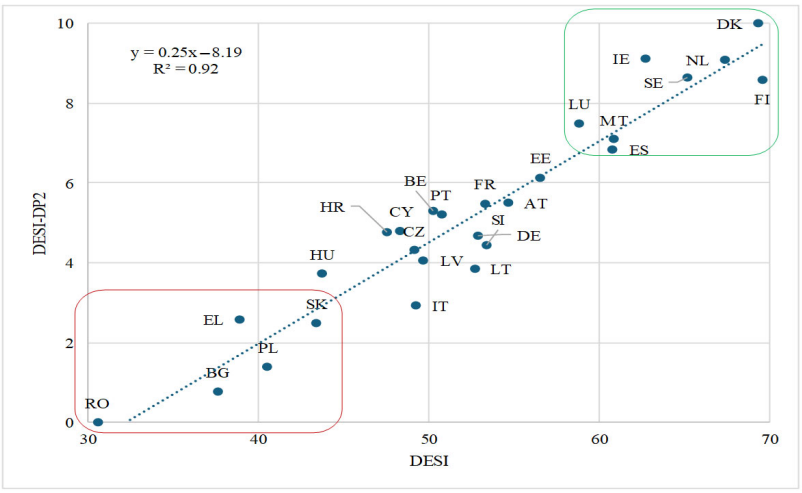

Figure 1. Correlation between DESI and DESI-DP2 in 2022 in the 27 EU Member States.

When both indicators are analysed by dimensions (Figure 2), a high structural coherence can be observed, indicating strong consistency between the DESI and its adjusted version, the DESI-DP2.

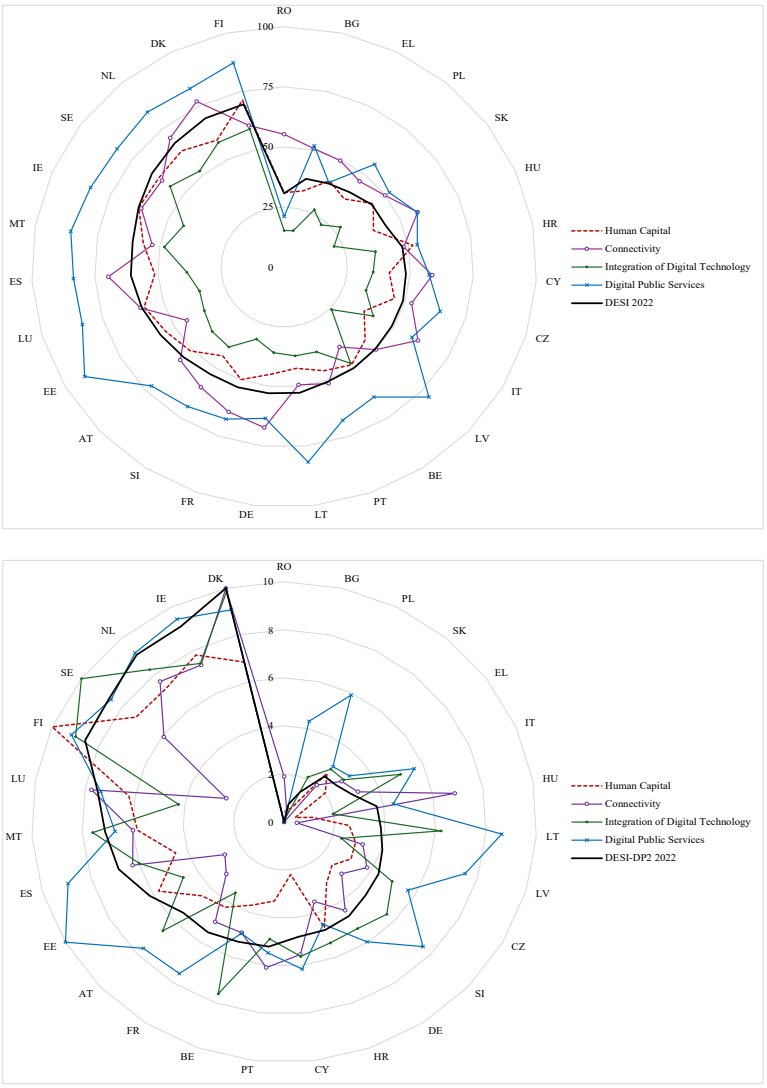

Figure 2. Dimensions of DESI and DESI-DP2 in 2022.

