sustainability

Article

Digitalisation as the Indicator of the Evidence of Sustainability in the European Union

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Abstract: Digitalisation provides access to an integrated network of information that can benefit society and businesses. However, the evidence of sustainability in business is less researched. In our paper, by building up the research approach, we address the relevant gap by investigating how sustainable development goals represent the interrelationship between digitalisation and sustainability. Such research is particularly important because understandings of digitalisation and sustainability determine how different actors, including business managers and policymakers, act in response to those imperatives to develop future employees skills starting from school age. Following a multi-method approach, we have combined our analysis into two steps examining the relationship between digitalisation and sustainability. Building digital networks, business managers and policy makers using digital means can create some unique opportunities to strategically address sustainable development challenges for the United Nations Targets (SDG) to ensure higher productivity, education, and an equality-oriented society. This point of view describes the potential of digitalisation for society and businesses of the future. The authors revise the links between digitalisation and sustainability in the European Union countries by using data available in Eurostat and UNECE public databases. The two-stage methodology for the identification of the relationship between ICT and sustainability is used in the paper and a linear regression model is applied. The results showed tiers with five SDGs, focusing on business, and all these tiers are fixed in the constructed equations for each SDG. The recommended solution is statistically valid and proves the novelty of this research. Among digitalisation indicators, only mobile-cellular subscriptions and fixed-broadband sub-basket prices in part do not affect researched sustainable development indicators.

Keywords: digitalisation; sustainability; sustainable development goals; European Union; regression equations

Citation: Burinskienė, A.; Seržantė, M. Digitalisation as the Indicator of the Evidence of Sustainability in the European Union. *Sustainability* **2022**, *14*, 8371. https://doi.org/10.3390/su14148371

Academic Editors: Adel Ben Youssef and Khalid Kisswani

Received: 3 June 2022
Accepted: 6 July 2022
Published: 8 July 2022

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1. Introduction

Digitalisation is a widely used phrase with several meanings, many of which are case-specific. As the concept of digitalisation is relevant to a wide range of various industries, it is natural that there are many studies that have been conducted on the topic. Digital connectivity, internet use, e-business, e-commerce, and e-services are all used to quantify digitalisation [1]. Ashok [2] presumes that digitalisation will regulate the link between co-operation (the breadth of external partners and the depth of consumers' involvement) and internal resource commitment to increase the advantages received from business process innovation. The expectation that everything should be online has led to the practice of mass digitalisation, but it is an ongoing process in society bringing new business practices. In a world of emerging and continuous change, digital transformation (DT) has become a necessity for most enterprises. The phrase DT has been so widely used (and misused) that it may be somewhat confusing [3]. Through the use of Internet of Things (IoT) technology, extensive data interchange, and predictive analytics, digitalisation is transforming how business is performed inside industrial value chains. However, technology innovation is insufficient to benefit from digitalisation; therefore, business model innovation, such as the move towards advanced service business models, is required [4]. The discussion about digital transformation is also essential in the light of artificial intelligence and ethical considerations. The application of artificial intelligence (AI) in the business sector represents the next frontier of digital-era governance (DEG), an extension of the traditional bureaucratic model that represents digital manifestations of instrumental rationality. However, the use of artificial intelligence also introduces new risks and ethical challenges (such as biased data, fairness, transparency, the surveillance state, and consumption behaviour) that businesses must address [5,6]. The Sustainable Development Goals, which were introduced in 2015 as part of the United Nations 2030 Agenda, have the potential to help close the present gaps of digitalisation if the underlying issues are addressed. The idea of data-driven governance introduced in the 2030 Agenda for Sustainable Development emphasizes the need to "increase significantly the availability of high-quality, timely, reliable and disaggregated data by 2030". Digital transformation is described as "the profound transformation of business and organizational activities, processes, competencies, and models in a strategic and prioritized way, with present and future shifts in mind, to fully leverage the changes and opportunities of a mix of digital technologies and their accelerating impact across industries." [7] The combination of sustainability and digitalisation creates both untapped potential and serious challenges to the 2030 Agenda, while also offering attractive research and policy development options. Additionally, by offering new data sources and increased analytical capabilities, digital paradigms might help to close several SDG research gaps. By limiting the negative effects and achieving true sustainability in business, digitalisation should be carefully embraced [8].

Using digital tools to build a digital network and society may provide one-of-a-kind opportunities to proactively solve the sustainable development concerns outlined in the United Nations' Sustainable Development Goals (SDGs), and guarantees increased production, qualified education, and more gender equitable business. This viewpoint outlines the future possibilities of digitalisation for society and industry. This review aims to re-examine the connections between digitalisation and sustainability in European Union nations and to discover how digitalisation indicates sustainable business development.

The literature review shows that publications on digitalisation are increasing in recent decades (see Table below). The authors revised the number of publications by using the keywords "digitalisation", "sustainability", and "SDG".

The analysis of the publications (i.e., the review of books published by Oxford University Press, Cambridge University Press, Harvard University Press, Springer, M.E. Sharpe, and Routledge) shows that the attention to digitalisation and sustainability was constantly growing but in the last period the number of publications was doubled. The analysis presented in Table 1 shows that less than 2.4% of the above publications contain investigations in the digitalisation and SDG area. That is why it is important to investigate the possibilities for activating sustainable development through digitalisation. This data mentioned in Table 1 shows that digitalisation supports sustainability in various forms and that the research about the links between digitalisation and SDG has already been started.

The authors formulated a research question: revise 19 digitalisation indicators indicating the evidence of sustainability in businesses operating in the European Union. Sustainable business operations require effective leadership throughout the organization and cross-functional business processes.

