

Article

Digital Revolution, Sustainability, and Government Revenues: A Transversal Analysis of How Digital Transformation and Sustainable Practices Impact Sustainable Government Revenues

Anca Antoaneta Vărzaru ^{1,*} , Claudiu George Bocean ^{2,*} , Dalia Simion ³ , Dorel Berceanu ³
and Mădălina Giorgia Mangra ³ 

- ¹ Department of Economics, Accounting and International Business, Faculty of Economics and Business Administration, University of Craiova, 13 AI Cuza Street, 200585 Craiova, Romania
- ² Department of Management, Marketing and Business Administration, Faculty of Economics and Business Administration, University of Craiova, 13 AI Cuza Street, 200585 Craiova, Romania
- ³ Department of Finance, Banking, and Economic Analysis, Faculty of Economics and Business Administration, University of Craiova, 13 AI Cuza Street, 200585 Craiova, Romania; dalia.simion@edu.ucv.ro (D.S.); dorel.berceanu@edu.ucv.ro (D.B.); madalina.mangra@edu.ucv.ro (M.G.M.)
- * Correspondence: anca.varzaru@edu.ucv.ro (A.A.V.); claudiu.bocean@edu.ucv.ro (C.G.B.); Tel.: +40-7-2629-9522 (C.G.B.)

Abstract: In recent decades, digital transformation and sustainability have become two crucial aspects of economic and social development in the European Union (EU), improving government tax collection and other government incomes. This paper investigates the interplay between digital transformation and sustainability and their impact on total general government revenue (TGGR) in the European Union (EU). The study uses quantitative research methods to analyze relationships among variables, including artificial neural networks and cluster analyses. The variables considered in this research are the Digital Economy and Society Index (DESI), the Sustainable Development Goals (SDG) index, and TGGR. Our findings reveal intricate connections between digital transformation, sustainability, and TGGR across EU member states. The DESI score measures the level of digitalization within each country, while the SDG Index assesses sustainability performance. The study demonstrates that countries with higher DESI scores tend to experience increased TGGR, indicating that a more robust digital economy contributes positively to government revenue, among other elements. The research identifies clusters of EU member states with similar patterns of digital transformation, sustainability, and TGGR. These clusters highlight challenges and opportunities, guiding policymakers in tailoring strategies to boost digitalization and government revenue sustainably.

Keywords: digital transformation; digital economy and society index; sustainability; SDG score; cloud computing; e-commerce



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1. Introduction

In an era of digital transformation and growing sustainability concerns, Europe faces unprecedented challenges and opportunities concerning economic and financial development. Digital transformation has brought about a revolution in how economies and societies operate [1]. Advanced information technologies democratized access to information, services, and markets. This phenomenon has improved economic efficiency and competitiveness, increasing government revenues [2]. Following the digitization of economic sectors, tax collection, and other fiscal resources have increased, with digital transformation promoting innovation and developing new industries. Consequently, these processes generate new jobs and additional income for government budgets [3].

This paper focuses on the influence of digital transformation and sustainability on Total General Government Revenue (TGGR) in European Union (EU) member states. The empirical study uses variables such as the Digital Economy and Society Index (DESI), the

Sustainable Development Goals index (SDG), and TGGR. The paper addresses a gap in the literature regarding the impact of digital transformation and sustainability on total government revenues [2,4]. Most existing research primarily focuses on economic growth, factors compatibility, government regulations, and sustainable development [1]. Digital transformation can significantly assist in implementing tax-related reforms, such as fiscal decentralization and transfer pricing identification [5]. Public authorities should accelerate the implementation of digital technologies, especially artificial intelligence, big data, and cloud computing, to streamline fiscal management and reduce tax losses to ensure the sustainable development of government finances [6].

The fundamental purpose of this paper is to analyze how digital transformation and sustainability interact in the context of government revenue collection in the EU. This research relies on quantitative approaches, including artificial neural network analysis and cluster analysis, to illustrate and quantify the complex relationships between these factors. In our analysis, we aim to address several crucial research questions:

- What is the intensity of the influence exerted by the level of digital transformation, as measured by DESI, on general government revenues in EU countries?
- Is there a significant link between sustainability performance, measured by the SDG index, and TGGR in EU member states?
- How do European countries differ concerning the relationships between digital transformation, sustainability, and government revenues?

While there is extensive research on digital transformation and sustainability in Europe, few studies focus on how these two aspects directly relate to the evolution of general government revenues. This paper makes a significant contribution by exploring this connection and applying advanced quantitative methods to investigate and quantify this interdependence. The originality lies in a holistic approach, integrating both digital and sustainability aspects into a comprehensive analysis focused on the economic realities of the EU.

The structure of this paper implies six sections. The introduction presents the context, research questions, the literature gap, and the study's original contributions. The review of the relevant literature examines the relationships between digital transformation, sustainability, and government revenues in the context of the EU. The third section exposes the data collection and research methods. The following sections present the results from artificial neural network and cluster analysis, discussions on the implications, and contextualization within the existing literature. The final section summarizes the main conclusions and contributions, providing suggestions for future research.

2. Literature Review and Research Hypotheses

Digital transformation represents adopting and integrating digital technologies into all aspects of society and the economy. The COVID-19 pandemic has served as an accelerant for digital transformation. The abrupt shift to remote work, online education, telehealth, and e-commerce underscored the critical role of digital technologies in maintaining economic and social continuity during crises. A growing body of literature elucidates how the pandemic has expedited digitalization in both the public and private sectors [7–10].

Digital transformation in public governance embodies an adaptation to information technology requirements, profoundly impacting how government institutions operate [11]. This transformation entails a gradual shift from traditional public management methods to a more integrated approach to public functions. Civil society plays a crucial role in this context, exerting increasing pressure to provide innovative digital services and adopt advanced information and communication technologies in government administration [12]. The primary goal is to make governance more responsive and efficient in the face of political, economic, and social challenges [12]. New technologies enable governments to deliver faster and more efficient services, collect data, and evaluate policies with unprecedented precision and accuracy [11].