Despite the differences in scale, the relative positions of the countries and the location of maximum and minimum values remain fairly stable, suggesting that the second indicator refines—but does not alter—the general pattern of digital performance. The analysis by dimensions shows that Digital Public Services constitute the main factor differentiating countries, as they concentrate the highest values and the greatest dispersion. Connectivity plays a relevant structural role, contributing consistently to the aggregate index, while Human Capital acts as a supporting dimension with lower discriminating capacity. By contrast, the Integration of Digital Technologies exhibits systematically lower levels and greater heterogeneity, which limits its relative contribution to overall digital performance.

3.2. Comparison of the Level of Digitalisation in 2022 and 2025 Using the DESI-DP2

Once it has been verified that, despite its limitations, the DESI-DP2 can be used as an approximation of the relative level of digitalisation of EU countries, a comparative statics exercise is carried out, analysing the situation in both years. Although, as mentioned, some changes have occurred in the indicators that make up the aggregate index, these are not considered to be generally relevant, since the aim is to provide a ranking rather than a precise quantification of the evolution of the digitalisation process. Table 3 shows this evolution and reveals a significant reordering of the digital performance of the Member States of the European Union.

Table 3. DESI-DP2 in the 27 EU Member States, 2022 and 2025.

		2022		2025	
Code	**Countries**	**DESI-DP2**	**Order**	**DESI-DP2**	**Order**
DK	Denmark	10.0	1	10.0	1
FI	Finland	8.6	5	9.5	2
MT	Malta	7.1	7	8.7	3
SE	Sweden	8.6	4	8.4	4
NL	Netherlands	9.1	3	8.2	5
LU	Luxembourg	7.5	6	7.2	6
BE	Belgium	5.3	12	7.1	7
ES	Spain	6.8	8	7.0	8
EE	Estonia	6.1	9	7.0	9
AT	Austria	5.5	10	5.5	10
LT	Lithuania	3.8	20	5.5	11
PT	Portugal	5.2	13	5.3	12
SI	Slovenia	4.4	17	5.0	13
HU	Hungary	3.7	21	4.6	14
CY	Cyprus	4.8	14	4.5	15
FR	France	5.5	11	4.5	16
DE	Germany	4.7	16	4.5	17
IE	Ireland	9.1	2	4.3	18
LV	Latvia	4.1	19	4.2	19
HR	Croatia	4.8	15	4.2	20
IT	Italy	2.9	22	4.0	21
CZ	Czechia	4.3	18	3.7	22
PL	Poland	1.4	25	3.3	23
SK	Slovakia	2.5	24	2.0	24
EL	Greece	2.6	23	1.6	25
BG	Bulgaria	0.8	26	1.4	26
RO	Romania	0.0	27	0.0	27

Source: compiled by the authors.

Thus, the results combine stability in leadership, mobility within the intermediate groups, and persistent lagging at the lower end of the ranking. Denmark maintains a clearly dominant position in both years, confirming the structural strength of its digital model. Alongside it, Finland, Sweden and, notably, Malta reinforce their presence among the top positions, with the latter standing out for its rise from seventh to third place.

In contrast, some initially leading countries experience significant losses in relative position, such as Ireland and, to a lesser extent, the Netherlands. Within the intermediate group, a clear dynamic of convergence can be observed, with notable progress in countries such as Belgium, Spain, Estonia and Lithuania, reflecting processes of digital catching-up. Meanwhile, the countries located at the bottom of the ranking maintain persistently unfavourable positions, with limited improvements in absolute terms and little relative mobility. These results can be visualised more clearly in Figure 3.