The paper contains a literature review, which separately revised the connection between digitalisation and specific SDG elements. For the revision, five main SDGs were selected. Further on, the authors present the methodology and empirical research. Finally, the authors finalise the article with the discussion and conclusion sections.

Table 1. Review of the literature.

		Thematic of Sustainability	
Years	Publications on Digitalisation	Inside the Publication on Sustainability	Inside the Publication on SDG
1994–1998	195	26	1
1999–2003	536	146	4
2004–2008	1060	371	7
2009–2013	1750	699	8
2014–2018	5550	2810	298
2019–2022	12,700	8990	208
Total %	21,791 100%	13,042 59.8%	526 2.4%

Source: constructed by the authors, according to studies published by Elsevier, Springer, M.E. Sharpe, Routledge, and other publishers.

The purpose of this analysis is to investigate the relationships that exist between digitalisation and sustainability in the European Union and to determine the ways in which digitalisation is influencing sustainable development. However, since sustainability is a broad concept, the focus of this analysis is on the five main SDGs that have been identified, each of which is likely to contribute in some way to the effect that digitalisation has on the idea of sustainability in general.

2. Literature Review

First, a critical evaluation of the literature review will be carried out to identify the research gap and to provide an answer to the research question: "Are there any studies being conducted that investigate the link and impact of one of the selected specific sustainable goals, and are they cross-referenced?". For the study to be goal-oriented, it is necessary to conduct a critical assessment of the previous research.

The most recent research published in the last two years examines the concept of digitalisation in a wide variety of domains, ranging from economics and environmental performance to the micro-assembly space and the digital transformation of higher education [9–20]. Many of these studies are looking into the topic of digital transformation [15,21–31], and some of them are even continuing to review the relationship between digitalisation and long-term sustainability [32–43]. However, only a few of these scientific publications are performing a deeper discussion about particular SDGs under the digital transformation level. In Table 2, we have summarized some of the latest research on the particular topics, which provide a link between digitalisation, sustainability, and SDGs.

Table 2. The newest publications on the topic of digitalisation and SDGs.

Join Studies on Digitalisation, Sustainability and SDGs	Sources
Digitalisation & Sustainability	[32–43]
Digitalisation & SDG 4 (Quality Education)	[8,44–53]
Digitalisation & SDG 5 (Gender Equality)	[54–57]
Digitalisation & SDG 8 (Decent Work and Economic Growth)	[58–63]
Digitalisation & SDG 9 (Industry, Innovation, and Infrastructure)	[1,64,65]
Digitalisation & SDG 12 (Responsible Consumption and Production)	[66–71]

A good example of how to answer the question "How to Measure Digitalisation?" could be a Critical Evaluation of Digital Maturity Models prepared by Thordsen et al. [72].

In this paper, the authors analyse 17 current digital maturity models—found via a rigorous literature search (2011–2019)—in terms of measurement validity.

Reis et al. [73] made a systematic review and study on digitalisation in general, claiming that the development of new digital technologies, combined with automation and artificial intelligence, is enabling a new wave of smart companies, a topic that warrants further research.

Hellsten and Paunu [74] in their review "Digitalisation: A Concept Easier to Talk about than to Understand", discuss digitalisation as a commonly used concept with multiple meanings, many of which are case-specific. They demonstrate that the current definitions are not particularly specific, and they point out that the reality does not necessarily follow previous results, as seen by two studies looking at actual digitalisation programs.

Gong and Ribiere [3] examined 134 definitions of digital transformation to obtain an insight into six essential defining primitives of Digital Transformation (DT) to determine the language and conceptual clarity that distinguishes the concept from other comparable words.

Parida et al. [4] conducted a thorough evaluation of the literature on digitalisation, business model innovation, and sustainability in industrial settings to contribute by creating a framework that explains and directs future research.

Del Río Castro et al. [8] conducted a comprehensive analysis, revealing the confluence of digitalisation and sustainability as a means of achieving the Sustainable Development Goals (SDGs). Their findings show that the SDGs have several research gaps, including a lack of understanding of their complexities and interconnections, design flaws and imbalances, implementation and governance challenges, inappropriate indicators and assessment methodologies, truncated adoption and off-target progress, unclear responsibilities and lack of coordination, and an untapped role for technological innovation and knowledge management.

Digitalisation is often defined as digital connectivity, internet use, e-business, e-commerce, and e-government [1]. The notion of digitalisation, as defined by all of the above writers, relates to enabling or enhancing processes via the use of digital technology and digitised data.

The idea of this research is to revise link between digitalisation and some particular sustainable development goals. After analysing the scientific publications related to this topic, there were some useful publications describing or investigating the effect of digitalisation [7,8,58,75]. The following sections are dedicated to a comprehensive literature review of five sustainable development goals separately: Sustainable Development Goal 4 (SDG 4) for Quality Education; Sustainable Development Goal 5 (SDG 5) for Gender Equality; Sustainable Development Goal 8 (SDG 8) for Decent Work and Economic Growth; Sustainable Development Goal 9 (SDG 9) for Industry, Innovation, and Infrastructure; and Sustainable Development Goal 12 (SDG 12) for Responsible Consumption and Production.

2.1. The Link between Digitalisation and SDG 4

SDG 4 (Quality Education) aims to increase the number of young people and adults with the necessary skills for employment, decent work, and entrepreneurship at all stages of their lives. Gender and income inequities within the access to education are also envisioned as part of this goal [54].

In general, the importance of digitalisation in education in a broader sense was reviewed in several studies [47–50]. However, most scientists investigate these two expressions separately, and there is no detailed review of their interactions. There are no studies examining the effect of digitalisation on the sustainable development of higher education and there are no clear existing recommendations provided to improve the quality of education. All the provided studies are mainly focused on a theoretical review.