Digital technologies, information and communication technologies, and other technological innovations influence our daily lives [1,13,14]. A crucial aspect of this transformation is the ability to manage cross-sectoral transitions on a geographic level [15]. This fundamental change offers new planning, management, and development opportunities in an era of intelligent and innovative solutions [1].

Digital technologies have significant potential to enhance government operations, facilitating better resource management and the functioning of government organizations [16]. These technological innovations contribute to increasing national competitiveness [17]. The digital transformation driven by information and digital technologies is not limited to government administration but influences the entire spectrum of human activities [18,19]. It accelerates processes and increases efficiency, leading to faster economic growth than in previous periods [20,21]. In an increasingly digitally connected world, national competitiveness depends more and more on the ability to adapt and exploit information and digital technologies. This change also requires a review of government policies to facilitate and support this transformation [17].

Using digital technologies in governance brings numerous benefits, including reducing corruption and consolidating government power [12,22]. Digital technologies bring transparency to government processes, easing the monitoring and auditing of government activities. Transparency can contribute to rebuilding citizens' trust in government and greater accountability to the population's needs and expectations [23]. An efficient public administration powered by digital technologies can lead to more efficient government revenue collection [14]. Automating administrative processes, online tax collection systems, and digital monitoring of fiscal transactions can reduce tax evasion and improve revenue collection. Digital transformation can enhance the transparency and accountability of governments, increasing the trust of citizens and investors. Accountability can create a more attractive foreign direct investment environment, generating additional income [24].

Digital transformation is a profound process redefining how governments operate at micro and macro levels [17]. Stimulating the economy and accelerating the flow of capital significantly contributes to economic growth, generating additional government revenues. By facilitating innovation and economic growth, digital technologies can stimulate the development of new economic sectors or diversify the economy, resulting in higher tax revenues. Digital transformation contributes to increasing prosperity [25]. Policymakers have recognized this phenomenon and have increasingly emphasized smart solutions in their national and international sectoral development strategies [26]. Policymakers want powerful and efficient tools to develop appropriate strategies that respond to the complex challenges of an interconnected system [27].

Implementing digital technologies in revenue management is crucial in improving public revenue collection. The automation of budget payments and the digitization of processes can significantly impact the quality of budget management and enhance fiscal transparency. Additionally, digitization can improve spending efficiency in critical sectors such as healthcare and education [3].

The digital transformation of government services represents a significant opportunity to modernize the public sector. This transformation includes implementing digital solutions such as cloud storage, digital payment processes, and digital identification and developing internal systems to support revenue administration and public financial management. It may also involve providing online services to citizens, such as filing tax returns or managing medical records [28]. Digital transformation must be inclusive to ensure that all citizens, including those with low levels of digital literacy, have access to digital public services [29].

The relationship between digitization and public finances is bidirectional and has seen significant acceleration in recent years, especially during the COVID-19 pandemic [30]. Digital transformation facilitates the use of technology to improve financial and administrative processes and enhance fiscal transparency and government accountability [3]. Based on these findings identified in previous research, this paper proposes the following hypothesis:

Hypothesis H1. *The level of digital transformation, measured by DESI, significantly influences government revenues (TGGR) in EU countries.*

In today's world, three concepts are becoming increasingly relevant and significant in transition and development processes: digital transformation, innovation, and sustainability [14]. Their importance is growing as we face increasingly complex and diverse global challenges. These challenges impact the private sector and government administration, growing the need to find interdisciplinary and multidimensional solutions. Such challenges include climate change, environmental pollution, migration, and pandemics [4,31]. Digital transformation brings challenges, new opportunities, and solutions for various stakeholders, individuals, companies, sectors, or regions [32].

The technological characteristics of the digital economy have become a significant force in promoting sustainable development, bringing innovations that significantly impact people's quality of life and environmental protection. This technical progress opens new opportunities for increasing organizational profitability and implementing more sustainable economic practices [33].

Digital transformation and a focus on sustainability are closely related concepts [34,35]. The digital economy is characterized by technologies that can reduce carbon emissions and promote circular economies, which benefit global sustainability [33]. Technological advancements within the digital economy allow business leaders and decision-makers to monitor and evaluate business activities and regulations to promote sustainable development [1,36,37].

Sustainable performance is a significant topic today, with profound implications for government revenues in the EU [1]. Improved sustainability performance can reduce the costs associated with environmental and public health issues. Fewer pollutants and better access to quality healthcare can reduce government expenditures on environmental remediation and treating environmentally related illnesses [38]. Thus, the government can allocate the saved resources to other essential sectors, contributing to revenue growth.

However, the influence is bidirectional [4]. Government revenues can, in turn, influence sustainability performance. Governments with larger budgets have the resources to invest in sustainable development projects and promote greener economic practices. They can also implement fiscal policies and incentives to encourage sustainable behaviors among citizens and companies.

Sustainability performance and government revenues are closely intertwined and mutually influential in EU member states [1]. More remarkable progress in achieving Sustainable Development Goals can bring significant economic benefits by increasing government revenues and reducing the costs associated with environmental and public health issues. Government revenues can support sustainable development and create a more prosperous and equitable future. Therefore, governments and the international community need to continue to invest in and promote these objectives, recognizing their fundamental importance for society's and the environment's well-being [33]. Better performance in achieving Sustainable Development Goals can lead to a more stable and sustainable economy. Investments in renewable energy and eco-friendly technologies can reduce dependence on fossil fuels and increase economic competitiveness. These investments can increase production, exports, and government revenues from taxes and fees. The paper proposes a second hypothesis based on findings identified in previous research:

Hypothesis H2. *Sustainability performance, measured by the SDG index, significantly influences government revenues (TGGR) in EU member states.*

Digital transformation is an evolving reality, bringing both significant challenges and opportunities. This transformation is accompanied by radical changes across all aspects of society, impacting not only individual sectors but entire regions. It is a process that brings unique solutions to address the issues we face on both social and economic levels, even

in the environmental context [1]. Government competition policy is an essential tool for supporting and guiding the digital transformation of businesses in the modern era [39]. This policy should be dynamic, adapting to the continuous changes in the business environment. Government expenditures on research and development and government subsidies significantly facilitate digital transformation [40]. By reducing financing constraints and enhancing businesses' financial stability, these government measures can promote innovation and the adoption of digital technology in the private sector [41].