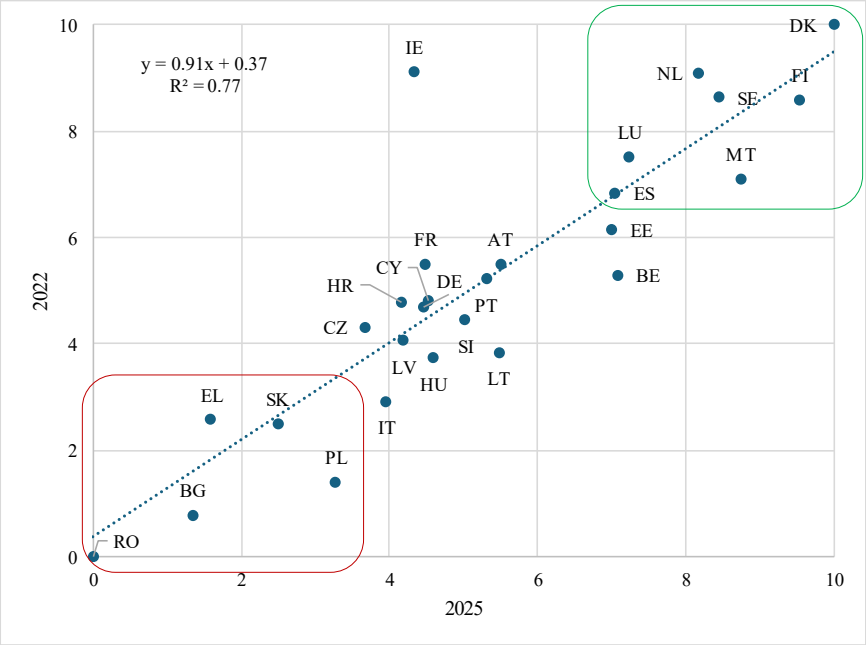

Figure 3. DESI-DP2 in the 27 EU Member States, 2022 and 2025.

Given the disparate development levels across EU Member States, Figure 4 plots the 2025 DESI-DP2 against the Human Development Index (HDI), for the latest year published (2025)[3]. It should be noted that all 27 EU Member States are considered to have very high human development according to the latest published HDI[4], ranking from 4th (Denmark) to 55th (Bulgaria and Romania), although in the previous year Bulgaria was placed in the high human development group (ranked 70th). As shown, there is a relationship whereby countries with higher HDI scores generally exhibit higher levels of digitalisation. However, Belgium, Spain, and Estonia display very similar DESI-DP2 values for 2025 despite having different HDI levels, and even more striking is the similarity in digitalisation levels between Germany and Hungary, whose HDIs diverge significantly. Likewise, the country pairs of Bulgaria and Greece; Germany and Latvia; and Austria and Portugal, exhibit a similar DESI across its various versions and years, while having different HDIs. In the case of Belgium, Finland, and Ireland, highly disparate digitalisation levels are observed despite similar HDI values, a pattern also observed when comparing Estonia, Greece, and Italy. It is therefore the case that additional factors influence the level of digitalisation, such as a firm commitment from the stakeholders involved to achieve digital transformation.

