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# **The impact of digital development on human well-being and vice versa**

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## **Abstract**

This study examines the relationship between human well-being and digital development, focusing on the case study of EU-27 countries during the period from 2018 to 2021. The investigation utilizes two key indicators: the Digital Economy and Society Index (DESI), which assesses the digital performance of Europe, and the Human Development Index (HDI), a United Nations metric for measuring citizen well-being. The primary objective of this study is to determine the relationship between a country's DESI and HDI values and to explore the possible categorization of countries based on these indicators over the study period. Additionally, the impact of the Covid-19 pandemic on these indicators is examined. According to the findings a better understanding of the dynamic interplay between digital development and human well-being is achieved, offering valuable insights for policymakers and researchers.

**Keywords:** Digital Economy and Society Index (DESI), Human Development Index (HDI), European countries, Covid-19 pandemic, regression analysis

## **I. Introduction**

In the modern era, the pervasive influence of computer and information technology has significantly impacted various aspects of people's lives [1]. Computers have seamlessly integrated into work environments, entertainment, and everyday routines, shaping societies at different levels, even within the European Union. This prompts a compelling question: do citizens in countries with high digital competitiveness also experience a high quality of life, and conversely, does a high quality of life contribute to a Nation's advanced digital maturity?

Understanding the interplay between digital competitiveness and quality of life necessitates a comprehensive analysis. By utilizing two key indicators, namely the Human Development Index (HDI) and the Digital Economy and Society Index (DESI), we can explore these relationships and seek answers to these questions. The time period from 2018 to 2021 was selected based on the availability of data for both indexes.

Specifically, the Human Development Index (HDI) [2], [3], [4] was developed by Pakistani economist Mahbub ul Haq and was further used to measure a country's development by the Human Development Report Office of the United Nations Development Program (UNDP). It is a summary measure of achievements in three key dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions.

Minimum and maximum values (goalposts) are set in order to transform the indicators expressed in different units into indices between 0 and 1. The HDI dimensions are presented in the following Table 1.

Table 1 HDI Dimensions

Dimension	Indicator	Minimum	Maximum
Health	Life expectancy at birth (years)	20	85
Education	Expected years of schooling (years)	0	18
	Mean years of schooling (years)	0	15
Standard of living	GNI per capita (2017 PPP\$)	100	75,000

In this study, the estimated indicators are expressed using the following parameters:

- **LIFE\_EXP** for Life expectancy at birth
- **EXP\_SCH** for Expected years of schooling
- **MEAN\_SCH** for Mean years of schooling and
- **GNIPC** for GNI per capita

Moreover, a well-known index has been chosen as a means to compare digital competitiveness. The Digital Economy and Society Index (DESI) [5], [6], [7] is a composite index that has been developed to rank EU member states in terms of digital performance and to track their digital competitiveness evolution. The DESI has a three-level structure as depicted in the Table 2 [8] .

DESI encompasses the four main policy areas outlined in the 2030 Digital Compass at the dimension level.

- The Human capital dimension (**HUMAN**) assesses both internet user skills of citizens and advanced skills of specialists. At least basic skills, ICT specialists and Female ICT specialists measure targets of the Digital Decade Compass.
- Under Connectivity (**CONN**), both fixed and mobile broadband are analyzed with indicators measuring the supply and the demand side as wells as retail prices. Fixed VHCN and 5G coverage [9], [10] measure targets of the Digital Decade Compass.
- The Integration of digital technology dimension (**IDT**) is made up of 3 sub-dimensions: digital intensity, take-up of selected technologies by enterprises and e-commerce. SMEs with at least a basic level of digital intensity, take-up of Big data, Cloud and AI are targets of the Digital Decade Compass.
- The Digital public services dimension (**DPS**) describes the demand and supply of e-government as well as open data policies. The Digital public services for citizens and businesses indicators assess targets of the Digital Decade Compass.