At the same time, government policies on interest rate liberalization can positively influence digital transformation [42]. A more accessible financial environment can stimulate investments in technology and innovation. However, in some cases, the government's objectives for rapid economic growth can inhibit the digital transformation of businesses [43]. This process can lead to a greater focus on immediate economic aspects at the expense of long-term investments in digital technology.

Public authorities can use data collected and analyzed through digital technologies to develop policies and regulations that encourage a rapid transition to more sustainable business practices [44,45]. There are numerous ways in which the digital economy can support sustainability, from increased resource efficiency to real-time monitoring of energy consumption and the promotion of the circular economy [46–48]. Digital transformation also contributes to developing and adopting renewable energy sources, helping to reduce greenhouse gas emissions [49], and creating smart cities that promote more responsible consumption [50]. This close link between digital transformation and sustainability significantly impacts government revenues. As the digital economy has demonstrated its essential role in promoting sustainability, the impact on government revenues has become increasingly evident and significant.

The relationship between digital transformation, sustainability, and government revenues is not necessarily directly proportional and straightforward. There are intermediate variables and specific national contexts that can influence this connection. The level of penetration of digital technologies in various economic sectors can vary between countries, leading to differences in the impact of digital transformation on government revenues.

Starting with digital transformation, it is evident that Europe is a continent with remarkable diversity in the adoption of digital technology [1]. Digital transformation, sustainability, and government revenues are vital dimensions that can be used to group European countries into homogeneous clusters. These clusters reveal significant differences in how these aspects are approached and can guide regional collaboration and the development of standard policies. It is clear that Europe is a diverse and complex continent, and understanding these differences can contribute to creating more efficient and tailored solutions to the specific needs of each country regarding digital transformation, sustainability, and government revenues. The paper proposes a third hypothesis based on findings identified in previous research:

Hypothesis H3. *European countries can be grouped into homogeneous clusters regarding digital transformation, sustainability, and government revenues.*

COVID-19 has forcefully underscored the vital role of digitalization in addressing the socio-economic and governmental challenges posed by the crisis. Lockdowns, remote work, online commerce, telemedicine, and digital education, among others, have accentuated the pivotal role of digital technologies [7–10]. Governments across the EU have been compelled to expedite the implementation of digital solutions to adapt to rapidly changing circumstances, reinforcing the importance of the digital transformation aspect in government practices [51–57]. The pandemic has revealed the significance of sustainability in crisis management [10]. Sustainable practices and policies have demonstrated their potential to enhance resilience and sustainability during times of crisis. As the EU grapples with the pandemic's economic and social consequences, understanding the relationship between sustainability, digitalization, and TGGR is now more relevant than ever.

3. Design and Research Methodology

The research process involved an exploratory investigation of the literature (Figure 1). Based on the new findings, we built a theoretical model and formulated three hypotheses for validation after collecting data on digital transformation, sustainability, and government revenues at the level of European Union member states.

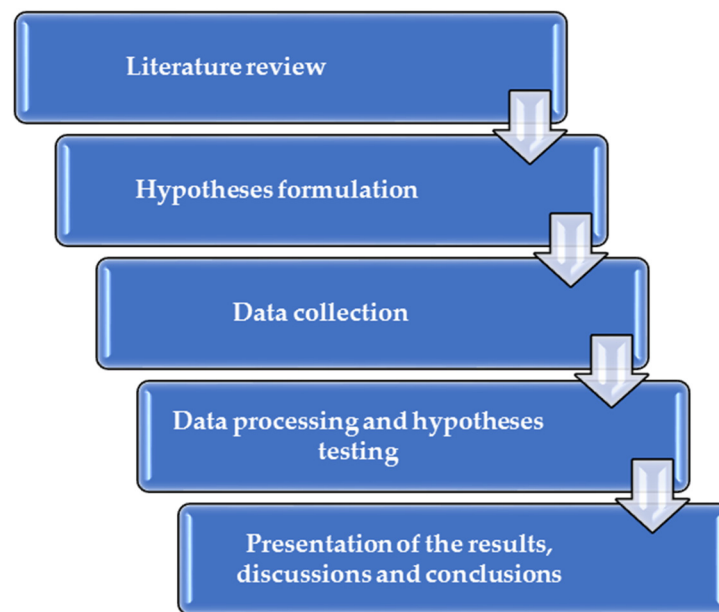


Figure 1. Research process stages. Source: designed by the authors.

The three hypotheses proposed in this study focus on the relationships between digital transformation, measured by the DESI index, sustainability measured by the SDG index, and government revenues evaluated using the Eurostat TGGR indicator.

Figure 2 illustrates the theoretical model underlying the research into the relationship between digital transformation, sustainability, and government revenues and the research hypotheses. There is a substantial body of literature supporting the theory that digitization and sustainable practices have a significant impact on government revenues [55–57]. This theory is grounded in research from various fields and empirical evidence that demonstrates how the interaction between digitization and sustainability can positively or negatively influence government revenues in various contexts [8,11,12,23,24,55–57].