In addition, researchers who have explored the interaction of digitalisation with the sustainability of education in one way or another [8,44,45,51,52,76] emphasize that the results of their research suggest the need for further interdisciplinary research, the need to strengthen the legal framework, and the necessity of clear practical guidelines on how to integrate digitalisation means into sustainable education.

For example, Brevik et al. [44] showed how a small private online course mixes professional digital competencies, university seminars, and practice, allowing student teachers to adapt to problems by turning them into opportunities for professional growth.

Burbules et al. [45] discuss five educational and technological trends for a sustainable future, with the basic premise that each of these movements includes both hazards and opportunities and arguing that our reforms must be made with an understanding of both.

De Sousa et al. [46] suggested a model of digital education methods and technologies that helps students in Higher Education (HE) build knowledge and entrepreneurial skills. The findings of this study show that the use of digital methodologies in education is on the rise, as evidenced by all the studies conducted in the last three years, and that these technologies can help students learn more effectively through innovations such as mobile technologies, tablets, and smartphone apps.

In addition, there are some interesting statistics about digitalisation's impact on sustainability. For example, [51] examined the role of ICT and education in economic development in Middle Eastern and OECD countries and discovered that ICT had a favourable impact on both sets of countries. Furthermore, the authors claim that the effect of mobile subscription is greater in the Middle East than in Organisation for Economic Co-operation and Development (OECD) nations.

Murphy and Costa [52] examined the backdrop of digital scholarship's expansion in the academy, as well as some of the problems that the digital scholarship movement and its attempts to 'publicise' intellectual life have encountered. The authors suggest that colleges take numerous actions to address this requirement and successfully anticipate the future in an already present occurrence.

2.2. Digitalisation's Link with SDG 5

SDG 5 (Gender Equality) aims to eliminate all forms of discrimination, violence, and harmful behaviours against women and girls in the public and private domains. It also advocates for women's full involvement and equal leadership possibilities at all levels of political and economic decision-making [54].

The digitalisation and sustainable development goal concerning gender equality is not a very popular topic among scientists, but there are some interesting reviews that state some interesting facts about this question. For example, Luo and Chan [57] claim that the development of digital entrepreneurship may improve women's role in the business sector in their paper "Gendered digital entrepreneurship in gendered coworking spaces: Evidence from Shenzhen, China". In terms of the under-representation of female leadership, the replication of feminine professions, work–life balance, stress, and loneliness, their research reveals that the socialization of gender identity leads to a gendered digital entrepreneurial process.

According to Galperin and Arcidiacono [56], the greatest single contribution to the digital gender gap is the disparity in the job patterns between men and women. Furthermore, women had a higher link between work and internet usage than males.

Generally, gender equality in access to the internet and mobile phones has become increasingly recognised as a development goal. Fatehkia et al. [55] used Facebook ad data to follow the worldwide digital gender gap and discovered that Facebook data is significantly associated with government statistics on digital gender disparities. Their technique demonstrates how online data may be used to improve coverage for a key development indicator, with low-income nations benefiting the most.

2.3. Digitalisation's Link with SDG 8

SDG 8 (Decent Work and Economic Growth) emphasises the need for long-term economic growth and high levels of productivity for the establishment of well-paying, high-quality jobs, as well as resource efficiency in consumption and production. It advocates for full employment and decent work for all, as well as the abolition of forced labour, human trafficking, and child labour, as well as the advancement of labour rights and the creation of safe and secure working environments [54].

There are plenty of examples showing how the new digital technologies positively affect wage growth and employment stability. For example, [62] examined the effects of new digital technologies on income and employment disparities in the United States. The findings demonstrate that labour-displacing technology lowers wage growth and job stability while improving individual labour market outcomes. It is worth noting that employees with a high degree of formal education are the ones who are most impacted.

Enciso-Santocildes et al. [63] investigated whether the novel method for combining employment with digitalisation is viable and trustworthy. The answer to this question is extremely important for corporate and governmental institutions interested in establishing effective anti-unemployment policies, particularly for vulnerable populations.

Ndubuisi et al. [60] investigated the impact of digital infrastructure on employment in the services sector in Sub-Saharan African nations, finding a considerable positive impact of digital infrastructure on employment in the services sector. Their research demonstrated that institutional and economic factors influence the impact of digital infrastructure on the services industry.

In the case of Italy from 2011 to 2016, [59] investigated the relationship between the digitalisation of labour processes, the amount of routineness of labour duties, and changes in employment. The levels of digitalisation are connected with favourable employment dynamics, but routineness is adversely or not significantly associated with employment change in certain cases.

Ballestar et al. [61] used a large sample of 5511 Spanish manufacturing enterprises from 1991 to 2016 to provide fresh data on the impacts of robotization, digitalisation, and innovation on productivity and employment in firms. For enterprises in a new global competitive environment, this data represents the reward of the high rates of investment required to modernize production technologies.

Domini et al. [58] examined how labour flows changed as a result of an investment in automation-intensive products. Using imports of capital goods with embedded automation technology, they discovered "automation spikes." Increases in automation have also been connected to an increase in businesses' net employment growth rate.

2.4. Digitalisation's Link with SDG 9

SDG 9 (Industry, Innovation, and Infrastructure) encourages the development of resilient and long-term infrastructure as well as inclusive and sustainable industrialisation. It also recognises the value of research and innovation in addressing long-term social, economic, and environmental issues [54].