Table 2 DESI structure

Dimension	Sub-dimension	Indicator
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
	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

Most of the data in the DESI is obtained directly from National authorities. Each of the four dimensions of the Digital Compass holds equal significance, as indicated by the equal weighting assigned to each dimension, presented in Table 3.

Table 3 Weights attributed to the DESI dimensions

Dimension	Weight
1. Human capital	25%
2. Connectivity	25%
3. Integration of digital technology	25%
4. Digital Public Services	25%

The research questions that this paper answers are as follows:

1. What is the relationship between HDI and DESI in European countries?
2. How has the Covid-19 pandemic affected these indicators?
3. In which groups are the European countries divided according to the values of these indicators during the period 2018-2021?

The remainder of this paper is structured as follows. Section 2 presents a literature review of the existing bibliography, while Section 3 describes the methodology. Section 4 presents the results and the related discussion. Finally, Section 5 summarizes the analysis of the findings.

## II. Literature Review

Several publications study the topics of digital development and well-being. Additionally, numerous studies examine each of these indicators, DESI and HDI, separately, identifying the parameters that influence their evolution. We will refer to some of these studies in chronological order.

Nagy [11] primarily focused on Hungary's digital economy and society, drawing comparisons with Ukraine. The study aimed to extract insights about future trends in digital development from this comparative analysis. The findings highlighted Hungary as an emerging digital nation, surpassing Ukraine in various crucial parameters related to the digital economy and society. However, despite the disparities, the author anticipates rapid progress in both Hungary and Ukraine's digital economy and society in the coming years. This prediction is based primarily on indications of the high growth rate of the internet and the increasing penetration of tablets and smartphones in both countries.

Moroz [12] assessed the level of digital economy development in Poland, comparing it with several selected European countries. The research methodology relied on statistical methods. To ensure a methodologically sound comparison, synthetic measures regarding the development of e-economy were used in the form of two indexes, namely NRI and DESI. Poland was compared to four European countries, and the results revealed a relatively unfavorable situation for Poland.

Following a methodological - oriented approach, Kotarba [13] focused on examining different metrics employed to assess digitalization activities. The study analyzed five primary levels, encompassing metrics related to the digital economy, society, industry, enterprises, and clients. The research relied on prominent public and commercial metrics commonly used to evaluate digital advancement. The study explored the similarities and differences among key performance indicators at each level, leading to conclusions about the scope and maturity of various measurement systems and suggesting potential improvement options.

Another study [14] focused on investigating the digital landscape in Romania. Burlacioiu et al. utilized the DESI index to examine the digital technology trends in Romania in comparison to other European Union countries. Their primary objective was to analyze a specific segment of the population, characterized as early adopters of new technologies, who played a crucial role in compensating for the country's digital skills gap. This study made a notable contribution by shedding light on the patterns and behaviors of this young user segment in Romania.

Česnauskė [15] conducted an evaluation of the digital advancement of the Baltic states in terms of developing a digital economy and society. The DESI index was utilized to assess the progress in this area. The author identified specific areas that demanded priority investments and actions for further development. The study provided insights into the digital performance of each Baltic country, allowing for comparisons among the Baltic states as well as with other European Union countries.

Smits and Permanyer [16] present the Subnational Human Development Database, which provides comprehensive data on human development at both national and subnational levels. The database covers the period from 1990 to 2017 and includes information on 1625 regions within 161 countries.

Sherman et. al [17] utilize machine learning and satellite imagery to develop global HDI estimates for second-level administrative units and a fine-grained grid. They create a downscaling technique based on satellite imagery that allows for training and predicting HDI values at different levels, using provincial administrative data as the basis. This approach expands the resolution of HDI estimates and provides valuable insights into local-level development.

It is noticed that while there is existing literature on the individual study of the DESI and the HDI indexes, there is a noticeable gap in the literature that specifically compares or correlates these two indexes and draws conclusions about their relationship. The present study aims to address this gap and contribute to the existing knowledge in the specific subject area.