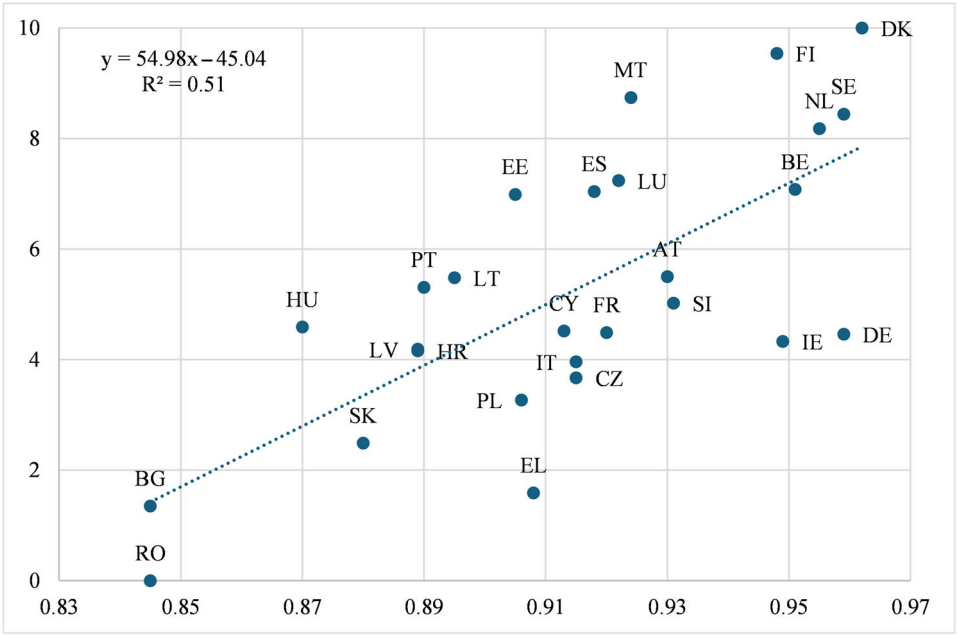

Figure 4. DESI-DP2 (*y*-axis) and HDI (*x*-axis) for the 27 EU Member States, 2025.

3.3. Dimensions of Digitalisation

In Figure 5, the values of the different dimensions of the DESI-DP2 in 2022 and 2025 are shown for the twenty-seven EU countries, revealing a clear hierarchical structure in the factors that explain the digital performance of the Member States, as well as heterogeneous dynamics of change across countries. In both years, the digitalisation of public services emerges as the most decisive and differentiating dimension, concentrating the highest values and showing a strong capacity to explain the differences between leading and lagging countries. This dimension strengthens its relative weight in 2025, especially in economies with sustained administrative modernisation trajectories.

Digital infrastructures (connectivity) maintain a structural and stable role, acting as an enabling condition for the other dimensions, with lower temporal volatility and a relatively persistent hierarchy of countries. Digital skills (human capital) show a more uneven evolution, with significant progress in some intermediate countries but with limited capacity to alter relative positions in the overall ranking. Meanwhile, the digital transformation of businesses continues to be the most lagging and heterogeneous dimension, reflecting structural difficulties in technological adoption across broad productive segments.

In comparative terms, a process of partial convergence can be observed, driven by medium-performing countries, while leaders maintain cumulative advantages and lagging countries show significant persistence in their positions, highlighting the existence of structural digital divides within the European Union.

Table 4 makes it possible to identify the relative importance of each dimension and sub-dimension in the construction of the DESI-DP2, as well as their capacity to explain the differences observed between countries.

In 2022 the dimensions most correlated with the DESI, using the DP2 methodology, are human capital and the integration of digital technology (providing 100% and 40.1% of non-redundant information, respectively), with the sub-dimensions of Internet user skills and digital intensity standing out as the most influential within these dimensions. In contrast, in 2025 the dimension most correlated with the DESI is the digital transformation of businesses, followed by digital skills (contributing 100% and 53.9% of new information, respectively), with the most important sub-dimensions being digital technologies for businesses and Internet user skills.