There are not many examples that provide an accent on the gross domestic expenditure on R&D. This aspect still requires a broader investigation. However, some of the existing studies on that particular topic are mostly about the expenditure level in the Higher Education (HE) sectors or about the GDP for measuring the digital economy. Vītola and Eriņa [64] examined R&D expenditures in the Higher Education Sector as well as Baltic Performance Indicators. The authors determined that certain performance metrics are related to the amount of spending in the HE sectors, but that other indicators are not. Some studies aim to identify challenges, the required competencies of the workforce, and the requirements for training to successfully implement digitalisation in Small and Medium Enterprises (SMEs) [66].

The productivity paradox and the limitations of GDP for evaluating the digital economy are discussed in [65]. With the advancement of ICT and a paradigm shift to the use of uncaptured GDP to measure the digital economy, the authors propose a potential solution to this critical issue through an analysis of the coevolution that emerges from a shift in people's preferences from economic functionality to super functionality that surpasses economic value.

Hustad and Olsen [77] expand on the ideas of digital infrastructure, service-oriented architecture, and microservices in their article. It stresses the advantages and difficulties of building a long-term infrastructure based on a service-oriented environment, which includes cloud services. They delineate the requirements for establishing a long-term digital infrastructure based on services.

To contribute to the development of sustainable cities, [78] conducted research on the Technology Acceptance Model and then further extended the model by adding new aspects to investigate the factors that influence the adoption of new technology on a mass scale as part of the implementation of Smart Cities. Using the basics of TAM, they conducted another study [79] that examined the ways in which farmers embrace and utilise goods and services that are based on information and communications technology (ICT).

Zoppelletto and Orlandi [80] presented research entitled "Cultural and digital collaboration infrastructures as sustainability enhancing factors: A configurational approach". This study intended to provide light on the role of collaborative networks in increasing country-level sustainability, both in terms of digital infrastructures and cultural aspects that encourage cooperation. It studies how various combinations of cultural elements promoting cooperation and digital infrastructure contribute to sustainability performance using three separate country-level datasets.

2.5. Digitalisation's Link with SDG 12

SDG 12 (Responsible Consumption and Production) calls on enterprises, policymakers, researchers, and consumers to take a comprehensive set of activities to adapt to sustainable practices. It predicts long-term production and consumption that is based on enhanced technological capability, resource efficiency, and reduced global waste [54].

There is some interesting research regarding the impact that digitalisation has on resource productivity and domestic material consumption. Some examples concern the effect of digitalisation on the energy consumption of passenger transport. Different scenarios enable evaluations of alternative digitalisation pathways, according to Noussan and Tagliapietra [71], and digitalisation requires appropriate policy assistance to prevent increasing energy use.

According to Lange et al. [70], energy consumption grows as a result of ICT, which reduces energy demand via energy efficiency and sectoral shift while increasing energy demand through a rising ICT sector, rebounding economies, and economic development. Digitalisation, according to the authors, does not separate economic development from energy use. The authors of [68] examined the impact of internet development on energy consumption in China and discovered that there was a considerable negative link between internet development and energy consumption structure.

Whereas some studies report on the impact of the digital transformation on Lean production systems [67].

Another interesting study was conducted by Pouri [69], where the author looks at eight different ways that the digital sharing economy affects resource use. Pouri [66] concluded that understanding the effects of the shared consumption promoted by digital platforms operating in the Digital Sharing Economy (DSE) domain necessitates an understanding of how sharing a resource of a specific type can affect the sustainability of that resource's consumption and other consumptions connected to it (as laid out in eight impact types).

To promote responsibility, the purpose of this study is to present a broad framework for assigning a level of accountability to specific plans or strategies to establish a baseline of accountability. From this vantage point, an expanded and more comprehensive picture of the relationship between the Sustainable Development Goals and digitalisation is presented. Both digitalisation and the Sustainable Development Goals (SDGs) are discussed in this paper, though they are distinct concepts that are interconnected. Afterwards, these concepts are explored in greater depth. According to a thorough review of the literature, researchers have given significant attention to several Sustainable Development Goals (SDGs 4 and 5 as well as SDGs 8, 9, and 12), raising the possibility that those SDGs might have been accelerated by digitalisation. The methodology for selecting SDGs will be discussed in the following next section, during which the primary criteria for selecting SDGs will be defined and discussed in greater detail.

Following a summary of the literature review of similar research, one can plainly identify the research gap that exists. Despite the significant amount of research that has been conducted on particular subjects, such as digitalisation and each Sustainable Development Goal (SDG) analysed independently, a thorough investigation of all of the important components in composition that links these subjects has not yet been conducted. The absence of these links also provides a response to the research question, which is whether any cross-referenced studies relating to the effect of digitalisation have been conducted in the past and whether they cover all of the specified SDGs. Considering that there are no existing examples of research that cover all of the SDGs that have been identified, this is an opportunity to examine a fresh path for exploring this specific field of study. The current study differs from the cited studies in that it proposes incorporating multiple SDG components into the composition and analyses of whether they may possibly affect digitalisation in general.

3. Methods

The authors have revised the literature and summarised the methods used for the studies under the thematic of digitalisation (Table 3).

Table 3. Hierarchy of quantitative methods and models for researching digitalisation.

