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To cite this article: Mohammed Ibrahim Gariba, Samuel Amponsah Odei, Frank Febiri & Romana Provazníková (2024) Exploring the mediating role of digital economy in the relationship between fiscal decentralization and the SDGs dimensions in the EU, Cogent Economics & Finance, 12:1, 2367219, DOI: [10.1080/23322039.2024.2367219](https://doi.org/10.1080/23322039.2024.2367219)

To link to this article: <https://doi.org/10.1080/23322039.2024.2367219>



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Published online: 09 Jul 2024.



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Exploring the mediating role of digital economy in the relationship between fiscal decentralization and the SDGs dimensions in the EU

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ABSTRACT

The motivation of this research is the surge in the integration of the digital economy (DE) and fiscal decentralization (FD) as crucial issues for countries. To maintain sustainable growth, it is important for EU to adopt sustainable development goal (SDGs) practices. However, the connection between DE, FD, and SDG practices has not been thoroughly examined in existing literature. Therefore, the objective of this study was to examine the mediating role of DE between FD and SDGs in EU. We employed a panel dataset between 2016 and 2022 from Eurostat, the Organization for Economic Cooperation and Development, and Government Finance Statistics, using a quantitative research design, and applied the structural equation model (PLS-SEM) analysis to test the hypotheses. The results indicate that FD has a significant negative effect on economic sustainability but a significant positive effect on environmental and social SDGs. In addition, FD has a significant positive effect on DE. We also found that DE has a significant positive relationship with economic and social SDGs. However, DE has a negative but significant influence on environmental sustainability. This study also proved that DE plays a mediating role between FD and Sustainability. This study contributes to theories of fiscal federalism and resource dependency. These original findings have several practical implications for policymakers and contribute to the current debate on the role of FD in SDGs through DE. Hence, we recommend that policymakers prioritize the development of broadband Internet access, e-governance resources, and invest in digital skill training programs.

IMPACT STATEMENT

This study examines the mediating role of digital economy between fiscal decentralization and sustainable development goals in the European union. The results indicate that fiscal decentralization has a significant negative effect on economic sustainability. Digital economy has a negative but significant influence on environmental sustainability. This study also highlights that digital economy plays a mediating role between fiscal decentralization and Sustainability. This highlights the importance of digitalization for sustainability dimensions. These robust results support efforts towards a move for a digital economy to foster sustainable growth.

Utilizing a panel dataset between 2016 and 2022 from Eurostat, the Organization for Economic Cooperation and Development, and Government Finance Statistics, using a quantitative research design, and applied the structural equation model analysis to test the hypotheses. The results indicate that fiscal decentralization has a significant negative effect on economic sustainability but a significant positive effect on environmental and social sustainable development goals. In addition, fiscal decentralization has a significant positive effect on digital economy. We also found that digital economy has a significant positive relationship with economic and social sustainable development goals. However, digital economy has a negative but significant influence on environmental sustainability.

The findings of this research have valuable practical implications for policymakers and guide governments in defining more interesting strategies to manage fiscal decentralization in a wise manner to successfully achieve the objectives of the sustainable development goals through the proper implementation of digital economy on a large scale

ARTICLE HISTORY

Received 20 February 2024
Revised 16 May 2024
Accepted 7 June 2024

KEYWORDS

Fiscal decentralization;
digital economy;
Sustainable Development
Goals; EU; PLS-SEM

REVIEWING EDITOR

Dr Chris Jones, Economics,
Finance & Entrepreneurship,
Aston University, United
Kingdom of Great Britain
and Northern Ireland

SUBJECTS

Development Economics;
Environmental Economics;
Econometrics

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

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among societies. It is important for policymakers to strike a balance in fiscal decentralization ensuring efficient revenue allocation mechanisms and enhancing fiscal responsibilities, ensuring that local governments have sufficient autonomy to address local needs while maintaining effective oversight and coordination. Consistent with our results on digital economy and sustainable development goals, governments should prioritize the development of broadband Internet access, e-governance resources, and other digital technologies. Investing in digital skills training programs will ensure that citizens and businesses can take advantage of the opportunities presented by digital economy. The study highlights further research could investigate this model in developing economies to enable comparison. Ultimately, the study paves the way for a more digital and sustainable drive by providing evidence and direction for future initiatives.