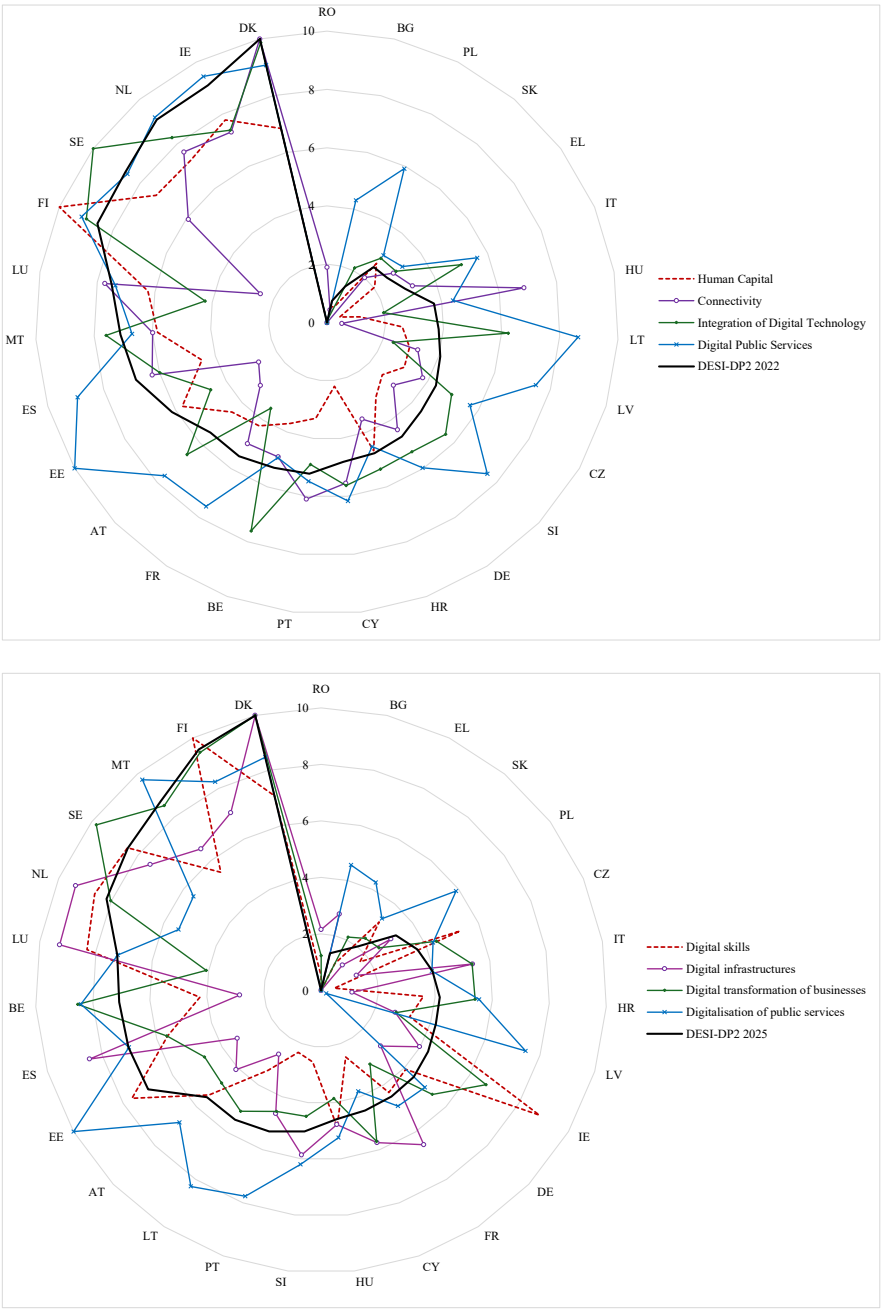

Figure 5. Dimensions of DESI-DP2 in EU-27. 2022 and 2025.

Table 4. Correlation coefficients and explanatory power of differences, 2022 and 2025.

Year 2022						
Dimensions	**Sub-Dimensions**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Human capital	Internet user skills	0.91	47.85	44.09	0.90	0.93
	Advanced skills and development	0.83	52.15		0.69	
Connectivity	Fixed broadband take-up	0.75	28.56	30.06	0.39	0.76
	Fixed broadband coverage	0.51	20.49		0.28	
	Mobile broadband	0.54	29.27		0.66	
	Broadband prices	0.62	21.69		0.49	
Integration of digital technology	Digital intensity	0.97	51.73	14.05	0.85	0.86
	Digital technologies for businesses	0.87	11.74		0.83	
	e-Commerce	0.84	36.53		0.64	
Digital public services	e-Government	1.00	100.00	11.80	0.79	