Model Type	Model Technique	Solution Method	Authors Researching Digitalisation
Mathematical programming method	Multiple objectives	Mixed-integer linear programming Analysis of hierarchical regression Stochastic dynamic programming Non-linear programming	[81–84]
	Time series	Multiple regression Two-step regression analysis	[85] This paper
Causal models	Causality identification methods	Diagram of causal systems	[86]
Heuristic methods	Artificial intelligence techniques	Object-oriented Petri nets Fuzzy logic	[87,88]
Analytical models	Multi-criteria decision making	DEMATEL	[89]
	Systematic models	Delphi method	[88]

In Table 3, the authors have examined which qualitative methods and models have been used for the research of digitalisation by other authors. Table 3 summarises and provides a review of the literature. Among the methods, the most popular are multi-objective methods in studies dedicated to above mentioned topic. The authors have identified that two-step regression method is not mentioned among the above-listed quantitative methods, but the multiple regression method was applied by Delgosha et al. (2021) for researching relationships between digitalisation and sustainable competitiveness and the application of such a method is investigated to definine relationships among variables [85]. The authors of [85] revised the main digitalisation indices, the ones that present supply side (ICT capabilities and infrastructure and the others that show demand side) ICT usage and adoption.

However, this method has been applied in studies of other disciplines. The two-phase approach was suggested by authors Murphy et al. (2002), Achen (2005), Anderson et al. (1982), and Thomson (1992) [90–93]. The aspects of analysis of correlation coefficients were provided by Mukaka (2012) [94].

Concerning the SDGs, the authors have selected different SDG values for deeper analysis. For example, the authors Grijalvo et al. (2020) selected SDG 3, SDG 4, SDG 5, SDG 8, SDG 9, SDG 10, and SDG 11 [95], but missed SDG 12, which is important for resource productivity especially in the industry 4.0 era. SDG 12 is highlighted in Agrawal et al.'s (2021) study focusing on business performance [81].

Van der Velden (2018) maintained that SDG 4 addresses quality education, which also includes training in the use of ICTs [96]. Ufua et al. (2021) highlighted SDG 4 and SDG 9 which together focused on educational development, industrial collaborations and improvements, respectively [97].

Shung-King et al. (2018) focused on SDG 5 as an important aspect for females to achieve promotions to senior management positions [98].

Conway et al. (2020) highlighted SDG 8 as important for building and transport sectors [99]. The author Kunkel et al. (2021) focused only on SDG 9's revision in terms of digitalisation [100]. The usage of digital technologies is also very crucial in the present COVID-19 pandemic era as a technique of limiting employees' physical contact between persons in order to limit the virus's transmission [101,102].

To explore the phenomena the authors investigated in phases, the authors applied a two-stage methodology to identify the relationships between ICT and sustainability indicators (as specified in Table 4) and later investigated how the pairs with defined relationships are interconnected with each other.

Table 4. Two-stage methodology for the identification of the relationship between ICT and sustainability: pair-based analysis.

Stages	**Approach**	**Technique**
The first-stage		
Revision of ICT and SDG indicators and construction of pairs	Identification of relationships between ICT and five sustainable development indicators (SDGs)	Construction of correlation matrix and pairs
The second-stage		
Revision of relationships among pairs	Identification of relationships between pairs constructed under the first-stage	Formation of five equations among pairs

For this study, the authors collected time-series data and investigated the links between ICT and sustainable development indicators.

The purpose of the study is to identify the main links between ICT and sustainability indicators, develop a regression model, and determine the correlation between pairs. Selected available data for ICT and SDG variables from the Eurostat and UNECE public databases for the 10 years 2011–2020 were used to analyse dynamic interactions with such indicators of the five sustainability goal variables:

1. SDG 4—Early leavers from education and training as promoting quality education and convenient skills for the future;
2. SDG 5—Positions held by women in senior management positions;
3. SDG 8—Employment rate;
4. SDG 9—Gross domestic expenditure on research and development activity towards generating innovations for the future;
5. SDG 12—Resource productivity and sustainable consumption with focus on business.

To identify linear relationships, the authors took 19 ICT variables (grouping them according to three categories: network infrastructure, Internet literacy, and shopping online) for the 27 EU countries.

The authors applied a linear regression model and use a simple regression analysis procedure to convert the regression coefficients into a model depicting a linear relationship between the dependent and the regressors.

The authors followed four steps:

(1) Data was selected from the public databases and a correlation matrix was constructed among ICT and five sustainable development indicators, and the results are presented in Appendix A. This analysis examined the existence (or non-existence) of relationships in the pairs. The authors of the dependent variables selected the ICT indicators that had a probability lower than 0.1.

The authors revised 17 SDGs and selected ones that related to digitalisation (SDG 4, SDG 5, SDG 8, SDG 9, and SDG 12). Other SDGs that were linked with agriculture, climate, peace, communities, life, and health practices were not revised in this paper:

Goal 1—No poverty
Goal 2—Zero hunger
Goal 3—Good health and well-being
Goal 4—Quality education
Goal 5—Gender equality
Goal 6—Clean water and sanitation
Goal 7—Affordable and clean energy
Goal 8—Decent work and economic growth
Goal 9—Industry, innovation, and infrastructure
Goal 10—Reduced inequalities
Goal 11—Sustainable cities and communities
Goal 12—Responsible consumption and production
Goal 13—Climate action
Goal 14—Life below water
Goal 15—Life on land
Goal 16—Peace, justice, and strong institutions
Goal 17—Partnerships for the goals

(2) A regression model was formed and presented under Equation (1). The model presents connections with one or two pairs of ICT-based sustainability development indicators. The links among the pairs are presented in Table 5.

(3) Following the regression model, the authors created five Equation (1a–e) between pairs, dedicated to all five ICT-based sustainability development indicators. The authors selected the pair data of correlations presented under the constructed matrix, shown in Appendix A.

(4) The authors provided validation analysis for five constructed equations according to the least square method in Figures 1–5, and presented the results in Table 6.

Table 5. ICT-based statistical relationships.

