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The Link between Digitization and the Sustainable Development in European Union Countries

Liliana Ionescu-Feleagă *, Bogdan-Ștefan Ionescu and Oana Cristina Stoica

Faculty of Accounting and Management Information Systems, The Bucharest University of Economic Studies, 010374 Bucharest, Romania

* Correspondence: liliana.feleaga@cig.ase.ro

Abstract: Digitalization and sustainable development represent two highly topical subjects, each of them being primarily debated in the literature. Although it is evident that digitalization brings new opportunities and challenges for the management of organizations and for meeting their sustainable strategies, there are relatively few studies analyzing the relationship between the two. Therefore, the objective of the present study is to analyze the relationship between digitalization and sustainable development in the European Union (EU) countries, between 2019 and 2021, before and during the COVID-19 pandemic. On this matter, the link between Digital Economy and Society Index (DESI), on one side, and Sustainable Development Goal Index (SDG Index) and Spillover Index (SS Index), on the other side, has been analyzed using correlations. While DESI refers to the monitoring of digital advancement of the EU member states, SDG Index and SS Index are based on many indicators and give a multidimensional perspective regarding sustainable development. Results show a positive and significant relationship between DESI and SDG Index, and the effect gradually decreases during the analyzed period. Regarding the relationship between DESI and SS Index, the correlation was negative, but significant in 2020 and 2019 only. At the level of each geographical region, the relationship between DESI and SDG Index was positive, with a larger effect in the Northern and Western region and the Southern region compared to the Central and Eastern region, but this effect was not statistically significant. In addition, the relationship between DESI and SS Index was negative and significant at the level of the Central and Eastern region and the Southern region but positive and not statistically significant at the level of the Northern and Western region. In addition to previous papers on this field, this study adds the analysis between digitalization and the Spillover Index. In addition, while previous studies seek to identify the relationship between digitalization and sustainability at a single country level or region, this study presents the correlation analysis at the EU level and compares the results for each EU region. Following the results, our study gives arguments for reshaping the concept of sustainable development given that digitalization is becoming an essential business component.

Keywords: digitalization; sustainable development; Digital Economy and Society Index (DESI); Spillover Index; EU countries

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1. Introduction

Digitalization is a widely used expression, but it does not have a unanimously accepted definition, even though this concept has been described in many ways over time [1]. We perceive digitalization as a process of transformation of society that uses ubiquitous digital technologies to connect social spaces in different areas of the world and collect/analyze/manipulate digital data in real time.

Digitalization is considered the fourth major innovation cycle in history. Although the benefits of this complex and dynamic process are apparent, they must be properly measured. Thus, indices that measure the progress generated by the adoption of technology in a particular field and global indices have been created (Digital Density Index (DDI),

Digital Economy and Society Index (DESI), etc.). Unlike other global indices, DESI uses quantitative indicators and a system of different component element weights, giving an objective assessment of the digital competition of different countries.

Technology is constantly evolving, but sometimes its costs are high. For this reason, measuring the impact of technological changes on sustainable development is important. Over time, different indices have been developed to measure aspects related to the sustainable development of the nations (Global Innovation Index, Global Competitiveness Index, The Good Country Index, Sustainable Society Index, Sustainable Development Goal Index, Spillover Index, etc.). However, not all of these indices are calculated annually.

Previous studies have directed their attention toward the relationship between digitalization and sustainability. For example, ref. [2] analyze this relationship in four countries of the Visegrad Group (Hungary, Czech Republic, Poland and Slovakia) by using DESI as an indicator of digitalization and SDG Index as an indicator of sustainability and correlation analysis. The results show a strong relationship between sustainability and digitalization. In addition, ref. [3]—measure this relationship in EU countries using panel regression modeling. Their results show that each component of DESI has a different influence on SDG Index, but overall, the impact is negative. At the level of EU countries, Ref. [4] investigates the effect of digital entrepreneurship on the achievement of SDGs. The results of her correlation and regression analysis show a positive influence and a difference in this matter between EU countries.

As it has been pointed out, the literature regarding the relationship between digitalization and sustainable development at the level of EU countries gives mixed results. In addition, to the best of our knowledge, so far, there have been no previous studies that discuss the relationship between digitalization and Spillover Index. This index is important because, depending on its impact (positive or negative), countries can meet difficulties in achieving their Sustainable Development Goals.

Our study aims to analyze the relationship between digitalization and sustainable development in as many countries as possible between 2019 and 2021. However, unlike sustainable development indices, DESI values are only available for EU member states. Therefore, we analyzed the relationship between DESI, on one side, and SDG Index and SS Index, on the other side, for all these countries. While empirical research regarding digitalization has grown enormously in the last decade, studies about the relationship between digitalization and sustainable development remain limited.

This paper contributes to the literature on digitalization and sustainable development in the following ways: First, this study empirically investigates the relationship between digitalization and sustainable development using DESI as an indicator of digitalization, while other studies use other substitutes [5] Second, whilst our study conducts an analysis of this relationship at the level of European Union countries, other studies conducted similar analysis at the level of companies [6] or at the level of Central European countries [2] without taking into consideration the Spillover Index. Overall, our research is particularly important because the relationship between digitalization and sustainable development determines how different actors, including managers, professionals and policymakers, act in response to those imperatives.

The remainder of the paper is structured as follows: Section 2 presents the relevant literature review, and Section 3 presents the study's methodology. The research results are presented analytically in Section 4 and discussed in Section 5. Section 6 is reserved for the main conclusions, implications and directions for future research.

2. Literature Review

Over time, many definitions have been given to digital transformation, but a unanimous definition for this concept is not yet accepted. In this respect [1], found about 23 definitions of digital transformation, but from the author's point of view, most of the terms included in those definitions are unclear, or conflation exists between the concept

and its impacts. However, two main key concepts of digitalization remain important: its benefits and challenges.