Table 4. *Cont.*

Year 2025						
Dimensions	**Sub-Dimensions**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Digital skills	Internet user skills	0.93	55.04	20.89	0.80	0.78
	Advanced skills and development	0.84	44.96		0.54	
Digital infrastructure	Fixed broadband	0.75	53.72	24.14	0.35	0.76
	Mobile broadband	0.75	46.28		0.79	
Digital transformation of businesses	Digital intensity	0.88	12.73	31.26	0.79	0.88
	Digital technologies for businesses	0.95	49.51		0.90	
	e-Commerce	0.83	37.76		0.61	
Digitalisation of public services	e-Government	0.74	61.33	23.70	0.79	0.70
	e-Health	0.74	38.67		0.25	

(1) Correlation coefficient of each sub-dimension with respect to its dimension. (2) Differences in each dimension explained by each sub-dimension (%). (3) Differences in the DESI-DP2 explained by each dimension (%). (4) Correlation coefficient of each sub-dimension with respect to the DESI-DP2. (5) Correlation coefficient of each dimension with respect to the DESI-DP2. Source: compiled by the authors.

Among the factors explaining the differences between EU Member States, in 2022 the human capital dimension accounted for 44.1% of the variation, whereas in 2025 the strongest dimension is digital transformation of businesses (explaining 31.3% of the differences). More specifically, the sub-dimensions standing out in 2022 and 2025 are, respectively, advanced skills and development and digital technologies for businesses, representing the areas requiring most emphasis in order to reduce the differences between countries. There has therefore been a shift from focusing on individuals' advanced digital skills to emphasising companies' digital technologies as the key factor in reducing disparities between countries, possibly due to the rapid narrowing of gaps among users, who are aware of the advantages of having advanced skills as a mechanism for occupational and social inclusion. This change must now occur within companies, as the intensified use of digital technologies is a necessary condition for competing in an increasingly digitally interconnected global market.

4. Discussion and Conclusions

4.1. Discussion

The primary scientific contribution of this research is the construction of a novel composite index (DESI-DP2) offering a synthetic measurement of the digitalisation process (both overall and by dimensions); this contribution becomes particularly relevant considering the information gap resulting from the European Commission's decision to cease publishing DESI scores and dimensions since 2022. By applying the DP2 methodology, the index allows not only for international comparability, but also the identification of the determining factors of cross-country differences in digital development, thus serving as a guide to foster strategies that can enable significant technological progress in lagging countries.

First, it has been verified that the correlation between DESI and DESI-DP2 in 2022 is very high, and most countries occupy very similar positions according to both indices. Moreover, when analysing both indicators by dimensions, a high degree of structural coherence is also observed. Therefore, there is strong consistency between the DESI and its adjusted version, DESI-DP2, which allows us to consider the methodology suitable for constructing a substitute indicator for DESI.

Next, based on the DESI-DP2, his study has therefore examined the level of digitalisation of the 27 EU Member States and the situation in 2022 and 2025 is compared, analysing

the relationship with their degree of development and the explanatory factors behind the differences in the digitalisation process, highlighting the following aspects:

— The leaders in digitalisation are Denmark, Finland, the Netherlands, Sweden, and Ireland; the level of digital development in Malta, Spain, and Luxembourg is also noteworthy. At the opposite end, the lowest positions are occupied by Slovakia, Poland, Greece, Bulgaria, and Romania. Applying different methods and using data from different years, the literature also identifies the first four aforementioned countries as leaders, and Bulgaria and Romania as lagging behind, generally alongside Greece (Bánhidi et al., 2020; Laitsou & Xenakis, 2023). No significant changes were observed in country rankings when comparing the DESI-DP2 for 2022 and 2025, except for specific cases such as Ireland, Malta, Lithuania, and Belgium. Fidan (2024), using different analysis methods to cluster countries by similar digitalisation levels, also maintains that most remain within the same group. As previously mentioned, some countries, such as Ireland, show a significant decline, while others, such as Malta, have improved. In order to identify the factors that explain cases such as that of Ireland (which worsens sharply) or that of Malta (which improves significantly), the Digital Decade 2025[5] reports for both countries were reviewed, showing that "Ireland maintains a high level of SME digitalisation, but growth has been stagnating since 2022", while "Malta performs very well on the uptake of AI and digitalisation of businesses [. . .] Significant progress has been achieved over the last year, particularly in the share of enterprises adopting AI".