### **III. Methodology**

In this study, data came from a variety of open sources. The following data were utilized:

- HDI and DESI values for all years from 2018 to 2021 for the 27 European countries [4], [5]
- DESI sub-indicator values at the first level, including Connectivity, Human Capital, Integration of Digital Technology, and Digital Public Services, for all years from 2018 to 2021 for the 27 European countries [5]
- HDI sub-indicator values, namely Life Expectancy Index, Expected Years of Schooling, Mean Years of Schooling, and GNI index, specifically for the year 2021 for the 27 European countries [4]

Subsequently, the following regressions are performed to examine the relationships among the parameters, as shown in Table 4:

Table 4 Regressions analyses

	Dependent variable	Independent variables	TIME PERIOD	COUNTRIES
1	HDI	DESI	2018-2021	27 EUROPEAN
2	HDI	HUMAN, CONN, IDT, DPS	2018-2021	27 EUROPEAN
3	DESI	LIFE_EXP, EXP_SCH, MEAN_SCH, GNIPC	2021	27 EUROPEAN
4	HDI	DESI, COVID	2018-2021	27 EUROPEAN
5	DESI	HDI, COVID	2018-2021	27 EUROPEAN

In the regression analyses, the natural logarithms (ln) of the parameters are employed to assess the proportional changes in variable values.

To account for the effects of the COVID-19 pandemic, a dummy variable named COVID is introduced, taking a value of 1 for the years 2020 and 2021 when the EU-27 countries faced the ramifications of the pandemic.

Furthermore, the countries are classified into four distinct categories based on the mean DESI and HDI values in the results section.

#### IV. Results and discussion

##### I. Regression analysis results

The results of the first regression findings (Table 5) indicate that the DESI index is significant. For every 1% increase in the DESI index, there is a corresponding 0.125% increase in the HDI.

Table 5 Dependent Variable: LNHDI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.574798	0.045792	-12.55225	0.0000
LNDESI	0.125367	0.012326	10.17110	0.0000
R-squared	0.493916	Mean dependent var	-0.109993	
Adjusted R-squared	0.489141	S.D. dependent var	0.042590	
S.E. of regression	0.030441	Akaike info criterion	-4.127692	
Sum squared resid	0.098227	Schwarz criterion	-4.078022	
Log likelihood	224.8953	Hannan-Quinn criter.	-4.107553	
F-statistic	103.4513	Durbin-Watson stat	1.688940	
Prob(F-statistic)	0.000000			

The results of the second regression (Table 6) reveal that the sub-indices CONN and DPS are not significant. Thus, the regression is repeated (Table 7) with only the independent variables HUMAN and IDT, which are found to be significant. The outcome demonstrates that for every 1% increase in the HUMAN index, there is a 0.068% increase in the HDI, and for every 1% increase in the IDT index, there is a 0.065% increase in the HDI.

Table 6 Dependent Variable: LNHDI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.442897	0.043623	-10.15287	0.0000
LNHUMAN	0.073561	0.021334	3.448063	0.0008
LNCONN	-0.017465	0.009209	-1.896448	0.0607
LNIDT	0.069740	0.011730	5.945630	0.0000
LNDDS	-0.003189	0.009882	-0.322667	0.7476
R-squared	0.697739	Mean dependent var	-0.109993	
Adjusted R-squared	0.686001	S.D. dependent var	0.042590	
S.E. of regression	0.023866	Akaike info criterion	-4.587548	
Sum squared resid	0.058666	Schwarz criterion	-4.463376	
Log likelihood	252.7276	Hannan-Quinn criter.	-4.537201	
F-statistic	59.44130	Durbin-Watson stat	1.778889	
Prob(F-statistic)	0.000000			