In the last decades, technological advances have grown enormously, modeling society and bringing many challenges for nations, organizations and individuals. The present era of digital transformation implies the application of digital capacity to assets, processes and products having as an objective an increase in efficiency, proper risk management and identification of new earning opportunities [7] Moreover, digitalization creates new systems of organizations that can be more effective and efficient and improve economic and social interactions [8].

By targeting quicker economic growth, countries globally have exploited their reserves of natural resources at alarming levels. For this reason, sustainable development represents a priority concern for researchers, authorities and society in general. Sustainable development refers to meeting the current needs without compromising the ability of future generations to meet their own needs [9]. This can be achieved through the synergistic effect of three dimensions: economic growth, social fairness and environmental protection. In addition, culture can be taken into consideration, as a fourth dimension of sustainable development [10]. However, ref. [11] argues that technical, legal and political dimensions should also be included as sustainable development dimensions. In the last few years, the original framework for defining the concept of sustainable development has been extended. Moreover, the member states of the United Nations have engaged in respecting the 17 Sustainable Development Goals, which offer specific objectives and deadlines for improving sustainable development.

Digital transformation is nowadays a crucial factor in achieving faster economic growth [12] and is considered one of the most important drivers for sustainability transformation [13]. The perspective of the United Nations regarding Sustainable Development Goals gives different opportunities for digitalization to help build a sustainable society for the future [14]. Thus, it could be stated that digitalization and sustainable development are priority issues of countries worldwide. However, it is not clear yet whether there is a positive relationship between the two concepts. In this respect, researchers have started to investigate the impact of digitalization on sustainability and the relationship between the two concepts in different countries.

Some researchers have analyzed the impact of digitalization through the circular economy, with this being considered an essential component of sustainable development [15,16]. Other researchers have pursued digitalization to prepare the business for sustainable development, by ensuring financial stability. In other words, they considered digitalization and the companies' financial stability, given that greater financial stability ensures a higher sustainable development [17]. In this respect, ref. [18] has proved that all the financial stability dimensions significantly influence economic growth, poverty and income inequality. In addition, financial stability enables the overcoming of financial crises in business, which contributes to constant sustainable development [19].

Ref. [20] found statistical evidence of the positive effect that the maturity of the digital business model has on the business sustainable success in the case of small and medium companies that operate in the tourism sector. Ref. [21] have identified how digital technologies could be applied more broadly to agri-food systems to achieve the sustainability principles outlined in policy strategies. Moreover, industrial digitization is seen as a mechanism that can help achieve Sustainable Development Goals by making more efficient use of resources and reducing CO_2 emissions. In this respect, ref. [22] analyzed the way business models from the automotive industry are affected by the digitalization trend and by the concern for sustainability pillars, while [23] compared the automotive sector with other major sectors. Ref. [24] studied the impact of digitalization on cost performance improvement, quality, productivity, programming and personalization of products and services. In the same direction, ref. [25] identified the potential of industrial digitalization for promoting sustainable innovations.

Other studies have sought to analyze the impact of digitalization on sustainable development at national or regional levels. For example, ref. [26] have analyzed the contribution of digital technology in achieving the SDGs in Italy. The results show a positive relationship between digitalization and SDGs. Furthermore, ref. [27] examined the relationship between digitalization and sustainable development in Hungary by highlighting the performance of this country in comparison to other EU countries. To see whether and to what extent digital transformation affects sustainable development and its components, ref. [28] compared DESI with different measures related to sustainable development components in the case of EU countries. The authors of this study observed that economic sustainability and the social aspect were positively influenced by DESI, while the impact on the environment was negative. Ref. [3] investigated the impact of digitalization on EU countries' SDG Index by using panel regression models. Their results show that the use of internet services, followed by connectivity and human capital, has a significant influence on the promotion of indicators for increasing sustainable development. Instead, the integration of digital technology and digital public services has been found to have little impact on the promotion of indicators for increasing sustainable development. A comprehensive review-based association between digitalization and sustainable development is provided by [29].

Given the above arguments, and the mixed results of the literature regarding the relationship between digitalization and sustainable development, the following three hypotheses are stated:

H1: *There is a positive relationship between DESI and SDG Index and a negative relationship between DESI and SS Index.*

H2: *There is a positive relationship between DESI variables and SDG Index and a negative relationship between DESI variables and SS Index.*

H3: *There is a positive relationship between DESI and SDG Index and a negative relationship between DESI and SS Index for each geographical group in the EU.*

3. Materials and Methods

As previously discussed, the objective of the present paper is to analyze the relationship between digitalization and sustainable development in EU countries.

Digital Economy and Society Index (DESI), which is annually published by the European Commission for measuring the digital competitivity of the EU member states, was chosen as a digitalization dimension. This index was calculated for the first time in 2014 and it was adjusted in 2021 to be in accordance with Digital Decade Compass, a digital political program, which presents the digital ambitions and identifies the main objectives for 2030 in four cardinal points: competencies, infrastructure, digital transformation of companies and public services. As a result, the 33 indicators composing DESI are structured on their turn on four dimensions presented in Table 1: human capital, connectivity, integration of digital technology and digital public services. Unlike other global indices, DESI does not use a system of equal weighting of different elements [28]. In addition, the indicators composing DESI are quantitative and give objective assessments regarding the digital performance of the UE member states, allowing the monitoring of their progress.

Values published for a certain year for DESI are based on the previous year's data. In the present study, we used the data published for the period 2019–2021, reflecting the status for 2018–2020. Thus, the study captures the state of the digital economy and society before the COVID-19 pandemic and in the first year of the pandemic.

