Sustainable Economic Development and Digital Progress of EU Countries

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Abstract. Global economic trends are shifting steadily in the direction of digital and sustainable economy, so countries throughout the world strive to achieve sustainable development along with digital change. Like the rest of the world, the EU economies face significant challenges related to new technologies, digital and sustainable economic development. The relationship between digitalization and sustainable development has been the subject of recent research. This paper's objective is to demonstrate the success of the European Union in digitalization and sustainable economic development. The paper uses regression to analyze the link between the DESI index and the variables of sustainable economic development in the EU countries for the period 2016–2020. The results show that all the variables are positive and statistically significant at the 1% level, except adjusted net savings (ANS) which is insignificant. Additionally, the DESI index will rise by 0.794%, 0.264%, and 9.602% respectively if income per capita, renewable energy, and urbanization grow by 1%. The variables of sustainable economic development have influence on digital performance of the EU economies.

Keywords: Digitalization · Sustainable economic development · EU countries

1 Introduction

Countries around the world are undergoing a digital and sustainable transformation. It is clear that the use of digital technology has increased during the COVID-19 pandemic. The increasing use of new technologies worldwide reflects the high level and speed of exchange of information and knowledge. The development, adaptation, and application of new technologies will benefit almost every sector of the economy. Technological impacts include competitiveness, efficiency, productivity, cost reduction, rapid technological change and innovation, the creation of new products and services, new jobs and market structures [1]. Digital economy, technology and digitization have significant social, economic, and environmental impacts. With economic progress, due to lack of resources, sustainability becomes important. Therefore, with the introduction of new digital technologies, countries are working to obtain sustainble development which has established Sustainable Development Goals (SDGs) and it can be defined in different

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ways. It is commonly defined as meeting environmental, social, and economic needs of both current and future generations by using resources without depletion. Sustainable development does not deplete natural resources and they need to be used efficiently and recycled for storage and improvement. The Brundtland Report [2] also provides another commonly used sustainable development definition: "the development that meets current needs without compromising the ability of future generations to meet their needs." According to these definitions, economic and business activities should be carried out without endangering natural resources and the environment. Renewable energy and innovation are important not only for environmental sustainability [3], but also for good economic and business performance.

Each SDG is directly or indirectly influenced by technology. Therefore, digitalization can lead to sustainable development. However, digitalization is not sustainable by definition. The unsustainability of new technologies may jeopardize the gains made in the field of digitalization and towards sustainable economy [4]. For this reason, various studies have focused on the relationship between sustainable development and digitalization [5–7].

According to these world trends and issues, the double transformation of going digital and going green is in the focus of the European economy. Additionally, EU countries want to increase social and economic resilience [8]. Digitalization and sustainable economic development are both important aspects of their overall progress. However, there are interrelations between the two, so it is difficult to state clearly which is more important, and whether digitalization will affect sustainable economic development or vice versa [9]. The aim of the paper is to show digital progress i.e., digitalization (D) and sustainable economic development (SED) in EU countries. The paper also analyses the link between digitalization and SED in EU countries for the period 2016–2020 by using regression. The research questions are as follows:

RQ1: What is the progress of D and SED in EU countries?
RQ2: What is the impact of SED on D in EU countries?

We use regression to show the impact of the selected proxy variables of SED (adjusted net savings (ANS), GDP per capita (constant 2015 US$), renewable energy (REN), and urbanization (URB) [10] on digitalization i.e., digital progress (the DESI Index) in EU. The results show that all variables have positive values and are statistically significant at the level of 1%, except ANS. In addition, a 1% increase in income per capita, renewable energy and urbanization will increase the DESI index by 0.794%, 0.264%, and 9.602%, respectively. Digital performance of the EU economy is influenced by sustainable economic development variables.

2 Literature Review

In many innovation, digital, and growth strategies digitalization and green economy are the issues without which inclusive and sustainable growth cannot be obtained. The great potential of new technologies is recognized for sustainable development and through different strategies focusing on the use of digital technology to solve sustainable development issues. According to Bhutani and Paliwal [11], digitalization is the first step

towards true virtual reality to achieve inclusive and sustainable growth. In addition, these authors claim that the digital age leads to sustainable development because digitally empowered societies are more Conscious, Collaborative, Compliant, Connected, and Content (5C) about their growth. The study attempts to show the extent of digitization in the current context and the role of digitalization in helping the world achieve the ideal goal of inclusive growth in a sustainable manner. It also presents the "5C" paradigm of inclusive and sustainable growth, which links digitalization and growth.