Table 7 Dependent Variable: LNHDI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.463756	0.042861	-10.81992	0.0000
LNHUMAN	0.067769	0.019617	3.454563	0.0008
LNIDT	0.064600	0.011393	5.670346	0.0000
R-squared	0.685368	Mean dependent var	-0.109993	
Adjusted R-squared	0.679375	S.D. dependent var	0.042590	
S.E. of regression	0.024116	Akaike info criterion	-4.584474	
Sum squared resid	0.061068	Schwarz criterion	-4.509970	
Log likelihood	250.5616	Hannan-Quinn criter.	-4.554265	
F-statistic	114.3618	Durbin-Watson stat	1.595322	
Prob(F-statistic)	0.000000			

The results of the third regression demonstrate that the only significant parameter is MEAN\_SCH (Tables 8, 9) and specifically, for every 1% increase in the MEAN\_SCH index, there is a 0.406% increase in the DESI.



Table 8 Dependent Variable: LNDESI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.106439	0.025265	-4.212912	0.0004
LNLFIE	0.001894	0.006973	0.271650	0.7884
LNEXPSCH	-0.000370	0.002127	-0.174103	0.8634
LNMEANSCH	0.406528	0.002548	159.5760	0.0000
LNGNI	-0.000137	0.000938	-0.145654	0.8855
R-squared	0.999426	Mean dependent var		0.918195
Adjusted R-squared	0.999322	S.D. dependent var		0.034792
S.E. of regression	0.000906	Akaike info criterion		-11.00974
Sum squared resid	1.81E-05	Schwarz criterion		-10.76977
Log likelihood	153.6315	Hannan-Quinn criter.		-10.93838
F-statistic	9582.274	Durbin-Watson stat		1.766444
Prob(F-statistic)	0.000000			

Table 9 Dependent Variable: LNDESI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.099838	0.004889	-20.41914	0.0000
LNMEANSCH	0.406205	0.001950	208.3279	0.0000
R-squared	0.999424	Mean dependent var		0.918195
Adjusted R-squared	0.999401	S.D. dependent var		0.034792
S.E. of regression	0.000851	Akaike info criterion		-11.22839
Sum squared resid	1.81E-05	Schwarz criterion		-11.13240
Log likelihood	153.5833	Hannan-Quinn criter.		-11.19985
F-statistic	43400.51	Durbin-Watson stat		1.695214
Prob(F-statistic)	0.000000			

The results of the fourth and fifth regressions (Tables 10, 11) highlight the impact of the pandemic on digital development and the human development index. Specifically, the fourth regression reveals a negative effect of the pandemic on the HDI, with a percentage decrease of 2.48%. On the other hand, the fifth regression shows a positive impact of the pandemic on the DESI, with a percentage increase of 18.36%. where the lockdown's pressing necessities generated by the epidemic's digital impact. The percentages are calculated using the formula (1), as described in [18].

$$100 \times (e^{covid\_coef} - 1) \quad (1)$$

Table 10 Dependent Variable: LNHDI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.627787	0.044009	-14.26494	0.0000
LNDESI	0.143050	0.012084	11.83787	0.0000
COVID	-0.025140	0.005744	-4.377146	0.0000
R-squared	0.572011	Mean dependent var		-0.109993
Adjusted R-squared	0.563859	S.D. dependent var		0.042590
S.E. of regression	0.028127	Akaike info criterion		-4.276779
Sum squared resid	0.083069	Schwarz criterion		-4.202275
Log likelihood	233.9461	Hannan-Quinn criter.		-4.246570
F-statistic	70.16674	Durbin-Watson stat		1.960396
Prob(F-statistic)	0.000000			

Table 11 Dependent Variable: LNDESI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.062842	0.041928	96.89972	0.0000
LNHDI	3.996259	0.337583	11.83787	0.0000
COVID	0.168526	0.028622	5.887960	0.0000
R-squared	0.619535	Mean dependent var		3.707547
Adjusted R-squared	0.612288	S.D. dependent var		0.238756
S.E. of regression	0.148665	Akaike info criterion		-0.946859
Sum squared resid	2.320632	Schwarz criterion		-0.872355
Log likelihood	54.13038	Hannan-Quinn criter.		-0.916650
F-statistic	85.48895	Durbin-Watson stat		1.727350
Prob(F-statistic)	0.000000			