For the sustainable development dimension, we chose two global indices: Sustainable Development Goal Index (SDG Index) and Spillover Index (SS Index). Unlike other indices, these two have been explicitly defined to measure sustainable development; they are published annually, and although their methodology is still developing, they are widely accepted.

Table 1. DESI description.

Dimensions of DESI	Sub-Dimensions and Numbers of Individual Indicators of DESI
Human capital (HC)	the internet user skills of citizens and the advanced skills of specialists (2 sub-dimensions and 7 individual indicators)
Connectivity (con)	fixed broadband and mobile broadband connection coverage and price (4 sub-dimensions and 10 individual indicators)
Integration of digital technology (IDT)	digital intensity, the adoption of selected technologies by businesses and e-commerce (3 sub-dimensions and 11 individual indicators)
Digital public services (DPS)	the demand and supply of e-government, as well as open data policies (1 sub-dimension and 5 individual indicators).

Source: authors, based on DESI data [30].

SDG Index is published by The Sustainable Development Solutions Network and the Bertelsmann Stiftung, which evaluates a country's performance regarding Sustainable Development Objectives (Sustainable Development Goals) adopted in 2015 by the United Nations [31]. Each of the 17 objectives addresses environmental, social and economic issues and has many indicators used to measure progress towards that objective. In addition, the objectives are related to each other and influence each other [32]. First, the SDG Index included 77 indicators, but currently, it has reached 99 indicators. Goal scores and the global score of SDG Index are interpreted as achievement percentages. In other words, the difference between 100 and a country's score represents, at a percentual level, the distance remaining for realizing the sustainable development objectives. Although there are different criticisms regarding the SDG Index, especially in relation to the qualitative nature of the indicators, unavailability of some data and ignoring links between sectors, societal actors and different countries, it represents a global index based on many indicators and it gives a multidimensional perspective to sustainable development.

SS Index measures the positive and negative cross-border impact generated by a country on the capacity of other countries to reach their sustainable development objectives. It consists of 12 indicators, and, for its structure, three dimensions are taken into consideration: environmental and social impacts embodied in trade, economy and finance, and security. The score of this index is calculated as an average of all indicators' scores [33]. A larger score means that a country causes more positive spillover effects and fewer negative ones. This index is of interest because, with the adoption of the European Green Deal in 2019, Europe announced a commitment to climate neutrality by mid-century. That commitment is extremely courageous given that European countries are generating considerable adverse effects outside the region [33].

The main characteristics of the analyzed variables are presented in Table 2 below.

The descriptive statistics of the DESI, SDG Index and SS Index are presented in Table 2, and the details on countries are given in Appendix A. The greatest value of the DESI indicator is exhibited by Finland in the first two years of the analysis, while in the last year, Denmark is situated at the top of the list. In 2019 and 2020, Bulgaria is situated at the bottom of the list regarding the DESI indicator, while in 2021, the smallest value belongs to Romania. The human capital index presents the highest value in Finland in each year of the analysis and the lowest value in Bulgaria in 2019 and 2021 and Italy in 2021. With respect to the connectivity component, the highest value is achieved by Sweden in the first two years and by Denmark in the last year, while the lowest value is taken by Greece every year. The largest value of the integration of the digital technology index goes to Ireland in 2019 and 2020 and to Finland in 2021, whilst the smallest value goes to Bulgaria each year. Regarding the digital public services index, Estonia takes the highest value every year, while Romania takes the lowest value every year. SDG Index has the largest value in Finland in all three years, while SS Index has the lowest value in Luxembourg in 2019 and Bulgaria in 2020 and 2021. With respect to SS Index value, Romania was situated at the top of the list in 2019 and 2020, and Bulgaria was situated at the top of the list in 2021; Luxembourg is situated at the bottom of the list in 2019, 2020 and 2021.

Table 2. Descriptive statistics of variables analyzed for the period 2019–2021.

Variable	Min	Max	Mean	St. Dev.
Year		2019		
DESI	33.80	68.10	50.13	9.49
HC	28.50	77.50	47.78	12.52
con	29.50	60.10	46.83	7.78
IDT	16.90	69.10	40.84	13.97
DPS	45.00	85.00	67.52	12.26
SDG Index	0.74	0.86	0.80	0.03
SS Index	0.42	0.94	0.70	0.12
Year		2020		
DESI	36.40	72.30	53.48	9.84
HC	32.50	78.40	49.30	12.73
con	33.40	64.40	51.65	8.26
IDT	17.90	74.30	43.30	15.25
DPS	48.40	89.30	72.17	11.76
SDG Index	0.74	0.86	0.80	0.03
SS Index	0.34	0.92	0.66	0.12
Year		2021		
DESI	32.90	70.10	51.15	9.96
HC	32.70	71.10	48.47	9.67
con	37.70	74.00	51.14	8.75
IDT	20.50	59.50	39.01	10.82
DPS	21.50	91.80	64.47	16.33
SDG Index	0.74	0.86	0.80	0.03
SS Index	0.31	0.87	0.67	0.12

Source: authors, based on DESI, SDG Index and SS Index.

Study hypotheses were tested using Pearson correlation analysis in SPSS, for each of the three years. This analysis helps us understand the evolution of the relationship between the DESI and the two sustainable development indices, before and during the COVID-19 pandemic, within the European Union countries. While previous studies used correlation analysis to identify the relationship between DESI and SDG Index [2] they did not take into consideration the impact of the SS Index, which can have a real influence on the relationship between the two, as it can positively or negatively influence countries' sustainable development and their analysis has been performed for a small number of countries. In addition, unlike regression analysis used in previous studies [3], this study used correlation analysis to show the direction of the relationship and its strength.

