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Digitalisation affecting sustainability evidence from the European Union

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Abstract: Digitalisation provides access to an integrated network of information that can benefit society, and business. Building digital network and society using digital means can create something unique opportunities to strategically address sustainable development challenges for the United Nations Targets (SDG) to ensure higher productivity, education and to equality oriented society. This point of view describes the potential of digitalisation for society and business of the future. The authors revise the links between digitalisation and sustainability in the European Union countries. The methodology for the research is suggested in the paper and linear regression method is applied. The results showed tiers with five SDG, focusing on society and business, and all these tiers are fixed in the constructed equations for each SDG. The suggested solution is statistically valid and proves the novelty of research. Among digitalisation indicators, only mobile-cellular subscriptions and fixed-broadband sub-basket prices in part have no effect on researched sustainable development indicators.

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

1. Introduction

Digitalisation is a widely used phrase with several meanings, many of which are case-specific. Digital connectivity, internet use, e-business, e-commerce, and e-government are all used to quantify digitalisation [1]. 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 [2]. 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; business model innovation, such as the move to advanced service business models, is required [3]. The Sustainable Development Goals, which were introduced in 2015 as part of the United Nations 2030 Agenda, have the potential to help close 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 society." [4].The combination of sustainability and digitization creates both untapped potential and serious challenges to the 2030 Agenda, while also offering up attractive research and policy development options. From another hand, by offering new data sources and increased analytical capabilities, digital paradigms might help to close a

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number of SDG research gaps. By limiting negative effects and achieving true sustainability, digitalisation should be carefully embraced [5].

Using digital tools to build a digital network and society may provide one-of-a-kind opportunities to proactively solve sustainable development concerns for the United Nations' Sustainable Development Goals (SDGs) to guarantee increased production, education, and a more equitable society. This viewpoint outlines the future possibilities of digitization for society and industry. The aim of this review is to re-examine the connections between digitalisation and sustainability in European Union nations, and to find out how does the digitalisation affecting sustainability.

The literature review shows that publications on digitalisation are increasing in recent decades (see Table below).

Table 1. Review of 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	1 060	371	7
2009-2013	1 750	699	8
2014-2018	5 550	2 810	298
2019-2022	12 700	8 990	208
Total	21 791	13 042	526
%	**100%**	59,8%	2.4%

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

The analysis of publications (i.e., review of books published by Oxford University Press, Cambridge University Press, Harvard University Press, Springer, M.E. Sharpe, 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 under Table 1 shows that less than 2.4 per cent of the above publications contain investigations in digitalisation and SDG area. That is why it is important to investigate possibilities to activate the impact of digitalisation on sustainability, specifically on SDG. This shows that it is evident that digitalisation supports sustainability in various forms and the research about the impact of digitalisation on SDG have already been started.

The paper contains from the literature review, which is separately revise the connection of digitalisation and specific SDG elements. For the revision five main SDG were selected. Further on, the authors present methodology and empiric research. Finally, the authors finalise the article with discussion and conclusion sections.

2. Literature review

As the concept of digitalization is relevant to a wide range of various industries, it is natural that there is a large number of studies conducted on it. Here are some newest examples of it [6]–[17]. Many of these studies are looking into the topic of digital transformation [18]–[29], and even some of them are continuing to review the relationship between digitalization and long-term sustainability [30]–[41]. However only few of these scientific publications are going into a deeper discussion on impact of some particular SDGs on the digital transformation level. In table 2 we summarized some newest researched on the particular topics, which provide a link between the digitalization and sustainability and SDGs.

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Table 2. The newest publications on topic of Digitalization and SDGs.

Topic	Sources
Digitalisation & Sustainability	[30]–[41]
Digitalisation & SDG4	[5], [42]–[51]
Digitalisation & SDG5	[52]–[55]
Digitalisation & SDG8	[56]–[62]
Digitalisation & SDG9	[63]–[65]
Digitalisation & SDG12	[66]–[71]

Good example on 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 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 & 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 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 & Ribiere [2] examined 134 definitions of digital transformation in order to get insight into six essential defining primitives of Digital Transformation (DT) in order to determine the language and conceptual clarity that distinguishes the concept from other comparable words.