## II. European countries classification based on HDI-DESI values

Figure 1 presents a scatterplot illustrating the relationship between the HDI and the DESI for the 27 European countries at the beginning of our study period in 2018. The Y-axis represents HDI, while the X-axis represents DESI. To ensure uniformity in the scale, the HDI values on the scatterplot have been multiplied by a factor of 100. The red lines indicate the mean values of the respective indicators, with DESI having a mean of 37.24 and HDI having a mean of 0.8955.

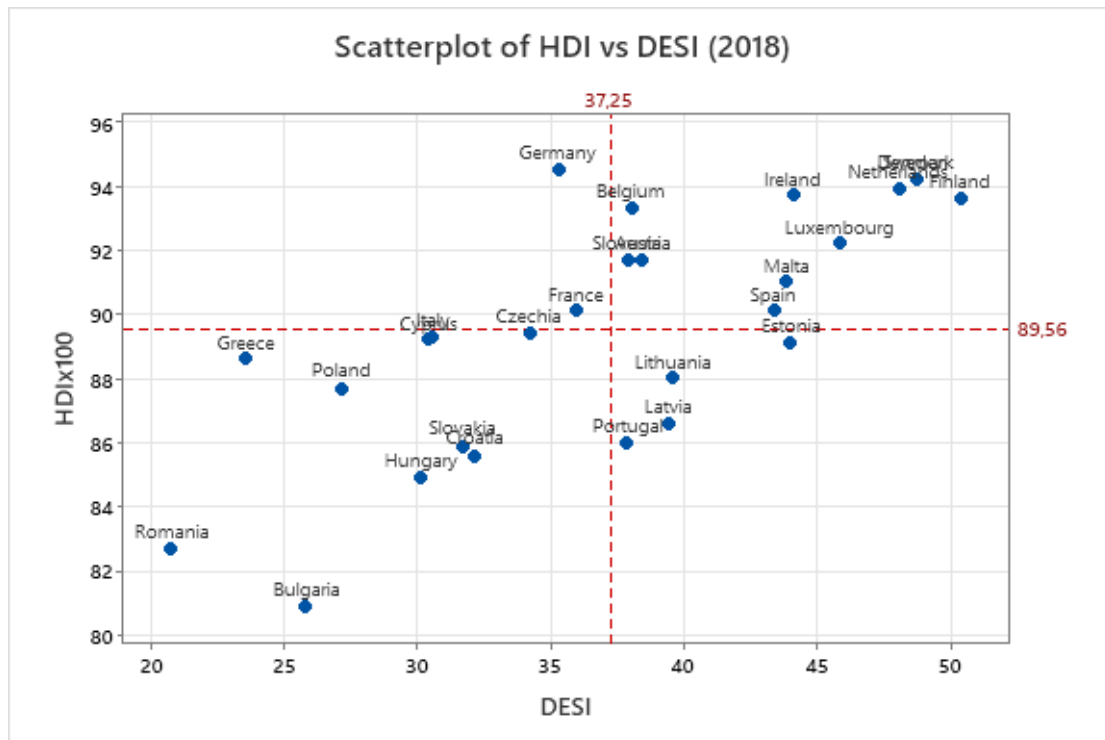


Figure 1 HDI vs DESI in 2018

The countries are divided into four groups based on their HDI and DESI values:

**Group A: Countries Above the Mean:** This group consists of countries that had both HDI and DESI values above the mean in 2018. These countries include Austria, Belgium, Denmark, Finland, Ireland, Luxembourg, Malta, Netherlands, Slovenia, Spain, Sweden.

**Group B: High HDI, but Below the Mean DESI:** France and Germany were classified in this group, indicating that they had relatively high HDI scores compared to the mean, but their DESI values fell below the mean in 2018.