4. Results

Table 3 reveals the correlation between the DESI, SDG Index and SS Index for the period 2019–2021. The results show that, in all three years, there is a positive and significant correlation between the DESI and the SDG Index with a medium effect. Therefore, the first hypothesis is supported for this case. These results are in line with the results of other previous papers that analyzed this relationship at different levels [4,26,28] and differ from the results obtained by [3] which show that DESI has a negative impact on SDG Index. With respect to the relationship between the DESI and the SS Index, the correlation shows to be negative with a small effect but not significant in 2019. In addition, a negative and significant correlation with a medium effect has been found in 2020 and 2021. Thus, our second hypothesis needs to be rejected in 2019, but the results provide enough statistical evidence for 2020 and 2021 when correlating the DESI with the SS Index.

Table 3. Correlations between DESI, SDG Index and SS Index.

Variable	DESI	DESI HC	DESI con	DESI IDT	DESI DPS	SDG Index	SS Index
Year				2019			
DESI	1						
DESI HC	0.923 **	1					
DESI con	0.653 **	0.513 **	1				
DESI IDT	0.841 **	0.733 **	0.265	1			
DESI DPS	0.806 **	0.606 **	0.583 **	0.613 **	1		
SDG Index	0.686 **	0.698 **	0.418 *	0.586 **	0.462 *	1	
SS Index	−0.378	−0.326	−0.067	−0.446 *	−0.322	0.020	1
Year				2020			
DESI	1						
DESI HC	0.917 **	1					
DESI con	0.539 **	0.422 *	1				
DESI IDT	0.861 **	0.759 **	0.203	1			
DESI DPS	0.770 **	0.599 **	0.401 *	0.576 **	1		
SDG Index	0.678 **	0.651 **	0.252	0.622 **	0.463 *	1	
SS Index	−0.533 **	−0.465 *	−0.313	−0.470 *	−0.511 **	−0.106	1
Year				2021			
DESI	1						
DESI HC	0.881 **	1					
DESI con	0.708 **	0.626 **	1				
DESI IDT	0.841 **	0.840 **	0.544 **	1			
DESI DPS	0.908 **	0.734 **	0.467 *	0.702 **	1		
SDG Index	0.632 **	0.711 **	0.437 *	0.647 **	0.472 *	1	
SS Index	−0.608 **	−0.544 **	−0.558 **	−0.487 **	−0.571 **	−0.117	1

Source: authors, based on DESI, SDG Index and SS Index. Notes: * $p < 0.05$; ** $p < 0.01$.

For testing the second hypothesis we have correlated DESI components with SDG and SS indices for the three years of the analysis. As Table 3 shows, the results are statistically significant with a large effect when correlating the human capital component (DESI HC) and integration of the digital technology component (DESI IDT) with the SDG Index for all three years. The result regarding the relationship between the connectivity component and SDG is in line with the findings of [3], which show that connectivity has a significant influence on the promotion of indicators for increasing sustainable development. Additionally, a medium effect and a significant and positive correlation exist every year for the relationship between the digital public services component (DESI DPS) and the SDG Index but only in 2019 and 2021 for the relationship between the connectivity component (DESI con) and the SDG Index. The result regarding DESI DPS is similar to the result obtained by [3], which shows that digital public services have been found to have little impact on the promotion of indicators for increasing sustainable development. Regarding the relationship between the DESI components and the SS Index, results reveal that in 2019 the only significant correlation with a small effect is the one between the integration of the digital technology component (DESI IDT) and the SS Index. In 2020, SS Index is negatively and significantly correlated with a small effect with DESI HC and DESI IDT and with a medium effect with the DESI DPS component, while in 2021, SS Index is negatively and significantly correlated with most of the DESI components except the DESI IDT component where the effect is small. Given that most of the DESI components are positively correlated with the SDG Index and SS Index in each year of the analysis, we can conclude that the second hypothesis is accepted.

The last hypothesis aims to measure the correlation between the DESI, SDG Index and SS Index at the level of each EU region. Before correlating the three indices, an analysis of differences between the EU regions for each index was needed. The assumption verifications for ANOVA have been tested as follows: First, we assessed the distribution normality with skewness and kurtosis statistics in SPSS and checked the statistic values. Normality was assumed for all the variables except for Connectivity in 2019 (K statistic = 3.48), SDG in 2020 (K statistic = 2.03) and SDG in 2021 (K statistic = 2.99). Second, we assessed the homogeneity of variances, and the *p*-value was higher than 0.05. Therefore, the homogeneity of variances was not assumed.

As Table 4 shows, in 2019, there is a positive and significant difference between the three regions not only at the level of DESI and at the level of two of its components (DESI HC and DESI IDT), but also at the level of SDG Index and SS Index. In 2020, only the difference regarding DESI con showed to not be statistically significant, unlike the other indicators. In 2021, as shown in the last column of Table 4, the difference at the level of each indicator is statistically significant. As shown by the underlined results, the correlation analysis has been tested.

Table 4. Group test on regions at the EU level.