ICT-Based Sustainability Indicators	ICT-Based SDG 4	ICT-Based SDG 5	ICT-Based SDG 8	ICT-Based SDG 9	ICT-Based SDG 12
ICT-based SDG 4			X		
ICT-based SDG 5			X	X	
ICT-based SDG 8	X	X			
ICT-based SDG 9		X			X
ICT-based SDG 12				X	

Dependent Variable: SDG4
Method: Least Squares
Date: 02/18/22 Time: 07:51
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.062345	0.034655	1.798999	0.0824
SDG8	-0.528506	0.068530	-7.712025	0.0000

R-squared	0.672225	Mean dependent var	-0.162608
Adjusted R-squared	0.660922	S.D. dependent var	0.178924
S.E. of regression	0.104188	Akaike info criterion	-1.622901
Sum squared resid	0.314798	Schwarz criterion	-1.530386
Log likelihood	27.15496	Hannan-Quinn criter.	-1.592743
F-statistic	59.47533	Durbin-Watson stat	1.523760
Prob(F-statistic)	0.000000		

Figure 1. Correlation between ICT-based sustainability SDG 4 and SDG 8 variables.

Dependent Variable: SDG5
Method: Least Squares
Date: 02/18/22 Time: 07:53
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.023454	0.031816	0.737194	0.4671
SDG8	0.286414	0.105622	2.711699	0.0113
SDG9	0.372655	0.074829	4.980072	0.0000

R-squared	0.860819	Mean dependent var	0.277468
Adjusted R-squared	0.850878	S.D. dependent var	0.233302
S.E. of regression	0.090093	Akaike info criterion	-1.884193
Sum squared resid	0.227267	Schwarz criterion	-1.745420
Log likelihood	32.20499	Hannan-Quinn criter.	-1.838957
F-statistic	86.58861	Durbin-Watson stat	1.920713
Prob(F-statistic)	0.000000		

Figure 2. Correlation between ICT-based sustainability SDG 5, SDG 8, and SDG 9 variables.

Dependent Variable: SDG8
Method: Least Squares
Date: 02/18/22 Time: 07:55
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.135951	0.034185	3.976889	0.0004
SDG4	-0.649725	0.178007	-3.649997	0.0011
SDG5	0.663278	0.136517	4.858571	0.0000

R-squared	0.822157	Mean dependent var	0.425640
Adjusted R-squared	0.809454	S.D. dependent var	0.277572
S.E. of regression	0.121164	Akaike info criterion	-1.291571
Sum squared resid	0.411063	Schwarz criterion	-1.152798
Log likelihood	23.01935	Hannan-Quinn criter.	-1.246335
F-statistic	64.72125	Durbin-Watson stat	2.040808
Prob(F-statistic)	0.000000		

Figure 3. Correlation between ICT-based sustainability SDG 8, SDG 4, and SDG 5 variables.

Dependent Variable: SDG9
Method: Least Squares
Date: 02/18/22 Time: 07:57
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.022454	0.031750	-0.707200	0.4853
SDG12	0.585450	0.093326	6.273191	0.0000
SDG5	0.741051	0.151532	4.890405	0.0000

R-squared	0.926945	Mean dependent var	0.354497
Adjusted R-squared	0.921726	S.D. dependent var	0.391793
S.E. of regression	0.109614	Akaike info criterion	-1.491942
Sum squared resid	0.336425	Schwarz criterion	-1.353169
Log likelihood	26.12511	Hannan-Quinn criter.	-1.446706
F-statistic	177.6352	Durbin-Watson stat	2.146509
Prob(F-statistic)	0.000000		

Figure 4. Correlation between ICT-based sustainability SDG 9, SDG 12, and SDG 5 variables

Dependent Variable: SDG12
Method: Least Squares
Date: 02/18/22 Time: 07:44
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.026039	0.034603	-0.752516	0.4578
SDG9	0.898993	0.066079	13.60487	0.0000

R-squared	0.864545	Mean dependent var	0.292651
Adjusted R-squared	0.859874	S.D. dependent var	0.378808
S.E. of regression	0.141801	Akaike info criterion	-1.006443
Sum squared resid	0.583118	Schwarz criterion	-0.913928
Log likelihood	17.59987	Hannan-Quinn criter.	-0.976286
F-statistic	185.0925	Durbin-Watson stat	1.799058
Prob(F-statistic)	0.000000		

Figure 5. Correlation between ICT-based sustainability SDG 12 and SDG 9 variables.

Table 6. Formation of regression equations.

Indicators of Statistics	Equation (1a)	Equation (1b)	Equation (1c)	Equation (1d)	Equation (1e)
Durbin Watson statistics	1.52	1.92	2.04	2.14	1.79
Determination coefficient	0.66	0.86	0.82	0.93	0.87
Adjusted R^2	0.65	0.85	0.81	0.92	0.86
F-statistics	59	86	64	177	185
Probability of F-statistics	0	0	0	0	0

By applying the first step, the authors identified that almost all selected ICT indicators have a strong link to sustainable development, except mobile-cellular subscriptions and fixed-broadband sub-basket prices.

In the next stage, the regression model was developed to define the relationships among ICT and SDGs indicators:

$$sdg_n = \beta_0 + \beta_1\, sdg_r + \beta_2\, sdg_v + u_t \quad (1)$$

where
sdg_n—logarithmic dependent variable of the ICT-based sustainable development indicator in the EU 27 countries.
β_0—intercept.
sdg_r, sdg_v—a pair of the relationships between ICT and particular r or v sustainable development indicators in the 27 EU countries, where r and v equal to one sustainable development goal (4, 5, 8, 9, or 12); both r and v are not equal to n and fulfil the condition that r is not equal to v.
u_t—random model error.
$\beta_1, \ldots, \beta_\text{n}$—coefficients of elasticity reflect the influence of independent variables on ICT-based sustainable development.