Esses et al. [5] investigated the main features of digitalization contributing to sustainable development in the Visegrad Group (V4) countries. Their main goal was to investigate the link that exists between sustainable development and digital transformation in Central Europe. They used the Digital Economy and Society Index (DESI). The authors used V4 to examine the relationships between the DESI index dimensions and the SDG goal indicators to represent changes, evaluate and rank the selected countries based on these characteristics. The results showed the degree of digital performance of countries and the relationship between digital performance and sustainable development indicators.

Jovanović et al. [12] examined the DESI methodology to see how the EU digital performance affects three key components of sustainable development: economic, social, and environmental. As a result, they explored the relationship between the DESI and other composite indices assessing sustainability factors. In addition, they explored the relationship between Hofstede's cultural dimensions and the effectiveness of digital technologies. Finally, they emphasized the importance of digitalization as the key factor in sustainable development of society.

Filipiak et al. [13] explored the relationship between tourism industry development and GDP growth. These researchers focused their investigation on two specific issues, namely the connection between digitalization level (e-commerce) and tourism industry development, and the connection between tourism industry development and sustainability factors. The study observes the factors affecting the tourism industry and their relationship to digitalization, sustainability, and economic growth of the tourism economy. The results show that there is a causal relationship between tourism development and GDP growth in the EU. Greece was found to have a negative correlation.

Hosan et al. [7] observed how demographic dividend, digital economy, and energy efficiency might help emerging countries achieve more sustainable economic development. Their research focuses on the dynamic relationships between demographic dividend, digital innovation, energy intensity, and long-term economic growth in thirty emerging nations, using advanced econometric methodologies (Augmented Autoregressive Distributed Lag and Dumitrescu-Hurlin panel causality tests) for the period 1995–2018. Their findings imply that digitalization and demographic dividend drive long-term sustainable economic growth in all quantiles. In addition, capital formation urbanization, and industrialization correlate positively with sustained economic growth, while energy intensity is not correlated with economic sustainability.

Along with the reserach studies on sustinable development and digtialization, there are sutudies based on sustinablity and digitalization in business [14]. It is known that sustainability brings sustainable practices to business. Businesses face increasing requirements for environmentally friendly practices and the rapidly changing technology landscape. Digitalization affects businesses by adapting and combining different technologies that change the way business is done. For example, the study by Nikmehr et al. [15] makes a case for the combined economic and sustainability benefits of digitizing construction firm activities. They set forth the requirements for digitalization. Various ways to build a digitalization strategy and the aspects of a comprehensive digitalization strategy are examined. The elements of a digital strategy are offered by the authors. Finally, these authors analyze the several approaches to adopting a digital transformation strategy. The study provides a valuable framework for practitioners to assess their firm-level attempts at digitalization transition.

Annosi et al. [16] observed the main problems that agri-food companies encounter when using and adopting digital technologies. They also demonstrate how these problems affect the industry's sustainable development of digital technology and provide research opportunities. Their findings highlight the significant hurdles that agri-food companies encounter in digital technology adoption and utilization.

The relation between digitalization and sustainability can be also examined at a regional level. Thus, Tulchynska et al. [17] used a newly established analytical technique to find out how the development of regional economic systems is affected by innovative elements in digital economy. These researchers used the Runge-Kutta technique of fourth-order. Their findings revealed that the dynamic change parameters were obtained to determine the rate of change of the studied functions of regional economic system development in terms of digitalization, as well as determining the most optimal parameters for managing regional economic system development under the influence of innovative factors.

Most studies are oriented towards the fulfilment of SDGs and the link between digitalization and SDGs. The study by Castro et al. [18] aims to fill knowledge gaps by offering the first-of-its-kind review of the SDGs and their relationship with digitalization, as well as policy implications and future research initiatives. They employ an approach that includes a comprehensive, holistic evaluation and in-depth qualitative analysis of the literature on the SDGs and digitalization. The findings reveal that the SDGs have several research gaps. Also, it includes a faulty understanding of complexities and interconnections. In addition, the results are design flaws and imbalances, implementation and governance challenges, inappropriate indicators and evaluation methods, omitted referrals, and untargeted progress as well as the lack of clear responsibility and coordination, and undeveloped role of knowledge management. Furthermore, the findings present rising expectations for the added value that digitalization may provide to the SDGs, such as better analytical capabilities, new sources of data, and digital ecosystems that are collaborative. Finally, the study results show that more multidisciplinary research, dialogue, and focused reform activities are needed. The findings intend to guide and stimulate ongoing study and science-policy discourse on the promising link between the SDGs and digitalization.