Variables	Central and Eastern (n = 10)		Western and Northern (n = 8)		Southern (n = 9)		One-Way ANOVA
	M	SD	M	SD	M	SD	F
Year				2019			
DESI	48.42	5.32	60.06	7.15	43.19	7.70	7.82 **
DESI HC	46.93	8.00	60.05	10.44	37.82	8.87	12.83 **
DESI con	46.83	5.44	51.48	7.58	42.71	8.51	3.13
DESI IDT	34.94	8.30	56.31	11.14	33.63	10.34	13.99 **
DESI DPS	66.70	12.57	75.03	7.24	61.76	13.05	2.89
SDG Index	0.80	0.02	0.82	0.04	0.77	0.02	8.81 **
SS Index	0.75	0.07	0.60	0.11	0.73	0.14	4.08 *
Year				2020			
DESI	51.58	5.11	63.68	7.07	46.52	8.93	12.89 **
DESI HC	47.64	9.85	61.00	10.38	40.73	10.01	8.81 **
DESI con	52.29	5.94	55.06	7.65	47.91	10.15	1.73
DESI IDT	37.35	8.92	60.04	12.82	35.02	10.99	13.61 **
DESI DPS	71.70	11.80	79.64	5.60	66.06	12.92	3.36 *
SDG Index	0.80	0.02	0.82	0.38	0.77	0.02	8.17 **
SS Index	0.69	0.80	0.56	0.12	0.71	0.12	4.84 **
Year				2021			
DESI	50.73	7.15	61.50	6.83	45.42	9.12	9.32 **
DESI HC	47.06	6.67	58.36	7.74	41.26	6.52	13.15 **
DESI con	49.11	5.00	58.31	9.46	47.02	8.16	5.43 **
DESI IDT	34.6	7.53	49.55	8.77	34.54	9.55	8.52 **
DESI DPS	68.13	13.96	79.69	7.18	58.87	19.29	4.33 *
SDG Index	0.80	0.02	0.82	0.04	0.77	0.02	8.37 **
SS Index	0.70	0.08	0.57	0.12	0.73	0.10	6.32 **

Source: authors, based on DESI, SDG Index and SS Index. Notes: * $p < 0.05$; ** $p < 0.01$.

As previously mentioned, Table 5 presents the correlation analysis between the DESI, SDG Index and SS Index at the level of each EU region (Central and Eastern, Western and Northern and Southern). In Central and Eastern Europe, the results show a low degree of positive correlation between the DESI and the SDG Index in 2019 and a moderate degree of positive correlation in 2020 and 2021. However, the effect is not statistically significant. With respect to the correlation between the DESI and the SS Index at the level of the Central and Eastern region, the results show a negative correlation with a low degree in 2019 and a negative and high-degree correlation in the following two years. In addition, the results for 2020 and 2021, when correlating the DESI with the SS Index, are statistically significant. In the Western and Northern region, the DESI and the SDG Index are strongly and positively correlated in the first two years of analysis but moderately and positively correlated in the last year of study. As in the case of the Central and Eastern region, the effect is not statistically significant. By looking at the correlation between the DESI and the SS Index it can be observed that the correlation is positive and moderate in 2019, positive and high in 2020 and positive and low in 2021, but none of the effects are statistically significant. Regarding the Southern region, results reveal that the DESI is positively and strongly

correlated with the SDG Index in 2019 and 2021 and positively and moderately correlated in 2020, and these effects are not statistically significant. For the correlation between the DESI and the SS Index, results gradually increase from a negative and moderate correlation in 2019 to a negative and high correlation in the following two years. In addition, in 2021, the result is statistically significant.

Table 5. Correlations between DESI, SDG Index and SS Index at the EU region level.

Variable	DESI	DESI HC	DESI con	DESI IDT	DESI DPS	SDG Index	SS
Region				Central and Eastern			
Year				2019			
DESI	1						
DESI HC	0.774 **	1					
DESI con	0.435	0.013	1				
DESI IDT	0.603	0.441	−0.210	1			
DESI DPS	0.798 **	0.386	0.563	0.281	1		
SDG Index	0.265	0.624	−0.024	0.043	−0.015	1	
SS Index	−0.260	−0.262	−0.047	−0.263	−0.127	−0.168	1
Year				2020			
DESI	1						
DESI HC	0.846 **	1					
DESI con	0.042	−0.214	1				
DESI IDT	0.579	0.526	−0.597	1			
DESI DPS	0.704 *	0.359	0.081	0.270	1		
SDG Index	0.366	0.641 *	−0.110	0.157	0.007	1	
SS Index	−0.655 *	−0.596	0.082	−0.595	−0.344	−0.434	1
Year				2021			
DESI	1						
DESI HC	0.665 *	1					
DESI con	0.279	0.323	1				
DESI IDT	0.572	0.760 *	−0.044	1			
DESI DPS	0.928 **	0.642 *	0.000	0.612	1		
SDG Index	0.308	0.619	0.576	0.362	0.138	1	
SS Index	−0.639 *	−0.702 *	−0.489	−0.770 **	−0.458	−0.506	1
Region				Western and Northern			
Year				2019			
DESI	1						
DESI HC	0.906 **	1					
DESI con	0.620	0.654	1				
DESI IDT	0.530	0.278	−0.287	1			
DESI DPS	0.864 **	0.665	0.372	0.656	1		
SDG Index	0.616	0.479	0.122	0.588	0.690	1	
SS Index	0.493	0.310	0.202	0.462	0.627	0.880 **	1
Year				2020			
DESI	1						
DESI HC	0.901 **	1					
DESI con	0.286	0.557	1				
DESI IDT	0.631	0.367	−0.299	1			
DESI DPS	0.769 *	0.657	−0.176	0.489	1		
SDG Index	0.638	0.492	−0.164	0.623	0.631	1	
SS Index	0.561	0.403	−0.297	0.660	0.539	0.923 **	1