— Regarding the relationship between digitalisation and development, while a correlation exists, many countries with similar HDI values exhibit markedly different digitalisation levels, or vice versa (i.e., very close DESI and DESI-DP2 scores despite highly divergent HDIs). This result, which is consistent with Laitsou and Xenakis (2023), suggests that factors beyond those included in the HDI (income, education, and health) influence digitalisation levels, although the two are correlated. Consequently, achieving a high level of development is insufficient to advance digital transformation: a firm commitment to fostering digitalisation is also required, both at national level and through coordinated action between Member States and European institutions. Among the measures that can accelerate digital development, Ciacci et al. (2024) highlight the regulatory framework (simplification of bureaucratic procedures, tax incentives, etc.) and national and international collaboration between public authorities, academic institutions, and businesses.

— An additional contribution of this study is the identification of a shift in the explanatory factors behind cross-country differences in the digitalisation process. Whereas in earlier stages digital skills played a predominant role, the results for 2025 point to the growing relevance of the digital transformation of businesses, particularly the adoption of digital technologies and digital intensity. This finding provides clear guidance for public policies, which should intensify their focus on the business sphere—especially on small and medium-sized enterprises—where significant barriers to digital adoption persist. Nevertheless, this shift in emphasis does not diminish the importance of digital skills, which remain a fundamental requirement both for the effective use of digital public services and for the successful integration of digital technologies within firms (Fidan, 2024; Magoutas et al., 2024; Török, 2024).

4.2. Policy Implications

Digital development is a key element of the EU's socioeconomic progress, a process that requires well-coordinated action by the 27 Member States in various fields. The EU's action programme for digital transformation is the Digital Decade, which is structured

around the four areas covered by the DESI: skills, infrastructure, businesses, and public services. In March 2021, the European Commission presented the Digital Compass, setting targets to foster EU digitalisation by 2030. In December 2022, the Parliament and the Commission adopted the Decision establishing the Digital Decade Policy Programme 2030. This Decision, in addition to defining targets for advancing the EU's digital transformation, establishes a monitoring and cooperation mechanism between European institutions and Member States.

The results of this study underscore the importance of coherent and integrated policies across these pillars. In particular, the growing relevance of business digitalisation requires policy instruments that facilitate technological adoption, promote innovation, and reduce administrative and financial barriers, especially in the case of SMEs. At the same time, continued investment in education and digital skills remains essential to ensure that citizens and workers can fully benefit from the opportunities offered by digitalisation and to guarantee the effective use of digital public services.

4.3. Limitations and Future Research

Despite its contributions, this study presents several limitations. First, the analysis depends on the availability and quality of official indicators. As a result, biases are inevitably introduced due to the time lag with which information is published, and the indicators may not fully capture qualitative aspects of digitalisation, such as intensity or effectiveness in the use of technologies. Second, the study is conducted at the national level, which may conceal important regional disparities within countries, as illustrated by the work carried out for Spain by Rodríguez-Pasquín et al. (2023). Third, although the DESI-DP2 allows for temporal comparisons, changes in the structure and availability of the underlying indicators may affect strict comparability over time.

These limitations open several avenues for future research. In particular, it would be of interest to extend the analysis to the regional level (for example, NUTS2) in order to examine intra-national digital divides. Likewise, incorporating qualitative indicators and microdata at the firm or household level would provide a more detailed view of the adoption and use of digital technologies. Additionally, the use of dynamic or causal approaches would facilitate the assessment of the impact of specific digitalisation policies and investments. Finally, comparative studies between the EU and other advanced economies would help contextualise Europe's digital performance within a global framework.

4.4. Conclusions

In conclusion, achieving a digitally advanced economy and society requires the balanced and coordinated development of all the dimensions involved in the digital transformation process. The DESI-DP2 constitutes an optimal and transparent tool for assessing the degree of digitalisation in the EU and for identifying the factors that explain cross-country differences. The results highlight both the persistence of leading and lagging countries and the evolving determinants of digitalisation, with a growing emphasis on the digital transformation of the business sector. Reducing existing digital divides will therefore require comprehensive public policies that combine investments in skills, infrastructures, business digitalisation, and public services, supported by effective coordination and international cooperation.