**Group C: High DESI, but Below the Mean HDI:** In 2018, Estonia, Latvia, Lithuania and Portugal fell into this group. These countries exhibited higher DESI scores compared to the mean, while their HDI values were below the mean.

**Group D: Countries Below the Mean:** This category comprises countries that had both HDI and DESI values below the respective means in 2018. The countries falling into this group are Bulgaria, Croatia, Cyprus, Czechia, Greece, Hungary, Italy, Poland, Romania and Slovakia.

Continuing our analysis, we examined the same set of countries in subsequent years of the study period to observe their progress or decline. Figures 2, 3, and 4 display the corresponding scatterplots, illustrating the relationship between HDI and DESI for the years 2019, 2020, and 2021.

We observed that most countries can be categorized into two groups: Group A and Group D, which simultaneously have above-mean or below-mean HDI and DESI values. This finding supports the correlation between these two indicators.

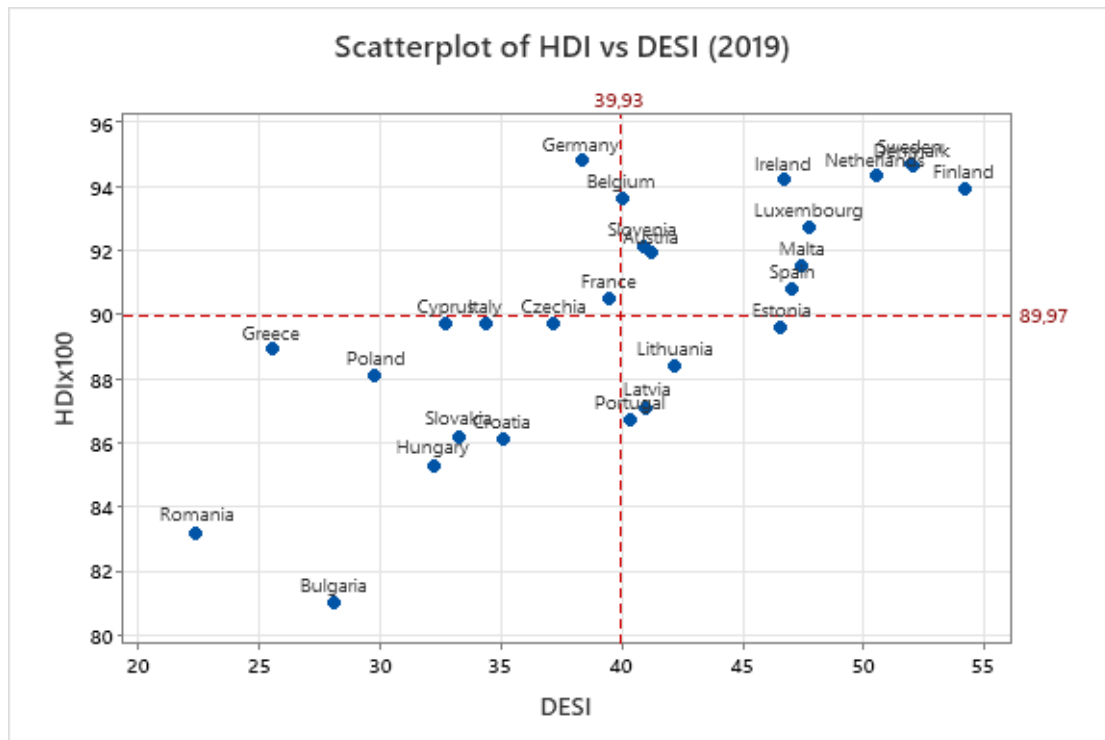


Figure 2 HDI vs DESI in 2019

Germany stands out as an exception, with a notably high HDI value but a DESI value below the mean.

Denmark, Sweden, Netherlands, and Finland consistently demonstrate positive performance, maintaining high values in both indices throughout the studied years.