The linear regression model will be applied for ICT and five SDGs indicators, and the results are presented in the next section.

4. Results

The authors identified that 13 out of the 19 digitalisation indicators have a strong enough correlation coefficients and a probability lower than 0.1. The other six indicators that followed the results of first step (fixed broadband subscriptions (per 100 people), fixed-broadband sub-basket prices % of GNI, internet use for participating in social networks, mobile-cellular subscriptions per 100 inhabitants, individuals with mobile internet access, and internet use for telephoning or video calls, as presented in Appendix A) were not representative for the further study and formation of equations.

By using a regression model, the authors identified ties. The study shows the ties between such indicators:

- ICT-based quality education (SDG 4) and ICT-based employment (SDG 8);
- ICT-based gender equality (SDG 5) with ICT-based employment (SDG 8) and ICT-based spending on R&D (SDG 9);
- ICT-based employment (SDG 8) has a link with ICT-based quality education (SDG 4) and ICT-based gender equality (SDG 5);
- ICT-based spending on R&D (SDG 9) has a link with ICT-based responsible consumption (SDG 12) and ICT-based gender equality (SDG 5);
- ICT-based responsible consumption (SDG 12) and ICT-based spending on R&D (SDG 9).

The relationships between the pairs are defined further and presented in Table 5.

Following the third step, the authors delivered five specific regression equations, which results in:

$$\begin{array}{c} sdg_4 = 0.06 - 0.52\, sdg_8 \\ (0.034) \quad (0.068) \end{array} \tag{1a}$$

The correlation between ICT-based sustainability SDG 4 and SDG 8 variables is presented below in Figure 1.

$$\begin{array}{c} sdg_5 = 0.02 + 0.28\, sdg_8 + 0.37\, sdg_9 \\ (0.03) \quad (0.10) \qquad (0.07) \end{array} \tag{1b}$$

The correlation between ICT-based sustainability SDG 5, SDG 8, and SDG 9 variables is presented below in Figure 2.

$$\begin{array}{c} sdg_8 = 0.06 - 0.65\, sdg_4 + 0.66\, sdg_5 \\ (0.03) \quad (0.17) \qquad (0.13) \end{array} \tag{1c}$$

The correlation between ICT-based sustainability SDG 8, SDG 4, and SDG 5 variables is presented below in Figure 3.

$$\begin{aligned} sdg_9 &= -0.02 + 0.58\, sdg_{12} + 0.74\, sdg_5 \\ &\quad\ (0.03) \quad\ (0.09) \qquad\ (0.15) \end{aligned} \tag{1d}$$

The correlation between ICT-based sustainability SDG 9, SDG 12, and SDG 5 variables is presented below in Figure 4.

$$\begin{aligned} sdg_{12} &= -0.02 + 0.89\, sdg_9 \\ &\quad\ (0.034) \quad (0.066) \end{aligned} \tag{1e}$$

The correlation between ICT-based sustainability SDG 12 and SDG 9 variables is presented below in Figure 5.

Finally, the authors performed statistical validity tests. All the results of the performed regression analysis are provided in Table 6 following the presentation of the results in Figures 1–5.

For all the constructed regression Equation (1a–e), the F-statistics are higher than the selected F critical value with two degrees of freedom and a probability equal to 0.05 (F_{crit} = 19). In addition, the probability of the F-statistics for all equations is equal to 0 and is lower than 0.05, which shows that the equations are valid.

The methodology suggested by the authors for the analysis of the links between digitalisation and sustainable development is two-staged. The results of the first stage are presented under the correlation matrix placed in Appendix A and the results of the second stage are presented under five valid specific regression equations. The performance of this research in two stages helps to understand the phenomena through a deep analysis.

5. Discussion

The sustainability Development Goals (SDGs) were established by the United Nations in 2015 to revise the social needs of justice, business, and society. The emergence of digital technology represents a ray of hope on the horizon, as it has the potential to guide and stimulate changes to achieve the SDGs in their entirety.

Del Rio Castro el al. [8] explain that digitalisation brings novel cultural, holistic, and multidimensional phenomena across business and society, blurring frontiers and driving a complex and highly interconnected network that fosters multi-shareholder partnership. The results of this study are important for digitalisation policy, thus helping policy-makers to achieve higher SDG values; the scientific studies, on the other hand, did not pay enough attention to the research of the relationship between digitalisation and business sustainable development indicators. The policymakers and government agencies can refer to the results of this paper to formulate requisite policies, plan implementation initiatives, conduct particular training programs, and assist in accelerating sustainability in the European Union. In this paper, the authors focus more on the business direction, aiming to reach sustainability through the evidence of business ties with digitisation.

This study extends Delgosha et al.'s (2021) research and integrates more digitalisation indexes [85] using multiple regression, and adjusts Grijalvo et al.'s (2020) study and integrates SDG 12 into the research [95]. Based on the research and indications of other authors, this study investigated the relationship between digitalisation and indicators of businesses' sustainable development.

The authors proposed a two-step regression method for researching the relationships promoted by [90–93] between the digitalisation and sustainable development variables, and the application of this method was investigated to define relationships among the variables, as suggested by Mukaka et al. [94].

The authors attempted to fill in the gaps in the existing research. This paper provides a theoretical and practical review of these connections, as well as significant new insights into the subject matter, which could be important for regulatory roadmaps and recommendations to support the adoption of digital technologies including the enhancement of capabilities for managing disruptions.

6. Conclusions

The literature review revealed that there are very few studies that are specifically dedicated to the current research area. There are a few studies, but not many, that investigate the link between digitalisation and sustainable production and other topics that contribute to the promotion of environmental sustainability. The authors of this study chose five indicators of sustainable development that represent the needs of the digital businesses to conduct their research.