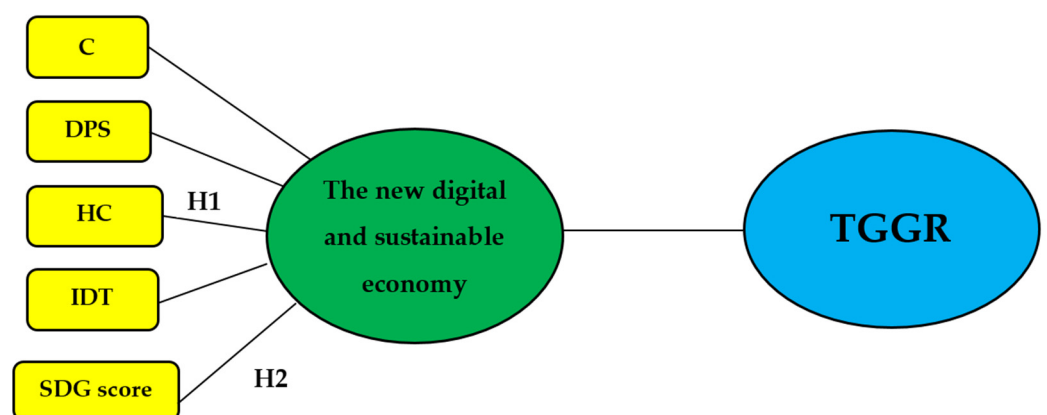


Figure 2. Theoretical model. Source: designed by the authors.

Government revenues (TGGR) are essential for providing public services such as healthcare, education, infrastructure, and social security [58]. These revenues mainly come

from taxes and fees collected by the government and other sources such as loans and income from natural resources.

There are many composite indicators to assess the impact of digital transformation in EU member countries. This research used the DESI (Digital Economy and Society Index) [59]. The DESI indicator, created by the European Commission, provides a measure of the degree of digitization in EU member countries, covering aspects such as digital infrastructure represented by connectivity (C), the digital skills of human capital (HC), the use of digital public services (DPS), and the integration of digital technologies (IDT) in businesses [60].

The United Nations Sustainable Development Goals (SDGs) can be a powerful and comprehensive tool for assessing country-level performance [61]. For this research, we used the SDG index as a variable describing sustainability. The SDG index, which illustrates a country's sustainability score, is a tool developed by the United Nations to assess each country's progress in achieving the 17 Sustainable Development Goals in the 2030 Agenda [61]. These goals cover a wide range of aspects, from poverty reduction and inequality to environmental protection and the promotion of social justice. A country's performance in these goals is measured based on various indicators, including access to education, water and air quality, population health, sustainable infrastructure, etc.

Table 1 presents the variables, data series used, units of measurement, and the reference to the collected data.

Table 1. Research variables.

Variable	Dataset	Measures	References
TGGR	Total General Government Revenue	Percentage of gross domestic product (GDP)	[58]
C	Connectivity	Weighted score (0 to 100)	[59]
DPS	Digital Public Services	Weighted score (0 to 100)	[59]
HC	Human Capital	Weighted score (0 to 100)	[59]
IDT	Integration of Digital Technology	Weighted score (0 to 100)	[59]
SDGi	SDG Index Score	Weighted score (0 to 100)	[60]

Source: developed by the authors based on [47,48,50].

Table 2 exposes the descriptive statistics of the research variables (including skewness and kurtosis).

Table 2. Descriptive statistics.

Variable	N	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
TGGR	27	23.00	53.40	42.8370	6.75632	−0.828	1.377
C	27	9.96	19.27	14.1195	2.15321	0.401	0.037
DPS	27	5.26	22.79	17.0511	4.16664	−0.869	0.863
HC	27	7.73	17.85	12.1133	2.50703	0.347	−0.324
IDT	27	3.79	14.77	9.2447	2.93160	0.092	−0.243
SDGi	27	74.10	86.40	79.5444	3.11699	0.340	0.219

Source: developed by the authors using SPSS v.27.

To test the hypotheses H1 and H2, we will apply artificial neural network analysis. The MLP allows for identifying relationships between variables placed in the input and output layers [62]. We selected a model based on back-propagation to determine these influences (1).

$$y = \left(\sum_{i=1}^n w_i x_i + b \right) = \varphi \left(W^T X + b \right) \quad (1)$$

w, x —vectors of weights and inputs;

b —bias;

φ —activation functions.

As activation functions, we used a hyperbolic tangent Function (2):

$$f(n) = \frac{e^n - e^{-n}}{e^n + e^{-n}} = \frac{e^{2n} - 1}{e^{2n} + 1} \quad (2)$$

n —input variables;

$f(n)$ —output variables.

For Hypothesis H3, the investigation uses cluster analysis (3). The optimal approach was the Ward linkage method [63]. The distance between two clusters, A and B, is how much the sum of squares will increase when we merge them [64]:

$$\Delta(A, B) = \sum_{i \in A \cup B} \left\| \vec{x}_i - \vec{m}_{A \cup B} \right\|^2 - \sum_{i \in A} \left\| \vec{x}_i - \vec{m}_A \right\|^2 - \sum_{i \in B} \left\| \vec{x}_i - \vec{m}_B \right\|^2 = \frac{n_A n_B}{n_A + n_B} \left\| \vec{m}_A - \vec{m}_B \right\|^2 \quad (3)$$

\vec{m}_j —the center of cluster j ;

n_j —number of points in cluster j ;

Δ —merging cost of combining the clusters A and B;

i —cases.

Ward's linkage is typically limited to the squared Euclidean distance metric, which measures original distances between observations [65].

For artificial neural network analysis and cluster analysis, the paper uses SPSS v.27.

4. Results

The first two hypotheses, which focus on the relationships established between digital transformation, measured by DESI, sustainability, measured by SDGi, and government revenues, measured by TGGR, were investigated using artificial neural network analysis.

To assess the impact of DESI indicators on TGGR in the EU, we used an MLP (multi-layer perceptron) model capable of uncovering complex relationships within datasets. The data included values for each of the four DESI indicators, the SDG index, and TGGR for each EU member country. We trained the model to identify correlations and predict TGGR based on variations in DESI and SDG index indicators.

Figure 3 exposes the empirical model generated using SPSS v27 software based on the conceptual model.