Table 5. *Cont.*

Variable	DESI	DESI HC	DESI con	DESI IDT	DESI DPS	SDG Index	SS
Year				2021			
DESI	1						
DESI HC	0.877 **	1					
DESI con	0.728 *	0.374	1				
DESI IDT	0.831 *	0.809 *	0.371	1			
DESI DPS	0.866 **	0.766 *	0.584	0.562	1		
SDG Index	0.468	0.500	0.000	0.746 *	0.314	1	
SS Index	0.246	0.329	−0.286	0.640	0.161	0.924 **	1
Region				Southern			
Year				2019			
DESI	1						
DESI HC	0.853 **	1					
DESI con	0.528	0.174	1				
DESI IDT	0.913 **	0.854 **	0.231	1			
DESI DPS	0.837 **	0.493	0.522	0.690 *	1		
SDG Index	0.518	0.382	0.455	0.502	0.346	1	
SS Index	−0.366	−0.204	0.188	−0.518	−0.503	0.040	1
Year				2020			
DESI	1						
DESI HC	0.875 **	1					
DESI con	0.717 *	0.441	1				
DESI IDT	0.929 **	0.871 **	0.514	1			
DESI DPS	0.786 *	0.491	0.578	0.617	1		
SDG Index	0.445	0.298	0.326	0.488	0.354	1	
SS Index	−0.649	−0.436	−0.230	−0.668 *	−0.766 *	−0.163	1
Year				2021			
DESI	1						
DESI HC	0.838 **	1					
DESI con	0.622	0.525	1				
DESI IDT	0.871 **	0.743 *	0.446	1			
DESI DPS	0.913 **	0.655	0.357	0.712 *	1		
SDG Index	0.524	0.558	0.381	0.599	0.349	1	
SS Index	−0.712 *	−0.556	−0.350	−0.607	−0.706 *	−0.111	1

Source: authors, based on DESI, SDG Index and SS Index. Notes: * $p < 0.05$; ** $p < 0.01$.

Taken together, the results regarding the correlation of the three indicators show that in the Central and Eastern Europe region, the only high and statistically significant correlations are the ones between the DESI HC component and SDG Index in 2021, between the DESI and SS Index in 2020 and 2021 and between two of the DESI components (DESI HC and DESI IDT) and SS Index in 2021. Regarding the Western and Northern region, the only strong and significant correlation is the one between the SDG Index and the DESI IDT component in 2021, while in the Southern region, as already mentioned, the DESI is strongly and significantly correlated with the SS Index in 2021, but there is also a high and significant correlation between DESI IDT and DESI DPS components and SS Index in 2020 and only between DESI DPS component and SS Index in 2021.

5. Discussion

As presented, the relationship between DESI and SDG Index was overall positive and significant in each year of the analysis, and the effect gradually decreased from one year to another. This means that the COVID-19 pandemic could have had a negative impact on the relationship between the two. In the Central and Eastern region, the positive correlation between DESI and SDG Index increased in 2020 compared to 2019, but it decreased in

the last year of analysis. However, the effect was not statistically significant in any of the three analyzed years. Similar results have been obtained in the case of the other regions but with a larger effect than that in the Central and Eastern region. At the level of the Central and Eastern region, the human capital component was positively and significantly correlated with the sustainable development index only in 2020 when the COVID-19 pandemic started. Because most of the activities moved online in 2020, the internet user skills of citizens and the advanced skills of specialists increased and, by default, influenced the sustainable development in this region. At the level of the Western and Northern region, the data technology integration component was significantly correlated with the Sustainable Development Goals with a large effect in 2021. This result suggests that the digital intensity and the adoption of selected technologies by businesses and e-commerce are factors that can contribute to the achievement of Sustainable Development Goals. At the level of the Southern region, none of the DESI components was significantly correlated with SDG Index, but all the relationships were positive. The non-significant effects between DESI and SDG Index at each geographical level could arise from the sample size (n = 10, 8, 9), considering that, overall (n = 27), the effect of the correlation between the two indicators was statistically significant in 2019, 2020 and 2021. Concerning the relationship between DESI and SS Index, findings showed a negative and significant relationship in 2020 and 2021, with the most prominent effect in 2020. As in the case of the relationship between DESI and SDG Index, the COVID-19 pandemic could have had a negative impact on this relationship. At the level of the Central and Eastern EU region, the relationship between the two was negative and significant only in 2020 and 2021, with a larger effect in 2020, when the COVID-19 pandemic started. This result could be explained by the fact that, as the spillover effect of a country on another one was, on average, the lowest in this year, a country caused, on average, more negative effects on another one at the level of this region. The result is more robust when correlating the Spillover Index with the human capital and the data technology integration component in 2021. The negative effects that a country has on another one in terms of sustainability can also have a real impact on these two components of the DESI. At the level of the Western and Northern region, the relationship between the SS Index and the DESI was positive, but not significant, and a negative relationship had been met in the case of SS Index and connectivity correlation. Regarding the Southern region, the relationship between the DESI and the SS Index was negative and significant, with a large effect in 2021 only. In addition, the Spillover Index is negatively and significantly correlated with digital and public services in 2020 and 2021 and with the integration of data technology in 2020. As in the case of the correlation between DESI and SDG Index, one of the reasons why the effect of the correlation between DESI and SS is not significant is related to the sample size, especially for the Western and Northern region (n = 8).

6. Conclusions

This study has investigated the relationship between digitalization and sustainable development at the level of EU countries over the period 2019–2021, before and during the COVID-19 pandemic. In this respect, the present paper used DESI as an indicator of digitalization and the SDG Index and SS Index as indicators for sustainable development. DESI has been created to measure the digital competitiveness of the EU member states and to monitor the digital advancement of the EU member states, while SDG Index and SS Index give a multidimensional perspective regarding sustainable development, being based on many indicators.