Van der Velden [4] examined the relationship between digitalization and SDGs. The analysis of digitalization and the SDGs demonstrates how digital technologies are viewed as both enabling and transformative in pursuing sustainable development.

Gupta and Rhyner [19] propose a new Digitainability Assessment Framework (DAF) for assessing the impact of digitalization interventions on SDGs. By systematically analyzing the influence of a digital intervention on the SDG indicators, their framework (DAF) permits a thorough evaluation of numerous distinct social, ethical, technical, and environmental elements of digital intervention. In addition, these authors use three test case studies to show the ways DAF can be used to provide a holistic understanding of the relationship between digitalization and the SDGs.

Dyatlov et al. [6] define the main principles, indicators, and criteria of sustainable development and expose the content of the digital concept. These authors employ a variety of indicators to characterize sustainable development. Furthermore, they observe these variables at various levels of hierarchy: global, national, regional, local, and industry-specific. The characteristics of the "green economy" as it develops throughout the digitalization of international and national economic systems are examined. Finally, the authors construct and suggest a model of the regional concept based on these characteristics. The proposed model includes sustainable development and organizational and economic methods that may be utilized to assess the efficiency of its implementation during the transition to the digital economy.

Karki and Thapa [20] examined how the terms digitalization (DT) and sustainable development (SD) are used in the current literature, and how these two domains are linked. Based on their findings, these authors recommend four research topics. First, a paradigm shift. Second, the clarity of the concepts related to SD and DT. Third, the theory that connects them, and fourth, the role of social enterprises in connecting SD and DT.

Lanshina et al. [21] conducted a content analysis of more than twenty policy ideas to address the COVID-19 crisis published by major international organizations, governments, businesses, academia, and civil society organizations. These authors examine the role digitalization plays during a crisis and the composition of the crisis responses that have already been implemented by the major economies. They seek a long-term solution for a more equitable and sustainable development of the global economy. The study finds that many public policy recommendations published since the beginning of the epidemic contained important green elements. Many of these proposals relate not only to addressing individual needs, but also to the development of impartiality and inclusiveness. The authors also identify key areas of sustainable development that require immediate attention and may offer new economic opportunities: circular economy, renewable energy, environmental protection, clean transportation, and digitalization. Finally, the findings underline that the transition to green economy is a long-term process that may conflict with the need to help the economy overcome the crisis in the short term.

Different objectives of SDGs allow investigation of digital and SDG targets. We present a short overview of the selected studies on the issues such as climate change, energy, renewable energy, energy efficiency, open platform, waste, and knowledge. Balogun et al. [22] look at the present trend in the digital revolution and how it relates to climate change adaptation, as well as the potential problems of digitalization. These

authors use a desk research approach to focus on the basic digital concepts that drive the Fourth Industry Revolution (IR 4.0). This study assesses the potentials and benefits of implementing digitalization in addressing climate threats, while taking into account the challenges and tensions of socio-environmental technologies surrounding IR 4.0. It includes 9 case studies from cities inside. Their findings show that digitization supports more effective early alert and emergency systems, improves food and water safety, improves energy infrastructure performance, and involves public involvement and participatory adaptive behavior. It shows how to enable and reduce the impact of climate disasters.

From 2000 to 2018, Ziolo et al. [10] investigated the link between sustainable financial and economic development, and energy efficiency in OECD economies. Data envelopment analysis and regression analysis were employed in this study. The findings reveal a minor increase in total factor energy efficiency (TFEE) among OECD nations over the studied period, while TFEE levels differ. TFEE levels are higher in developed OECD countries than in emerging OECD countries. Furthermore, the study demonstrates that the relationships between TFEE and sustainable economic and financial development have varying implications depending on the variables considered. These authors revealed that foreign direct investments (FDI) in TFEE are not statistically significant, while TFEE has a long-term favorable impact on sustainable financial development.

Jednak et al. [23] explored the role of the following variables - FDI, energy consumption, trade openness, income, capital, and carbon emission in sustainable economic development in Serbia during 1995–2018 using ARDL and the co-integration model.

Through qualitative research of micro-level interactions for knowledge integration on an open platform to combat food waste, Hellemans et al. [24] sought ways to uncover the positive aspects of a sustainability-oriented digital platform (SODP), while reducing the associated tensions and paradoxes. The participants explored sustainability issues: the breadth and variety of knowledge about platforms for building scale, mobilizing resources for solutions, and generating food waste issues with 11 different mechanisms and three major interactions. According to their analysis this identified the pattern. Their research adds to the growing body of knowledge about SODPs by demonstrating how users might behave as "distributed brokers" through their activities on the platform.