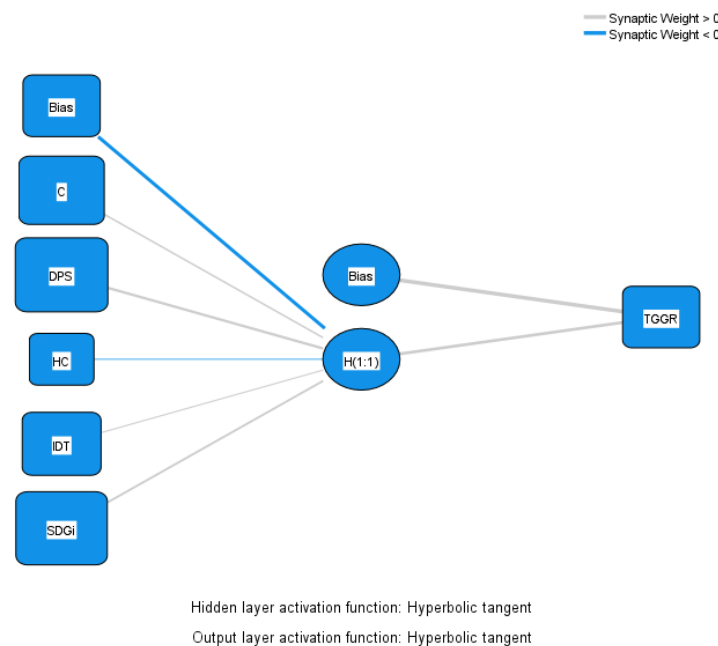


Figure 3. Theoretical model. Source: developed by the authors using SPSS v27.

Table 3 presents the parameter values of the MLP model.

Table 3. MLP parameters.

Predictor		Predicted		Importance	Normalized Importance
		Hidden Layer 1	Output Layer		
		H(1:1)	TGGR		
Input Layer	(Bias)	−0.467			
	C	0.289		0.227	76.7%
	DPS	0.372		0.296	100.0%
	HC	−0.039		0.028	9.4%
	IDT	0.212		0.164	55.4%
Hidden Layer 1	SDGi	0.366		0.285	96.1%
	(Bias)		0.550		
	H(1:1)		0.399		

Source: developed by the authors using SPSS v.27.

Artificial neural network analysis revealed the positive impact of DESI indicators on general government revenues in EU member states, with one exception. Human capital development, measuring the population's digital skills, exerts an insignificant influence on government revenues through the hidden layer. The hidden layer represents the new economic model based on digital transformation and sustainability. Expanding digital infrastructure, modernizing digital public services, and enhancing connectivity can be considered effective strategies for stimulating economic growth and improving government revenue collection within the European Union. Modernizing digital public services is the most critical component within DESI for better government revenue collection. This finding resulting from the analysis validates Hypothesis H1.

In turn, the SDG index has a more significant and positive influence on TGGR. This finding suggests that countries committed to achieving sustainable development goals tend to have higher government revenues. This relationship indicates that investments in sustainable development can yield long-term economic benefits, thus validating Hypothesis H2.

For cluster analysis (testing Hypothesis H3), we select the Ward linkage method, which examines data groups based on similarities between objects or units. Figure 4 presents the dendrogram constructed using SPSS v.27 for variables representing digital transformation, sustainability, and government revenues.

Three homogeneous clusters emerged following the hierarchical clustering of European Union countries based on digital transformation, sustainability, and government revenues. The first cluster comprises countries with a pronounced sustainability orientation, high levels of digitalization, and substantial government revenues (almost half of the gross domestic product) (Table 4).

Table 4. Cluster 1.

Country	TGGR (Percentage)	C (Score)	DPS (Score)	HC (Score)	IDT (Score)	SDGi (Score)
Denmark	48.6	19.27	20.77	14.80	14.50	85.4
Sweden	48.9	15.06	20.61	15.49	14.06	85.3
Finland	52.6	15.14	21.84	17.85	14.77	86.4
Austria	49.5	14.12	18.03	12.74	9.79	82.2
Germany	47.1	16.83	15.85	11.24	8.96	82.3
Italy	48.8	15.31	14.62	9.14	10.19	78.5
France	53.4	16.05	16.84	12.47	7.98	81.1
Belgium	49.7	9.96	16.19	12.17	11.99	79.7
Greece	50.2	12.39	9.85	10.03	6.66	76.5

Table 4. Cont.

Country	TGGR (Percentage)	C (Score)	DPS (Score)	HC (Score)	IDT (Score)	SDGi (Score)
Mean values of Cluster I	49.87	14.90	17.18	12.88	10.99	81.94
Mean values at UE level	42.84	14.12	17.05	12.11	9.24	79.53

Source: designed by the authors using SPSS v.27.