Parida et al [3] conducted a thorough evaluation of the literature on digitalisation, business model innovation, and sustainability in industrial settings in order to contribute by creating a framework that explains and directs future research.

Del Río Castro et al. [5] 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 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 [65]. 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 digitized data.

The idea of this research is to measure the impact of digitalisation on some particular sustainable development goals. After analysing scientific publications, related to this topic, there were some useful publication, describing or investigating the impact of digitalisation [4], [5], [59], [75]. Following sections are dedicated for a comprehensive literature review on five sustainable development goals separately: Sustainable Development Goal 4 (SDG4) for Quality Education; Sustainable Development Goal 5 (SDG5) for Gender Equality; Sustainable Development Goal 8 (SDG8) for Decent Work and Economic Growth, Sustainable Development Goal 9 (SDG9) for Industry, Innovation and Infrastructure; and Sustainable Development Goal 12 (SDG12) for Responsible Consumption and Production.

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2.1. The link between digitalisation and SDG4

SDG4 (Quality Education) aims to raise 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 in access to education are also envisioned as part of the goal [52].

In general, the importance of digitalisation in education in a broad sense is being reviewed in several studies [45], [47] [46], [48]. However, most scientists investigate these two expressions separately, and there are no detailed review on their interactions. There are no studies examining the impact of digitalisation on the sustainable development of higher education and, moreover, there are no clear existing recommendations provided in order to improve the quality in 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 [42] [43] [76] [49] [50] [77] emphasizes that the results of their research suggest the need for further interdisciplinary research, the need to strengthen the legal framework and clear practical guidelines on how to effectively manage the impact of digitalisation on sustainable education.

For example, Brevik et al. [42] 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. [43] discusses five educational and technological trends for a sustainable future, with the basic premise that each of these movements includes both hazards and opportunities, and our reforms must be made with an understanding of both.

De Sousa et al. [44] suggested a model of digital education methods and technologies to help 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 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.

Also, there are some interesting statistics about digitalisation impact on sustainability. For example, [49] looked at the role of ICT and education on 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 & Costa [50] looked at 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 'publicize' intellectual life have encountered. The authors suggest that colleges take numerous actions to address this requirement and successfully anticipate the future in an already current occurrence.

2.2. Digitalisation link with SDG5

SDG5 (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 [52].

Digitalisation and sustainable development goal concerning gender equality is not very popular topic between the scientists, but there are some interesting reviews, who states some interesting facts about these question. For example, Luo & Chan [55] claim that the development of digital entrepreneurship may boost women 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 & Arcidiacono [54], the greatest single contribution to the digital gender gap is disparities in job patterns between men and women. Furthermore, women had a higher link between work and Internet usage than males. The gender digital divide would be eliminated by at least a quarter if women were employed at the same rate as men.

Generally, the gender equality in access to the internet and mobile phones has become increasingly recognised as a development goal. Fatehkia et al. [53] 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 utilized to improve coverage for a key development indicator, with low-income nations benefiting the most.

2.3. Digitalisation link with SDG8

SDG8 (Decent Work and Economic Growth) emphasizes the need of 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 [52].

There are plenty of examples, showing how do the new digital technologies positively affect wage growth and employment stability. For example, [61] looked at the effects of new digital technologies on income and employment disparities in the United States. The findings demonstrate that labor-displacing technology lowers wage growth and job stability while improving individual labor market outcomes. It's worth noting that employees with a high degree of formal education are the ones who are most impacted.

Enciso-Santocildes et al. [62] investigated if the novel method for combining employment with digitalisation is viable and trustworthy. The response is extremely important for corporate and governmental institutions interested in putting in place effective anti-unemployment policies, particularly for vulnerable populations.

Ndubuisi et al. [58] investigates 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. Institutional and economic factors influence the impact of digital infrastructure on the services industry.

In the case of Italy from 2011 to 2016, [57] investigates the relationship between digitalisation of labour processes, the amount of routineness of labour duties, and changes in employment. 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. [60] used a large sample of 5511 Spanish manufacturing enterprises from 1991 to 2016 to give 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 high rates of investment required to modernize production technologies.

Domini et al. [56] looked at 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 the net employment growth rate of businesses.