According to Mondejar et al. [25], digitalization can improve energy efficiency and provide sustainable alternatives. They claim that developing intelligent systems that are connected to the Internet of Things can provide a unique opportunity to strategically tackle the challenges associated with the SDGs in order to ensure a just environment sustainability and health. The study explores how digitization can help to accelerate the transition to sustainable manufacturing methods and improve citizens' health by offering digital access.

Onyango and Ondiek [26] investigated the impact of ICT, internet connectivity, digital platforms, and personnel skills in implementing SDGs in Kenyan public organizations. Their findings reveal the lack of "cross-sectoral institutionalization and internalization". The findings are the result of limited acquisition of staff ICT skills and training, inadequate ICT platforms (primarily computers), inadequate internet connections, and inadequate investment by state agencies in digital platforms. Furthermore, they show

that the organizational culture that predisposes organizations to resist resistance also hinders the integration of SDG goals into government agencies.

Soldak [27] groups 68 economies based on the scale of their industrial ecosystem (value added), labor intensity, knowledge intensity and environmental performance (CO_2 emissions). The findings show that the qualitative characteristics, particularly the absolute leadership in labor productivity and R&D expenditures, are found to belong to the advanced industrial ecosystems of Europe, Asia-Pacific and the United States.

According to European Commission, the green transition and digital transformation are the focus of the EU agenda till 2030. Even though the EU made some progress in digitalization and achieving SDGs targets, investment needs to push up economies to achieve the set targets. The green transition is seen as an opportunity for EU sustainable and inclusive growth. In addition to tackling climate change, it will help reduce energy consumption and dependence on energy imports. For this purpose, the EU delivers the European Green Deal. However, digital transformation is in every segment of society and economy. The COVID-19 pandemic highlighted the importance of digital technologies for Europe's economic growth. Therefore, the EU proposed the Digital Compass by setting out the EU's digital targets for 2030. EU strategic agenda 2019–2024 set that digital transformation and sustainability should be complementary in order to obtain economic growth. Digitalization has the potential to lead the EU toward a low carbon circular economy because digital technology increases energy efficiency and decreases carbon emission, especially in energy, transport, agriculture, and manufacturing sectors. Eurostat's 2021 Sustainable Developments Goals [28] report shows overall progress in achieving sustainable development targets, mostly in climate change, energy consumption and education. The higher progress was made in the following SDGs: SDG1, SGD3, and SDG16, while average progress was made in SDG8, SDG4, SDG5, SDG10 and SGD17. According to DESI 2021 [29], the EU made digital progress by applying digital technology during the COVID-19 pandemic.

Based on the literature review and report, our study will analyze the progress and link between sustainable economic development and digitalization.

3 Data and Methodology

3.1 Data

The paper includes annual data for 27 EU countries for the period 2016 to 2020. World Development Indicators (WDI) [30] and Eurostat [31] provided the data. To indicate sustainable economic development, we employed proxy variables: adjusted net savings (ANS), GDP per capita (constant 2015 US$), renewable energy (REN), and urbanization (URB) [10], while for the digital transformation, we used the Digital Economy and Society Index (DESI). The DESI is a composite index that evaluates the development of digital economy and society across the EU. Each variable and its descriptive statistics are shown in Table 1.

Table 1. Summary statistics

Variable	Definition	Units	Mean	St. Dev.	Max.	Min.
DESI	Digital Economy and Society Index	weighted score (0 to 100)	41.93	9.17	62.80	21.39
GDP	Income per capita (constant 2015 US$)	GDP per capita (constant 2015 US$)	32073.36	21739.23	108570.03	7341.05
ANS	Adjusted net savings	including particulate emission damage (% of GNI)	−13.12	119.11	20.29	−615.80
REN	Renewable energy	(% of total final energy consumption)	21.93	11.65	60.12	5.36
URB	Urbanization	(% of total population)	73.38	12.94	98.08	53.73

Source: Authors' presentation and calculation.

3.2 Methodology

We used the model provided by Eq. (1) to address the primary study issue of the relationship between digitalization and sustainable economic development in EU countries. The purpose of modeling Eq. (1) is to ascertain the impact of the selected sustainable economic indicators on digitalization in EU countries from 2016 to 2020. Based on this, the subsequent model was examined:

$$DESI_{i,t} = C + GDP_{i,t} + ANS_{i,t} + REN_{i,t} + URB_{i,t} + \varepsilon_{i,t} \quad (1)$$

where DESI is Digital Economy and Society Index, GDP is GDP per capita (constant 2015 US$), ANS is Adjusted net savings, REN is Renewable energy, URB is Urbanization, i is country, and $i = 1,\ldots,27$, and t is the five years, ε_i denotes unexpected shocks of the model. Tenish et al. [32] use a similar model with different variables.