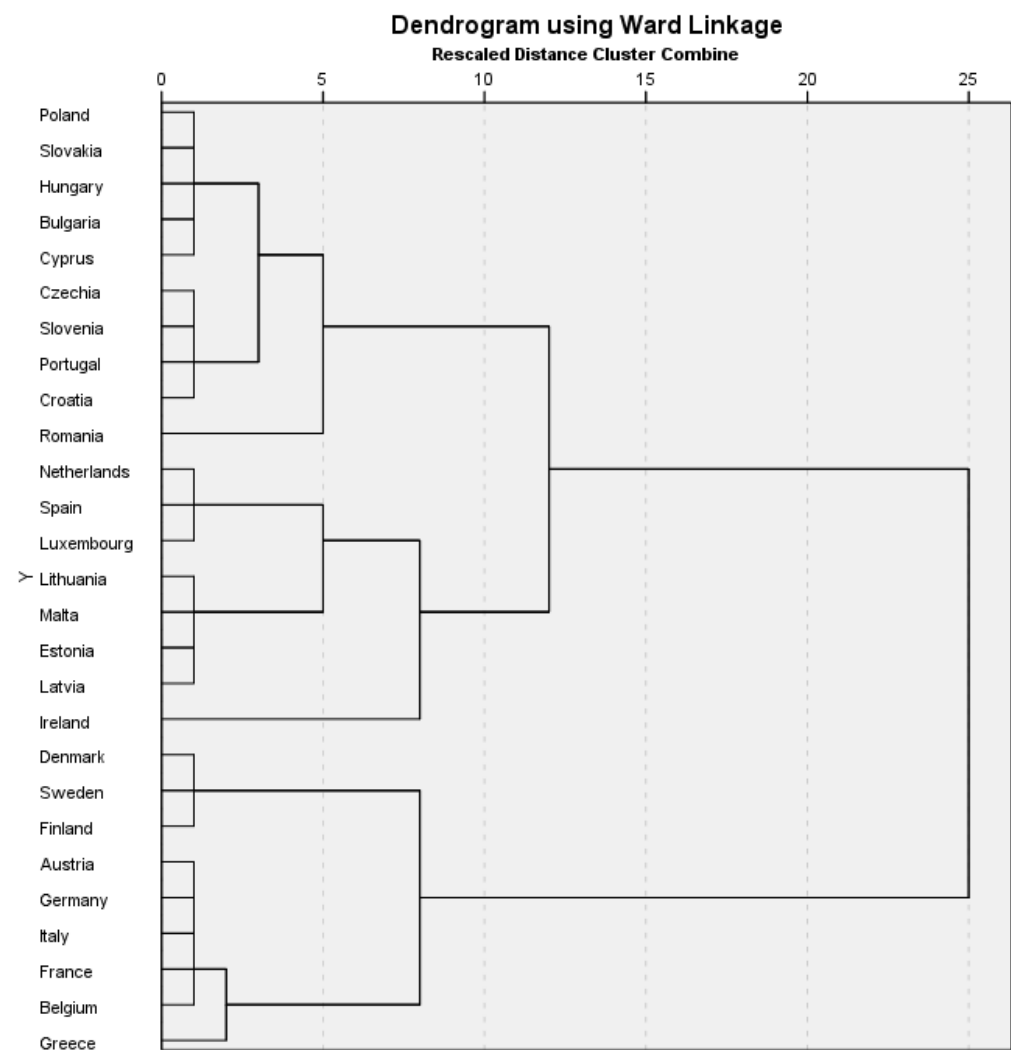


Figure 4. Dendrogram. Source: constructed by the authors using SPSS v.27.

Nordic countries like Finland, Sweden, and Denmark are exemplary leaders in this domain, with well-developed digital societies and governments that continue to invest in digital infrastructure, exhibit a strong sustainability focus, and maintain high government revenues. Developed European Union countries such as Germany, Italy, and France, which also have high levels of digitalization, sustainability, and government revenue collection, join these Nordic countries. Countries in this cluster should serve as a model for those seeking to increase government revenues through accelerated digital transformation and greater sustainability focus.

The second cluster encompasses countries with lower levels of digitalization and connectivity compared to the European average, a noticeably lower sustainability orientation

than the European average, and fewer government revenues collected as a percentage of GDP (Table 5).

Table 5. Cluster 2.

Country	TGGR (Percentage)	C (Score)	DPS (Score)	HC (Score)	IDT (Score)	SDGi (Score)
Poland	39.8	11.63	13.94	9.26	5.72	80.2
Slovakia	40.2	12.46	13.00	11.03	6.96	78.5
Hungary	41.6	14.40	14.35	9.61	5.40	78.8
Bulgaria	38.5	12.68	12.97	8.15	3.88	74.3
Cyprus	41.9	14.69	14.38	10.44	8.84	74.1
Czechia	41.0	13.17	16.11	11.40	8.46	80.4
Slovenia	42.5	14.97	17.37	11.06	9.96	80.1
Portugal	44.4	12.90	16.98	11.49	9.40	79.0
Croatia	45.2	12.01	13.39	12.96	9.18	78.9
Romania	33.5	13.81	5.26	7.73	3.79	77.6
Mean values of Cluster 2	40.86	13.27	13.78	10.31	7.16	78.17
Mean values at UE level	42.84	14.12	17.05	12.11	9.24	79.53

Source: designed by the authors using SPSS v.27.

At the lower end of this cluster are states like Bulgaria and Romania, which lag behind European average values despite significant progress in adopting digital technologies. Countries with lower government revenues, such as Bulgaria and Romania, face budget constraints and must prioritize their resources, including investments in digitalization and sustainability.

Cluster 3 includes countries with high levels of digitalization (above the European Union average) but lower levels of government revenue collection, with three exceptions: Netherlands, Spain, and Luxembourg (Table 6).

Table 6. Cluster 3.

Country	TGGR (Percentage)	C (Score)	DPS (Score)	HC (Score)	IDT (Score)	SDGi (Score)
Netherlands	44.5	17.53	21.05	15.78	13.02	80.0
Spain	43.0	17.43	20.88	12.83	9.63	79.7
Luxembourg	43.5	14.83	20.84	14.44	8.74	75.6
Lithuania	35.8	12.34	20.45	10.61	9.31	75.2
Malta	35.1	13.25	21.45	14.15	12.03	76.6
Estonia	38.5	11.11	22.79	13.49	9.12	80.6
Latvia	35.8	12.52	19.70	11.03	6.46	80.0
Mean values of Cluster 3	37.40	14.30	21.00	13.50	9.89	78.53
Mean values at UE level	42.84	14.12	17.05	12.11	9.24	79.53

Source: authors' design using SPSS v.27.

Cluster analysis validates Hypothesis H3. European countries can be grouped into digital transformation, sustainability, and government revenues clusters. Although values vary within clusters, this analysis provides an overall picture of how countries align at the European level in these critical areas. This data should be used as a starting point to understand each country's strengths and weaknesses better and develop appropriate policies and strategies to improve performance in digitalization, sustainability, and tax revenue collection.

5. Discussions

In recent decades, digital transformation and sustainability have become two crucial aspects of economic and social development, significantly influencing overall government revenues in the European Union. These two forces are profoundly interconnected and well-suited to shape the financial future of EU governments.