To investigate the relationship between the two concepts, a methodology based on correlations has been used. The results of the study show a positive relationship between DESI and SDG Index during the analyzed period, and the effect decreased from 2019 to 2021. In addition, a positive relationship has been found between the SDG Index and DESI components, especially for the human capital component and the integration of digital technology where the correlation effect was significantly high. The result of the

positive relationship between DESI and SDG is in line with the results obtained by [26], but their analysis has only been limited to a single county level. The results related to DESI components and their relationship with the SDG Index are similar to the results obtained by [3], who measured the impact of digitalization on the SDG Index in EU countries. Many factors could explain the positive relationship between the two indicators. Some factors have already been analyzed by previous studies. First, as digitalization evolves, the use of paper becomes unnecessary, which could have a positive impact on the environment [29]. Second, digitalization could lead to economic growth through the efficient use of resources [34]. Third, digitalization can contribute to the sustainability of the entire education system through actions such as research, education, campus operations, information, awareness and mobilization of local communities [35].

Furthermore, the results of the present paper show a negative relationship between DESI and SS Index that is only significant in 2020 and 2021, and the effect increases over time. Large effects are found for the relationship between the human capital component and the SS Index and for the digital public services component and the SS Index in 2020 and 2021. At the level of each EU region, there were no significant correlations between DESI and SDG Index, and there was only a significant correlation between the data technology integration component and SDG Index for the Western and Northern region in 2021. With respect to the relationship between DESI and SS Index, the results at the region level showed to be negative and significant for the Central and Eastern region in 2020 and 2021. At the level of the Southern region, there was a negative and significant relationship with a large effect between the digital public services component and SS Index in 2020 and 2021. Based on these findings, it should be recommended that countries attempt to cause less negative spillover effects on other countries, so the negative results on the relationship between DESI and SS Index can decrease. The effect of digitalization on sustainable development can increase if countries in general and policymakers give special attention to these two concepts.

Overall, our results reinforce the idea that digitization has a huge potential to contribute to the achievement of Sustainable Development Goals. They can help decision-makers better understand new trends in the application of digitization and the extent to which these trends facilitate the transition to greater sustainability. Such an understanding enables the development and coordination of national digital economy policies and programs serving better sustainable development. For example, it can stimulate governments to increase the construction of digital technology infrastructure and adopt an institutional perspective to remove barriers to the mobility of technology talents, achieving sustainable development. Furthermore, our findings will inspire future research exploring the effect of digitization on sustainable development.

The present paper's results should be considered in line with some limitations. First, this study identifies only the relationship between digitalization and sustainable development and its strength without looking for causality. Future studies could identify to what extent digitalization influences sustainable development. Second, this analysis has been limited to three years to understand whether the COVID-19 pandemic affected the relationship between the two variables. Researchers could extend the analysis for a longer period to understand whether other factors or events affected the relationship between digitalization and sustainable development. This paper does not analyze each component of the SDG Index in relation to digitalization, which could be another limitation. To better understand the relationship between digitalization and sustainable development at the level of EU countries, future studies can consider the relationship between each component of the Sustainable Development Goals in relation to DESI and in relation to each component of DESI. In addition, to shed light on how individuals come to understand the relationship between digitalization and sustainable development, a more nuanced view becomes necessary through the use of different theories, such as social representations theory [36] and framing theory [37].

Despite its limitations, this study could be of interest to researchers as it provides a starting point for studying the influence of digitalization on sustainable development at the level of EU countries, given that a relationship between them exists. Moreover, the results can help the authorities understand that digitalization and sustainable development are in close connection and that changes generated by one of them could cause changes in the other.

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Appendix A. Database

Ref. No.	Year	Country	DESI	DESI HC	DESI Con	DESI IDT	DESI DPS	SDG Index	SS Index
1	2021	Austria	56.9	53.3	53.0	41.3	79.8	0.82	0.60
2	2021	Belgium	53.7	50.8	48.4	49.8	65.8	0.82	0.62
3	2021	Bulgaria	36.8	32.7	38.1	20.5	56.0	0.74	0.87
4	2021	Croatia	46.0	46.7	45.4	40.0	52.0	0.80	0.85
5	2021	Cyprus	43.5	39.7	41.8	30.5	61.8	0.75	0.64
6	2021	Czech Republic	47.4	47.2	44.6	39.1	58.6	0.81	0.68
7	2021	Denmark	70.1	61.2	74.0	57.9	87.1	0.85	0.61
8	2021	Estonia	59.4	57.9	46.6	41.5	91.8	0.82	0.72
9	2021	Finland	67.1	71.1	51.3	59.5	86.7	0.86	0.70
10	2021	France	50.6	47.4	47.4	34.8	73.0	0.82	0.56
11	2021	Germany	54.1	55.2	58.0	35.5	67.5	0.83	0.60
12	2021	Greece	37.3	41.0	37.7	28.5	41.9	0.75	0.72
13	2021	Hungary	41.2	40.5	52.0	23.3	49.2	0.79	0.80
14	2021	Ireland	60.3	54.1	56.4	48.0	82.6	0.81	0.60
15	2021	Italy	45.5	35.1	42.4	41.4	63.2	0.79	0.71
16	2021	Latvia	59.5	41.1	50.4	26.8	79.6	0.79	0.72
17	2021	Lithuania	51.8	46.1	41.7	41.2	78.0	0.77	0.68
18	2021	Luxemburg	59.0	56.2	61.0	39.4	79.4	0.74	0.31
19	2021	Malta	59.6	49.1	54.1	50.8	84.2	0.76	0.61
20	2021	Netherlands	65.1	61.5	68.4	50.7	79.9	0.82	0.47
21	2021	Poland	41.0	37.7	45.3	25.9	55.1	0.80	0.84
22	2021	Portugal	49.8	45.6	48.5	36.6	68.5	0.79	0.70
23	2021	Romania	32.9	33.1	53.2	23.8	21.5	0.75	0.84
24	2021	Slovakia	43.2	43.8	46.3	29.1	53.7	0.80	0.75
25	2021	Slovenia	52.8	47.8	53.2	42.3	68.0	0.82	0.61
26	2021	Spain	57.4	48.3	62.0	38.8	80.7	0.80	0.65
27	2021	Sweden	66.1	64.6	59.6	56.3	83.0	0.86	0.67
1	2020	Austria	54.3	56.7	47.2	40.6	80.8	0.82	0.56
2	2020	Belgium	58.7	50.4	52.0	65.9	71.7	0.82	0.60
3	2020	Bulgaria	36.4	33.9	38.5	17.9	61.8	0.74	0.85
4	2020	Croatia	47.6	49.2	41.2	41.5	55.8	0.80	0.83
5	2020	Cyprus	44.0	35.8	38.5	34.5	69.0	0.75	0.60
6	2020	Czech Republic	50.8	48.6	44.9	49.6	62.4	0.81	0.70
7	2020	Denmark	69.1	61.3	45.8	65.1	87.1	0.85	0.66
8	2020	Estonia	61.1	66.7	51.9	41.1	89.3	0.82	0.69
9	2020	Finland	72.3	78.4	59.2	67.0	87.0	0.86	0.67
10	2020	France	52.2	47.4	49.8	42.0	76.7	0.82	0.51
11	2020	Germany	56.1	56.4	59.4	39.5	66.4	0.82	0.57