On the other hand, Romania and Bulgaria consistently exhibit low values in both indicators throughout the entire study period.

Cyprus, Italy, and the Czech Republic have HDI values close to the average, but they lag behind in terms of DESI. Greece follows a similar trend with a slight deviation in terms of HDI.

Several countries undergo a change in category during the study period:

Latvia, Lithuania, and Portugal transition from Group C to Group D in 2021, experiencing a decline in their DESI values, which fell below the mean in 2021, contrasting with their previous positions.

Belgium also shows a deterioration, with a DESI value slightly below the mean in 2021 compared to its position in 2018.

Finally, Slovenia's DESI value drops below average in 2020 but rebounds in 2021.

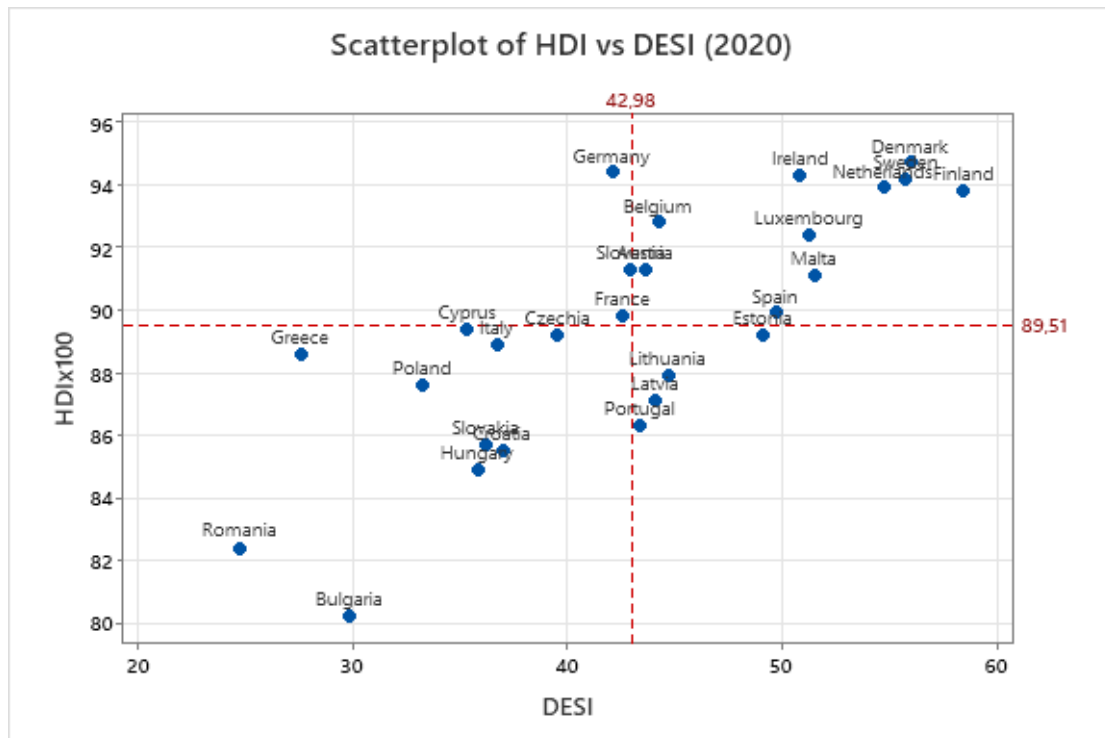


Figure 3 HDI vs DESI in 2020

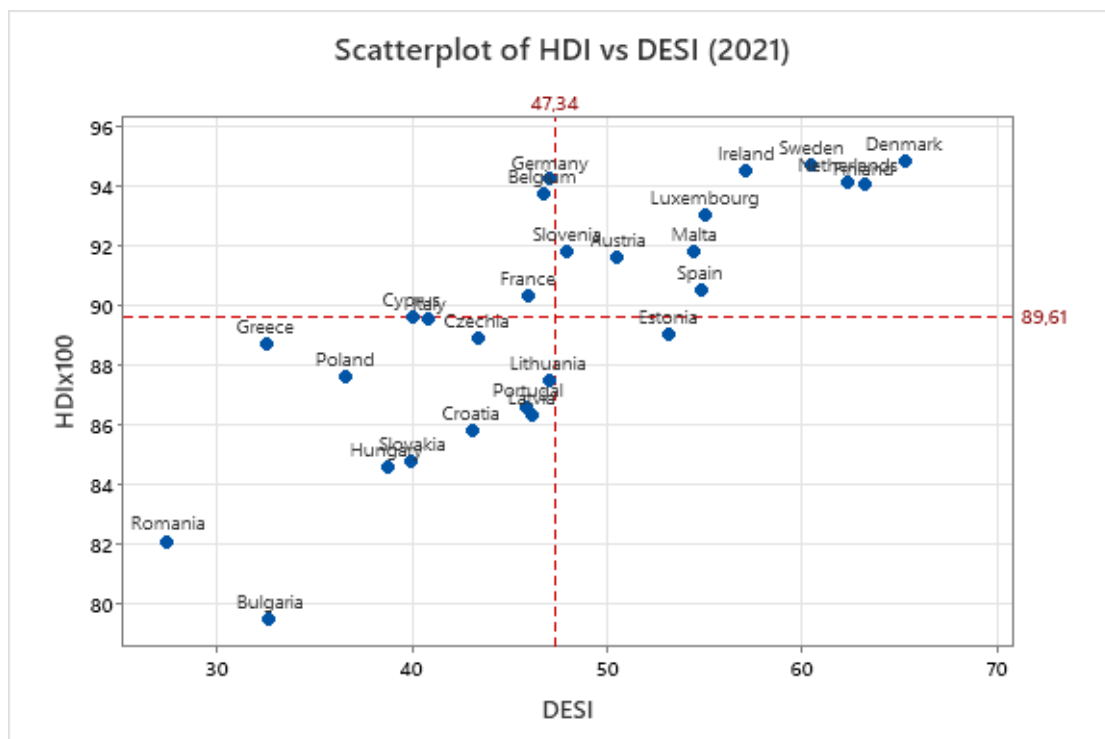


Figure 4 HDI vs DESI in 2021

## **V. Conclusions**

Based on the survey conducted on European countries during the period 2018-2021, the following key findings can be drawn:

1. There is a significant and positive relationship between the two indicators DESI and HDI. This implies that as the adoption and utilization of digital technologies increase, the quality of life also improves, and vice versa.
2. Among the sub-indicators, it is observed that human capital and integration of digital technology (IDT) have a notable impact on HDI. This underscores the importance of providing training and specialized skills in the field of information and communication technology (ICT), as well as the significance of private sector investments in digital transformation initiatives.
3. The sub-indicator of HDI, mean years of schooling, has been observed to have a significant effect on the DESI index. This reaffirms the importance of enhancing the education level within countries to foster digital development.
4. The period of the pandemic had a significant and positive effect on the integration of digital technologies. However, it had a negative impact on people's quality of life index. This suggests that while digitalization has progressed during the pandemic and positively affect the quality of life index, the overall well-being of individuals has been adversely affected.
5. Classification of countries based on HDI and DESI indicators reveals the existence of four distinct categories. It is worth noting that a significant number of countries fall into either one of two categories: those that are consistently above mean in both indicators and those that are consistently below mean. This finding reinforces the notion that there is a strong connection between these indicators, indicating that they mutually influence each other.

These conclusions shed light on the importance of digital development in shaping the quality of life and emphasize the need for focused efforts in enhancing human capital, the education level and digital transformation with a particular emphasis on the private sector. Policymakers and stakeholders can leverage these findings to develop targeted strategies that promote both digital competitiveness and overall well-being for individuals and societies.

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