4 Results

All the variables were logarithmized, and their stationarity was examined before the model was tested. The stationarity test for each variable in the panel is presented in Table 2. The test created by Levin et al. [33] is used to assess the stationarity of the observed data (i.e., to explore the order of integration). Panel unit root tests' null hypothesis assumes that all variables have a unit root. On the other hand, the alternative hypothesis continues to hold that each panel series is stationary [34]. In Minović et al. [35], the same panel unit root test is utilized.

The results in Table 2 demonstrate a comparable degree of integration, i.e., that each variable typically follows a stationary process I(0). As a result, it is safe to infer that all of the variables I(0) that are served are processes.

Table 2. Unit root test.

Variable	LLC	Order of integration
DESI	−4.816***	I(0)
GDP	−6.133***	I(0)
ANS	−19.184***	I(0)
REN	−6.835***	I(0)
URB	−110.454***	I(0)

Note: *** denotes statistical significance at 1% level. LLC is Levin, Lin & Chu t* test. Schwarz automatic selection of the lag length has been used for the unit root test. DESI is Digital Economy and Society Index, GDP is GDP per capita, ANS is Adjusted net savings, REN is Renewable energy, and URB is Urbanization.
Source: Authors' calculation.

Since our dataset had missing values (in variable ANS there are missing values), we assessed the unbalanced panel. Table 3 displays the outcomes. Given that the Hausman's test p-value was less than 0.05 and that fixed effects estimates are efficient and consistent, we estimated a regression model with fixed effects (for more details, see [32]).

Table 3. Regression results. Dependent variable is DESI.

Variable	Coefficient	Prob.
C	−46.065	0.000
GDP	0.794	0.000
ANS	−0.023	0.145
REN	0.264	0.000
URB	9.602	0.000
Adjusted R2	0.949	
F-statistic	84.371	0.000
Hausman test	149.821	0.000

Notes: DESI is Digital Economy and Society Index, C is constant, GDP is GDP per capita, ANS is Adjusted net savings, REN is Renewable energy, and URB is Urbanization.
Source: Authors' calculation.

The estimated model has a statistically significant regression toward the F-test value and its p-value, which is less than 0.05. Furthermore, the model's determination coefficient adjusted R^2 reveals that 94.9% of the variability in the variables can be explained by it, whereas the remaining 5.1% of the variations cannot be.

Table 3 shows that, except for adjusted net savings (ANS), all variables are positive and statistically significant at the level of 1%. The ANS variable is insignificant. Additionally, the DESI index will rise by 0.794%, 0.264%, and 9.602%, respectively if

GDP per capita, REN, and URB grow by 1%. As a result, we can conclude that sustainable economic development indicators affect digitalization in EU countries. These results present the answers to RQ1 and RQ2. There is progress in achieving sustainable economic development and digitalization (RQ1). Our findings are according to the results of Eurostat's 2021 SDGs report [28], DESI 2021 [29] and studies [5, 6, 12, 18, 25]. The Eurostat results show that the EU has achieved sustainable development targets, mainly in climate change, energy consumption and education. The following SDGs made the most progress: SDG1, SDG3, and SDG16, while SDG8, SDG4, SDG5, SDG10, and SDG17 made average progress. According to DESI 2021 [29], the EU made digital progress during the COVID-19 pandemic by utilising digital technology. Besides, the findings show that sustainable economic development affects digitalization (RQ2), which partially aligns with the findings of previous studies that show SED influences some aspects of digitalization [21, 26].

5 Conclusion

The aim of the paper is to demonstrate how digitization and SED are linked in EU countries. The paper uses regression to examine the link between digitization and SED in EU countries for the period 2016 to 2020. The results show that variables are positive and statistically significant at the level of 1%, except ANS. In addition, a 1% increase in renewable energy, GDP per capita and urbanization will raise the DESI index by 0.794%, 0.264%, and 9.602%, respectively. The sustainable economic development variables impact the EU's digital performance. The EU policies and agendas are oriented toward digital transformation and obtaining SDGs targets. They are two main issues and challenges that have to go hand in hand in order to make progress in the EU economies. The pandemic highlighted the importance of digital technology and sustainability, so the EU made a plan for investment in digital, sustainable, and green economy. Even though the EU has made some progress in digitalization and meeting SDG targets, more investment is needed to propel economies toward the goals. The limitation of this research is comparison of individual SED and D variables and targets. Further research will focus on Southeastern Europe countries applying other economic techniques.

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