Ref. No.	Year	Country	DESI	DESI HC	DESI Con	DESI IDT	DESI DPS	SDG Index	SS Index
12	2020	Greece	37.3	34.8	33.4	28.2	51.5	0.75	0.69
13	2020	Hungary	47.5	41.8	59.8	25.3	57.8	0.79	0.77
14	2020	Ireland	61.8	56.4	45.7	74.3	80.6	0.81	0.58
15	2020	Italy	43.6	32.5	50.0	31.2	67.5	0.79	0.69
16	2020	Latvia	50.7	35.0	61.8	28.3	85.1	0.79	0.70
17	2020	Lithuania	53.9	43.8	48.9	49.5	81.4	0.77	0.66
18	2020	Luxemburg	57.9	58.2	63.3	38.2	73.7	0.74	0.34
19	2020	Malta	62.7	61.8	58.7	54.9	78.1	0.76	0.56
20	2020	Netherlands	67.7	64.2	60.3	65.7	81.0	0.82	0.45
21	2020	Poland	45.0	37.3	51.3	26.1	67.4	0.80	0.82
22	2020	Portugal	49.6	37.8	53.9	40.9	75.1	0.79	0.67
23	2020	Romania	40	33.2	56.2	24.9	48.4	0.75	0.92
24	2020	Slovakia	45.2	41.8	47.5	32.6	55.6	0.79	0.73
25	2020	Slovenia	51.2	48.3	50.2	40.9	70.8	0.82	0.66
26	2020	Spain	57.5	47.6	60.8	41.2	87.3	0.79	0.61
27	2020	Sweden	69.7	71.7	64.4	62.1	79.3	0.86	0.67
1	2019	Austria	51.1	55.7	43.5	34.8	76.3	0.82	0.63
2	2019	Belgium	53.0	49.6	39.9	61.4	65.8	0.82	0.59
3	2019	Bulgaria	33.8	28.5	37.2	16.9	56.5	0.75	0.90
4	2019	Croatia	44.3	46.8	37.2	38.5	50.8	0.80	0.86
5	2019	Cyprus	41.5	34.6	34.6	33.5	65.7	0.75	0.50
6	2019	Czech Republic	47.3	44.8	43.5	42.7	59.9	0.81	0.80
7	2019	Denmark	66.0	61.1	59.2	61.2	82.7	0.85	0.76
8	2019	Estonia	58.3	62.4	49.9	39.8	85.0	0.82	0.83
9	2019	Finland	68.1	77.5	54.5	60.1	82.0	0.86	0.67
10	2019	France	49.8	47.0	48.0	40.8	69.3	0.82	0.62
11	2019	Germany	51.2	54.4	47.7	39.2	58.8	0.82	0.68
12	2019	Greece	35.1	32.7	29.5	30.2	46.4	0.76	0.65
13	2019	Hungary	42.3	42.1	45.9	24.9	50.7	0.79	0.82
14	2019	Ireland	58.0	54.2	42.5	69.1	78.1	0.81	0.62
15	2019	Italy	41.6	32.0	48.2	30.0	61.9	0.78	0.66
16	2019	Latvia	49.9	40.4	59.8	24.7	80.2	0.79	0.72
17	2019	Lithuania	51.8	42.2	46.0	47.6	79.4	0.77	0.73
18	2019	Luxemburg	54.5	57.4	57.1	37.4	64.9	0.74	0.42
19	2019	Malta	55.3	55.0	43.9	49.6	75.2	0.76	0.63
20	2019	Netherlands	63.6	62.0	50.5	62.6	79.6	0.81	0.50
21	2019	Poland	40.7	36.8	43.8	23.5	61.5	0.81	0.85
22	2019	Portugal	47.0	35.2	48.4	41.4	73.4	0.78	0.71
23	2019	Romania	36.5	31.1	50.0	21.3	45.0	0.75	0.94
24	2019	Slovakia	42.9	44.2	39.6	33.1	50.7	0.79	0.71
25	2019	Slovenia	48.7	46.3	48.6	39.1	64.5	0.81	0.70
26	2019	Spain	53.6	44.5	55.4	41.3	80.9	0.79	0.70
27	2019	Sweden	67.5	71.6	60.1	57.9	77.9	0.85	0.68

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