Digital transformation has revolutionized how economies and societies operate, fostering innovation and the development of new industries, thereby creating jobs and, consequently, additional revenues for government budgets [1]. On the other hand, sustainability is a critical factor for the financial viability of governments [33]. In a world with limited natural resources, investments in sustainable solutions can reduce long-term costs and enhance economic resilience. Additionally, sustainability-oriented policies can attract foreign investments and increase global market competitiveness, generating additional government revenues.

This paper aims to provide a comprehensive perspective on how digital transformation and sustainability influence overall government revenues in the EU, thus contributing to a deeper understanding of the links between these critical areas of the contemporary economy by testing three hypotheses regarding this relationship.

In recent years, government revenues and fiscal expenditures have been significantly affected by the rapid growth of the global digital economy. Despite the significant role of the digital economy in improving the government's ability to generate tax revenues, there is relatively little empirical evidence of this effect [66,67]. The COVID-19 pandemic has exerted increasing pressure on budget deficits, seriously impacting the balance between government revenues and expenditures worldwide [68,69]. The growth of government revenues has gained widespread attention among governments and all sectors of society [2].

Data analysis and the results obtained in the empirical study confirm the validity of Hypothesis H1, highlighting the significant impact of digital transformation on government revenues in the EU. The research results indicate a significant positive correlation between the level of digital transformation, as measured by DESI, and overall government revenues. This finding is consistent with the previous literature [3,35,70–73] and theoretical expectations, suggesting that investments in digital technologies can enhance the efficiency of tax collection and contribute to the development of new industries that generate additional government revenue.

Quasi-experimental studies based on microdata have demonstrated that implementing electronic transactions can significantly impact taxable revenues [70,73]. Furthermore, adopting electronic invoicing and fiscal devices can improve revenue collection [71,72]. The impact of digitalization is pronounced in the case of value-added tax and profit taxes [71,73].

Developing a national digital strategy is essential to facilitate the adoption of digital technologies in fiscal operations. This strategy should consider the current level of digital transformation required in public finances (digitization, digitalization, digital transformation) and provide a framework for implementing digital solutions [3]. It is essential to advance towards digital transformation, which involves redesigning processes to produce new outcomes and services and improve citizen interaction with the government. With the support of appropriate digital infrastructure and well-trained personnel, developing economies can transition from basic infrastructure to cutting-edge digital technologies [74].

Abendin and Duan [4] and Niyazbekova et al. [5] suggest that digital transformation represents an opportunity that countries should seize to increase government revenues. Digital transformation can significantly promote economic growth, reduce transaction costs, and enhance public management efficiency [75]. Government revenues can be increased with the acceleration of digital transformation at the public level through better revenue collection management and the improvement of national income databases, ensuring the adaptability of government policies.

The MLP model developed provides significant evidence supporting Hypothesis H1, showing that the level of digital transformation, as measured by DESI, has a positive and significant impact on overall government revenues in the EU. Only one component indicator

of DESI, human capital, related to the population's digital skills, does not positively correlate with government revenues. However, the researchers must continue investigating this complex relationship and exploring intermediate and contextual factors to promote economic development and increase government revenues.

Digital transformation represents a profound shift in governance with significant implications across all sectors of society. It opens new opportunities for governments to become more efficient, transparent, and accountable to their citizens. At the same time, it brings economic benefits and enhances national competitiveness, serving as a driving force for societal progress and development. Digital transformation can promote modern economic growth by creating a balanced economic environment, reducing information asymmetry, ensuring better demand–supply alignment [76], and eliminating the geographical constraints of traditional economies. It promotes the free flow of production factors among various regions and increases factor productivity [41,77]. In many studies, digital transformation is associated with a sustainable economic approach [78,79], with digital technologies contributing to improved production efficiency, reduced energy consumption, and the promotion of carbon emissions reduction. Zhang et al. [80], Li et al. [81,82], and Dou and Gao [83] have shown that digital transformation enhances government regulation capacity, leading to better control over economic processes.

The analysis conducted based on the MLP model illustrates a significant positive relationship between sustainability and government revenues. The research findings confirm the validity of Hypothesis H2, demonstrating a significant and positive correlation between sustainability performance, as measured by SDG, and overall government revenues, measured by TGGR. This finding indicates that countries making significant progress in achieving sustainable development goals, such as reducing carbon emissions or promoting renewable energy, benefit from higher long-term government revenues [33]. This relationship is due partly to sustainability-oriented policies that can stimulate investments in sectors with economic growth potential, such as green energy and clean technologies [1,84]. Such investments can lead to job creation and the development of new industries, which, in turn, can contribute to additional fiscal and economic revenues for governments.

There are significant differences among EU member states regarding sustainability performance and digital transformation levels, suggesting that sustainable development and digitalization policies must be tailored to each country's context [33]. The relationship between digital transformation and government revenues may vary depending on each country's context [85]. Some countries may benefit more from digitalization investments, while this factor may have less influence on others. Therefore, fiscal policies and economic development strategies must consider national peculiarities to maximize the benefits of digital transformation on government revenues [33,86].

Regarding the investigation of Hypothesis H3, suggesting that European countries can be grouped into homogeneous clusters concerning digital transformation, sustainability, and government revenues, the empirical analysis shows that this hypothesis is validated. Cluster analysis indicates the existence of distinct development patterns within the EU. These results suggest significant differences among EU member states in how these aspects interact and manifest in their policies and economies.

One cluster comprises countries that have achieved high levels of digital transformation and sustainability and generally record significantly higher government revenues. This group of states represents a successful example of efficiently integrating digital transformation and sustainable development goals into government policy, translating into higher government revenues. In contrast, another cluster comprises countries facing digital transformation and sustainability challenges, with potentially lower government revenues. These countries may need additional efforts to improve their performance in these areas and benefit from the positive impact on government revenues. Some countries may fall into an intermediate cluster, indicating the complexity and variability of the European landscape concerning the relationships between digital transformation, sustainability, and government revenues.

These clusters are not fixed; countries can evolve based on policies and measures taken. Therefore, it is crucial to highlight the need to adapt policies and strategies to each country's specificity and how these aspects interact within their national context [1]. The government plays a significant role in promoting digital technologies and creating an environment conducive to innovation [87,88]. Adequately developed IT infrastructure can facilitate the implementation of digital technologies within enterprises [35].