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Appendix A

Appendix A.1. DESI. Dimensions, Sub-Dimensions and Indicators, Year 2022

Dimensions	Sub-Dimensions	Indicators
1 Human capital	1a Internet user skills	1a1 At least basic digital skills 1a2 Above basic digital skills 1a3 At least basic digital content creation skills
	1b Advanced skills and development	1b1 ICT specialists 1b2 Female ICT specialists 1b3 Enterprises providing ICT training 1b4 ICT graduates
2 Connectivity	2a Fixed broadband take-up	2a1 Overall fixed broadband take-up 2a2 At least 100 Mbps fixed broadband take-up 2a3 At least 1 Gbps take-up
	2b Fixed broadband coverage	2b1 Fast broadband (NGA) coverage 2b2 Fixed Very High Capacity Network (VHCN) coverage 2b3 Fibre to the Premises (FTTP) coverage
	2c Mobile broadband	2c1 5G spectrum 2c2 5G coverage 2c3 Mobile broadband take-up
	2d Broadband prices	2d1 Broadband price index
3 Integration of digital technology	3a Digital intensity	3a1 SMEs with at least a basic level of digital intensity
	3b Digital technologies for businesses	3b1 Electronic information sharing 3b2 Social media 3b3 Big data 3b4 Cloud 3b5 AI 3b6 ICT for environmental sustainability 3b7 e-Invoices
	3c e-Commerce	3c1 SMEs selling online 3c2 e-Commerce turnover 3c3 Selling online cross-border
4 Digital public services	4a e-Government	4a1 e-Government users 4a2 Pre-filled forms 4a3 Digital public services for citizens 4a4 Digital public services for businesses 4a5 Open data

Appendix A.2. DESI. Dimensions, Sub-Dimensions and Indicators, Year 2025

Dimensions	Sub-Dimensions	Indicators
1 Digital skills	Internet user skills	Internet use At least basic digital skills Above basic digital skills At least basic digital content creation skills (*)
	Advanced skills and development	ICT specialists ICT graduates (*)
2 Digital infrastructure	Fixed broadband	Overall Internet take-up Share of fixed broadband subscription $\geq$ 100 Mbps Share of fixed broadband subscription $\geq$ 1 Gbps Fixed Very High Capacity Network (VHCN) coverage Fibre to the Premises (FTTP) coverage
	Mobile broadband	Mobile broadband take-up Overall 5G coverage 5G coverage in the 3.4–3.8 GHz band 5G spectrum 5G SIM cards (share of population) Edge nodes
3 Digital transformation of businesses	Digital intensity	SMEs with at least a basic level of digital intensity
	Digital technologies for businesses	Electronic information sharing Social media Data Analytics—former Big Data Cloud Artificial Intelligence (AI) AI or Cloud or Data Analytics e-Invoices Unicorns
	e-Commerce	SMEs selling online e-Commerce turnover
4 Digitalisation of public services	e-Government	e-Government users Digital public services for citizens Digital public services for businesses Pre-filled forms Transparency of service delivery, design and personal data User support Mobile friendliness
	e-Health	Access to e-Health records

Source: European Commission (2022, 2025) and (*) https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts/desi-indicators?period=desi_2025 (accessed on 7 May 2025).

Notes

1 As seen here: https://digital-strategy.ec.europa.eu/en/policies/desi (accessed on 7 May 2025).
2 In this article, for the indicators or variables used, the influence of outliers is small, so the estimate based on the DP2 distance can be considered robust.
3 There is an inherent time lag in the data included in both HDI and our DESI-DP2 indicator, as they rely on the most recent data available at the time of publication.
4 Information available at: https://hdr.undp.org/data-center/documentation-and-downloads (accessed on 7 May 2025).
5 Available at: https://digital-strategy.ec.europa.eu/es/library/digital-decade-2025-country-reports (accessed on 7 May 2025).

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