2.4. Digitalisation link with SDG9

SDG9 (Industry, Innovation and Infrastructure) encourages the development of resilient and long-term infrastructure as well as inclusive and sustainable industrialization. It also recognizes the value of research and innovation in addressing long-term social, economic, and environmental issues [52].

Making an accent on the gross domestic expenditure on R&D, there are not much examples with regard to that. This aspect still needs to be investigated broader. However,

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some of the existing studies on that particular topic is mostly about the expenditure level in the Higher Education (HE) sectors or about the GDP in measuring the digital economy. Vītola & Eriņa [63] 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. While from the one hand some studies aim to identify challenges, required competencies of the workforce and requirements for trainings to successfully implement digitalisation in Small and Medium Enterprises (SMEs) [66].

The productivity paradox and the limitations of GDP in evaluating the digital economy are discussed by [64]. 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 suprafunctionality that goes beyond economic value.

Hustad & Olsen [78] 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 lay forth the requirements for establishing a long-term digital infrastructure based on services.

Zoppelletto & Orlandi [79] presented a work "Cultural and digital collaboration infrastructures as sustainability enhancing factors: A configurational approach". This study intends 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 link with SDG12

SDG12 (Responsible Consumption and Production) calls 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 [52].

There are some interesting researched regarding the digitalisation impact on the resource productivity and domestic material consumption. Some examples with regard to the effect of digitalisation in the energy consumption of passenger transport. Different scenarios enable evaluating alternative digitalisation pathways, according to Noussan & 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 them, does not separate economic development from energy use. [68] looked at the impact of internet development on energy consumption in China and discovered that there is a considerable negative link between internet development and energy consumption structure.

While from the one hand some studies report about the impact of the digital transformation on Lean production systems [67].

One more interesting research is by Pouri [69], where author looks at eight different ways that the digital sharing economy affects resource use. Pouri concluded that understanding the effects of 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).

Following a summary of the literature review, it can be seen that despite extensive research on specific topics such as digitalization and the UN Sustainable Development

Goals (SDGs), a comprehensive examination of all of the critical elements that link these topics has not been done in the past. 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 in order 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 digitalization is presented. Both digitalisation and the Sustainable Development Goals (SDGs) are discussed in this paper, though they are distinct concepts that are interconnected. After that, these concepts are explored in greater depth later in the paper. 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 may have an impact on the overall level of digitalisation. The methodology for selecting SDGs will be discussed in the following session, during which the primary criteria for selecting SDGs will be defined and discussed in greater detail.

2. Methods and results

To explore the phenomena the authors investigated in phases. The authors apply a two-stage methodology to identify the relationships between ICT and sustainability indicators (as specified in Table 3) and later investigated how whose pairs with defined relationships, are interconnected among each other.

Table 3. 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 the 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 figure out the correlation between pairs. Selected available data for variables from the Eurostat and UNECE public databases for the 10 years 2011-2020 are used to analyse dynamic interactions with such indicators of five sustainability goals indicators:

1. SDG4 - Early leavers from education and training,
2. SDG5 - Positions held by women in senior management positions,
3. SDG8 - Employment rate,
4. SDG9 - Gross domestic expenditure on research and development activity,
5. SDG12 - Resource productivity and domestic material consumption.

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

The authors apply 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) selected the data from the public databases and constructed a correlation matrix among ICT and five sustainable development indicators. This analysis the existence (non-existence) of relationships in pairs. The authors of the dependent variables selected the ICT indicators having probability lower than 0.1;

(2) formed the regression model and presented it under Equation (1). The model presents interlinks with one or two pairs of ICT-based sustainability development indicators. The links among pairs are presented in the Table 4;

(3) following the regression model, the authors created five Equations (1.1-1.5) 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) provided validation analysis for five constructed equations according to the least square method Appendix B and presented the results under Table 5.

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

Under 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 indicator in the EU 27 countries, where r and v equal to one sustainable development goal (4, 5, 8, 9 or 12), both are not equal to n and fulfil the condition that r is not equal to v

u_t – random model error

$\beta_1, .., \beta_n$ – coefficients of elasticity reflect the influence of independent variables on ICT-based sustainable development.

The relationships between pairs are defined further and presented under Table 4.

Table 4. ICT-based statistical relationships.