Digital transformation significantly impacts the government and how it conducts its activities. Government digital transformation involves using digital technology to enhance governance processes and provide citizens with more efficient and transparent services [86]. This process can reduce administrative corruption, improve government efficiency, and stimulate innovation in the public sector [24]. When combined with a sustainability orientation, it can increase total productivity and positively impact the business environment [89].

5.1. Theoretical Implications

The empirical study in this paper provides valuable insights into the relationships between government revenues and the economic environment characterized by digital transformation and sustainability issues. EU governments must develop fiscal strategies that promote investments in digital technologies [90] and sustainable development initiatives. The paper catalyzes debates on how fiscal policies can simultaneously be adapted to stimulate economic growth based on digitization and sustainability [91]. Through empirical analysis, the paper aims to significantly contribute to theoretical developments in digital transformation and sustainability within the European Union using a multidimensional approach. This process could lead to a deeper and more comprehensive understanding of how these factors interact and the development of better-informed strategies for governments and economic actors across the region.

Overall, digital transformation is a complex and dynamic phenomenon that involves both the private and public sectors. Government policies, research and development expenditures, and other factors significantly impact digital transformation, influencing how businesses and the government adopt and use digital technologies to promote innovation and economic growth [92]. The paper's findings contribute to the growing body of knowledge regarding the complex relationship between digital transformation, sustainability, and government revenues, offering valuable insights for policymakers looking to leverage digitization for economic growth and fiscal sustainability in the European Union.

The methodology of this study can be adapted and successfully used for research outside of Europe. By adjusting the data and objectives to reflect the specific context of other regions, the research can provide valuable insights into the interaction between digitization, sustainability, and government revenues in different parts of the world. This methodology can serve as a robust framework for investigating the impact of digitization and sustainable practices on government finances in various global regions.

5.2. Practical Implications

The study results offer guidance on using digital transformation and sustainability to increase government revenues. Practical strategic guidance includes promoting investments in digital infrastructure, supporting the development of a digital and sustainable economy, and creating fiscal policies that encourage innovation and the adoption of digital technologies and sustainable practices across all economic sectors.

The pandemic has also had significant repercussions on government revenues due to disruptions in economic activity, shifts in consumption patterns, and the implementation of fiscal measures. Our research explores how digital transformation and sustainable practices can serve as mechanisms for recovery and adaptation in the post-pandemic era. Our findings, therefore, offer not only a comprehensive understanding of the interplay between digitalization, sustainability, and government revenue in EU member states but also valuable insights for policymakers.

Developing policies to enhance sustainability involves encouraging investments in renewable energy, clean technologies, and carbon emissions reduction initiatives. By adopting such policies, governments can reduce environment-related expenses and potentially increase fiscal resources. The study provides theoretical foundations for identifying and developing policies combining digital transformation and sustainability, fostering innovation in green technologies, smart transportation, efficient resource management, and AI-driven automated production and services. These sectors could become significant sources of government revenues and employment.

As governments handle the consequences of the pandemic, our research underscores the role of digital transformation and sustainable practices as viable mechanisms for recovery and adaptation in the post-pandemic era. In light of our findings, governments must design fiscal policies that stimulate innovation and the widespread adoption of digital technologies and sustainable practices across all economic sectors. Such policies should create incentives for businesses to invest in research and development, embark on digital transformation journeys, and integrate sustainability measures, all of which hold the potential to augment tax revenues.

5.3. Limitations and Further Research

The limitations of this paper include, first and foremost, issues related to the availability and accuracy of the data used for analysis. General government revenue data can vary based on the data collection and reporting methods used by different EU member states. Additionally, DESI and SDG indicators data may suffer from reporting errors or limitations concerning cross-country comparability. Another limitation is related to the complexity and interdependence of the analyzed variables. Digital transformation and sustainability are broad and multifactorial concepts, and various other factors may mediate their impact on government revenues. These processes make it challenging to identify causal relationships and quantify the exact impact of each factor. Future research can expand the variables considered within the model, increasing the model's robustness. The research focuses on cross-sectional data analysis at a specific point in time and does not account for changes over time or long-term developments. Future research could benefit from longitudinal analyses and detailed case studies tracking the evolution over time of digital transformation, sustainability, and government revenues in the EU to gain a deeper understanding of the dynamics of these relationships. Furthermore, future research should continue to investigate these complex relationships and explore how fiscal policy and digital technologies can promote sustainable development and increase government revenues. Research can aim to identify the most effective policies and practices in various national contexts within the EU and explore ways to promote collaboration among member states in these critical areas.

6. Conclusions

Digital transformation and sustainability are two powerful forces that can significantly influence government revenues in the EU. By promoting a healthy digital economy and sustainability-oriented policies, European governments can enhance their revenues and contribute to addressing global issues. However, it is crucial to closely monitor and adapt to the digital landscape and sustainability context changes to ensure long-term economic and financial sustainability.

Using key variables such as the Digital Economy and Society Index (DESI), the Sustainable Development Goals index (SDG), and Total General Government Revenues (TGGR), along with quantitative research methods such as artificial neural networks analysis and cluster analysis, this study has examined the complex impact of digital transformation and sustainability on general government revenues in the European Union.

Digital transformation and sustainability are intricately interconnected. Furthermore, countries with higher levels of digitization tend to achieve higher government revenues. This finding suggests that investments in digital technologies can support economic growth

and contribute to government revenues. Sustainability performance can also influence government revenues, especially in green energy and clean technologies sectors.

These complex relationships depend on various factors, including economic context, government policies, and technological developments. Policies and strategies are needed to promote digital transformation and sustainability to boost government revenues tailored to each member state's specific contexts and needs. In an era characterized by rapid changes and global challenges, understanding the relationships between digital transformation, sustainability, and government revenues becomes crucial for shaping public policies and creating a more prosperous and sustainable future in Europe.

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