To broaden the scope of the investigation, the authors proposed a methodological framework that could be used in future studies of a comparable nature. As part of the empirical study, the authors revised 19 information and communication technology variables that described ICT networks, skills, and activities online. There were extremely strong relationships found between the majority of the ICT variables and sustainability indicators. During the study, the authors demonstrated that 13 of the 19 digitalisation indicators have positive results as represent a relationship with all five SDGs. The strongest relationship to SDGs was with digitalisation variables that represented shopping online, and the lowest number of digitalisation indicators with positive results were from the internet category. In addition, all network infrastructure category indicators have positive results except for the fixed-broadband indicators, representing the use of old technology infrastructure that is not important for sustainable business development, mentioned in this category. All these 13 indicators must be further supported when seeking to reach sustainable business development in the European Union.

During the study, the authors clarified the digitalisation indicators indicating the evidence of sustainability in businesses operating in the European Union.

According to the authors, a matrix of correlation coefficients between digitalisation and sustainability indicators was constructed. Using a two-stage methodology, the research shows that there is a strong relationship in all ICT-based sustainable development pairs. According to the findings of the study, digitalisation has a link with employment rates through education and gender equality; education is dependent on R&D spending, and gender equality is also dependent on R&D spending; R&D spending is also strongly linked to responsible consumption and vice versa; and responsible consumption is strongly linked to R&D spending. All of these connections are formed as a result of the use of information and communication technology. The results that have been presented have practical significance.

The study could be repeated by revising links to the country level and on an extended time interval level.

There are some limitations to this research. The authors provide no evidence that the model could be applied in countries other than those of the European Union. Such an aspect could be included and studied in greater depth in future research. It is also possible to revise different periods and to provide an indication of how many periods are required to achieve the greatest possible impact on sustainability indicators.

Author Contributions: The authors declare contributions "Literature review, M.S.; methodology, A.B.; validation and formal analysis, M.S. and A.B. All authors have read and agreed to the published version of the manuscript".

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Correlation between Digitalisation indicators and Sustainable Development Goals variables.

Groups	Digitalisation Indicators	Abbreviation	Statistics	SDG 4	SDG 5	SDG 8	SDG 9	SDG 12
Network infrastructure	Households—level of internet access	HIA	Corr. Coefficient	−0.319	0.501	0.667	0.605	0.586
			Probability	0.0001	0	0	0	0
	Availability of computers (percentage of households)	AOC	Corr. Coefficient	−0.327	0.423	0.660	0.653	0.586
			Probability	0	0	0	0	0
	Households—the type of connection to the internet	HCI	Corr. Coefficient	−0.283	0.490	0.646	0.566	0.487
			Probability	0.001	0	0	0	0
	Mobile internet access (percentage of individuals) individuals used a mobile phone (or smartphone) to access the internet	IMP	Corr. Coefficient	−0.226	0.476	0.561	0.401	0.389
			Probability	0.01	0	0	0	0
	Mobile−cellular subscriptions per 100 inhabitants	MCS	Corr. Coefficient	−0.096	−0.125	0.188	0.035	−0.064
			Probability	0.2	0.1	0.02	0.7	0.4
	Mobile−cellular sub−basket prices % of GNI	MCS01	Corr. Coefficient	0.2955	−0.257	−0.386	−0.393	−0.342
			Probability	0.0003	0.002	0	0	0
	Fixed broadband subscriptions (per 100 people)	FBS	Corr. Coefficient	−0.141	0.510	0.493	0.633	0.612
			Probability	0.09	0	0	0	0
	Fixed−broadband sub−basket prices % of GNI	FBS01	Corr. Coefficient	0.05	−0.162	−0.275	−0.435	−0.449
			Probability	0.5	0.05	0.001	0	0
Internet literacy	Individuals using the Internet (% of the population)	IUI	Corr. Coefficient	−0.359	0.395	0.682	0.626	0.513
			Probability	0	0	0	0	0
	Individuals–internet use	IIU	Corr. Coefficient	−0.319	0.483	0.691	0.653	0.546
			Probability	0.0001	0	0	0	0
	Individuals—mobile internet access	MIA	Corr. Coefficient	−0.179	0.349	0.494	0.568	0.423
			Probability	0.03	0	0	0	0
	Internet use finding information about goods and services	IFI	Corr. Coefficient	−0.325	0.286	0.584	0.546	0.435
			Probability	0.0001	0.0004	0	0	0
	Internet use Internet banking	IIB	Corr. Coefficient	−0.341	0.478	0.703	0.633	0.434
			Probability	0	0	0	0	0
	Internet use participating in social networks	ISN	Corr. Coefficient	−0.154	0.334	0.513	0.268	0.239
			Probability	0.06	0	0	0.001	0.004
	Internet usage seeking health information	IHI	Corr. Coefficient	−0.275	0.338	0.600	0.607	0.386
			Probability	0.0007	0	0	0	0
	Internet use telephoning or video calls	ITC	Corr. Coefficient	−0.337	0.217	0.471	0.017	0.022
			Probability	0	0.008	0	0.8	0.8
Shopping on−line variables	Last online purchase in the 12 months	IPO	Corr. Coefficient	−0.341	0.530	0.669	0.705	0.593
			Probability	0	0	0	0	0
	Individuals using the internet for ordering goods or services	IOG	Corr. Coefficient	−0.347	0.510	0.678	0.706	0.586
			Probability	0	0	0	0	0
	Individuals using the internet for selling goods or services, percentage of individuals	ISG	Corr. Coefficient	−0.332	0.484	0.477	0.628	0.450
			Probability	0	0	0	0	0

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