ICT-based sustainability indicators	ICT-based **SDG4**	ICT-based **SDG5**	ICT-based **SDG8**	ICT-based **SDG9**	ICT-based **SDG12**
ICT-based SDG4			X		
ICT-based SDG5			X	X	
ICT-based SDG8	X	X			
ICT-based SDG9		X			X
ICT-based SDG12				X	

The study shows the ties between such
- ICT-based quality education (SDG4) and ICT-based employment (SDG8),
- ICT-based gender equality (SDG5) with ICT-based employment (SDG8) and ICT-based spending on R&D (SDG9),
- ICT-based employment (SDG8) has a tier with ICT-based quality education (SDG4) and ICT-based gender equality (SDG5),
- ICT-based spending on R&D (SDG9) has a link with ICT-based responsible consumption (SDG12) and ICT-based gender equality (SDG5),
- ICT-based responsible consumption (SDG12) and ICT-based spending on R&D (SDG9).

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

$$sdg_4 = 0.06 - 0.52\, sdg_8 \quad (1.1)$$
$$\qquad (0.034) \qquad (0.068)$$

$$sdg_5 = 0.02 + 0.28\, sdg_8 + 0.37\, sdg_9 \quad (1.2)$$
$$\qquad (0.03) \qquad (0.10) \qquad (0.07)$$

$$sdg_8 = 0.06 - 0.65\, sdg_4 + 0.66\, sdg_5 \quad (1.3)$$
$$\qquad (0.03) \qquad (0.17) \qquad (0.13)$$

$$sdg_9 = -0.02 + 0.58\, sdg_{12} + 0.74\, sdg_5 \quad (1.4)$$
$$\qquad (0.03) \qquad (0.09) \qquad (0.15)$$

$$sdg_{12} = -0.02 + 0.89\, sdg_9 \quad (1.5)$$
$$\qquad (0.034) \qquad (0.066)$$

And finally, the authors performed statistical validity tests. All results of the performed regression analysis are provided in Table 5 following the presentation of the results in Appendix B.

Table 5. Formation of regression equations.

Indicators of statistics	Eq.1.1	Eq.1.2	Eq.1.3	Eq.1.4	Eq.1.5
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

For all constructed by the authors regression equations (1.1-1.5) F-statistics is higher than the selected F critical value with two degrees of freedom and probability equal to 0.05 (F_{crit} = 19). Also, the probability of 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 links between digitalisation and sustainable development is two-stage. The results of the first stage are presented under correlation matrix placed in Appendix A and the results of the second stage are presented under valid five specific regression equations. The performance of research in two stages helps to understand phenomena through deep analysis.

4. Discussion

Sustainability Development Goals (SDGs) were established by the United Nations in 2015 to examine the action plan, as well as 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 in order to achieve all 17 SDGs in their entirety. Other authors have demonstrated the importance of digitalisation and Internet of Things technologies, as well as their ability to solve major problems, by connecting food, water, and energy; creating the conditions for sustainable production and Industry 4.0; and improving social prosperity while mitigating global warming. In addition, the impact of cultural values on the quest for greater sustainability has been investigated. The scientific studies, on the other hand, did not pay enough attention to the impact of digitalisation on society and business sustainable indicators, as a result. The authors attempted to fill in the

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gaps in the existing research. The paper provides a theoretical and practical review of these connections, as well as significant new insights into the subject matter.

There are some limitations to the 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 directions. It is also possible to revise different time periods and to provide an indication of how many time periods are required to achieve the greatest possible impact on sustainability indicators.

5. Conclusions

The review of the literature reveals that there are very few studies that are specifically dedicated to the research area. There are a few studies, but not many, that investigate the impact of digitalization on sustainable production and other topics that contribute to the promotion of environmental sustainability. The authors of the study chose five indicators of sustainable development that represent the needs of the digital society and business in order to conduct their research.

In order 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 ICT variables and sustainability indicators.

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 an impact on 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 on country level and on extended time interval level.

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Appendix A

Correlation between ICT and sustainable development variables.

Groups	The number of visits to sharing platforms	Abbreviation	Statistics	SDG4	SDG5	SDG8	SDG9	SDG12
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

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			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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Appendix B

Correlation between ICT-based sustainability variables.

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		

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		

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		

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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		

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		

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