1. Introduction

The burgeoning digital economy (DE) is reshaping fiscal landscapes and policy frameworks within the European Union, potentially influencing the attainment of Sustainable Development Goals (SDGs). Fiscal decentralization (FD), which involves the devolution of financial responsibilities to local governments, may interact with the DE to affect the three dimensions of sustainability: economic, social, and environmental, as outlined by the SDGs. The interplay between digital transformation and sustainability has been recognized as a pivotal factor in enhancing government revenue and other fiscal outcomes (Vărzaru et al., 2023), while the role of the DE in localizing SDG strategies has been emphasized as a means to effectively tailor SDGs efforts effectively (ElMassah & Mohieldin, 2020). Contradictions and interesting facts emerged when considering DE's mediating role. While society is seen as a positive contributor to government revenue and sustainability (Vărzaru et al., 2023), digitalization a component of DE has been less explored in terms of its impact on the SDGs within the EU context (Karobliene & Pilinkiene, 2021).

Over the past decades, the digital divide among EU member states has presented challenges to uniform digital advancement and, consequently, to the homogeneous achievement of the SDGs (Grynja, 2023). The slow implementation of the SDGs in the EU's financial framework (Vavrik, 2021) and the need for a more sustainable financial model (Ziolo et al., 2021) further complicate the relationship between FD and SDGs. DE may serve as a critical mediator in the relationship between FD and SDGs in the EU. However, the complexity of this role is underscored by the varying levels of digital transformation across member states and challenges in aligning financial frameworks with sustainability goals. Understanding these dynamics is essential for policymakers aiming to leverage DE to support FD strategies that advance the SDGs (ElMassah & Mohieldin, 2020; Grynja, 2023; Karobliene & Pilinkiene, 2021; Vărzaru et al., 2023; Vavrik, 2021; Ziolo et al., 2021). DE can streamline administrative processes, enhance transparency and accountability, promote citizen engagement, and foster innovation in addressing environmental challenges (Saner et al., 2020). However, leveraging the full potential of DE for SDGs requires a strategic approach that considers local governments' specific needs and capacities (Muñoz & Cohen, 2017; Clement et al., 2023).

While existing literature has extensively examined the isolated effects of FD on SDGs (Fang & Fang, 2023; Pu et al., 2023), there is a dearth of study on the topic that focuses on the mediating role of the digital economy (Clement et al., 2023; Sofilda et al., 2023) in the relationship, both generally and in the European Union particularly. Researchers have shown that FD can have both positive and negative effects on the SDGs (Hui & Martinez-Vazquez, 2021; Ligthart & Oudheusden, 2017). Pu et al. (2023) find that FD has a positive relationship with SDGs driven by high-quality innovation. Contrary, the study by Pasichnyi et al. (2019) and Kopina and Kopin (2019) find a mixed relationship between FD and economic development in 27 emerging economies. The inconclusive findings means that further research is needed to understand the relationship. Therefore, this research aims to address this broader gap in the literature. In so doing, we draw intuitions from the fiscal federalism (Musgrave, 1956), and resource dependency (Pfeffer & Salancik, 2015) theories. The fiscal federalism theory emphasises how revenue generation, government expenditure allocation, and fiscal policies are organised and coordinated between various tiers of government such as central and subnational entities for example states or provinces (Udeagha & Breitenbach, 2023). The resource dependency theory on the other hand explains how organisations and actors rely on external resources and how this dependence shapes their behavior and interactions. We develop a simplified model

that, that firstly aims to assess the direct influence of FD on economic, social, and environmental sustainability. Second, we aim to examine the direct relationship between DE and the SDGs. Third, the European Union (EU) faces the challenge of fostering SDGs across its member states (Mentes, 2023). DE and FD vary across countries, with some granting greater autonomy to local governments and others maintaining a more centralized approach (Ladner et al., 2019; Zhang et al., 2023). While FD appears to foster DE, the mediating role of DE in the broader relationship between FD and SDGs within the EU warrants further investigation. This research motivation underscores the need to elucidate the nuances of this relationship, considering the potential for both synergies and trade-offs among the SDGs (Kostetckaia & Hametner, 2022), and the varying impacts of DE across different regions (Li et al., 2023). More specifically, we aim to establish whether DE could affect FD and SDGs indirectly (mediator). More specifically, we aim to establish whether DE could affect FD and SDGs indirectly (mediator). More specifically, this research aims to answer the following research questions: (1) Does FD influence economic SDGs? (2) Does FD influence social SDGs? (3) Does FD influence environmental SDGs? (4) Does DE influence SDGs? (5) Does DE mediate the relationship between FD and SDGs?

We test our empirical model and answer our research questions based on data from a sample of about 144 observations from EU-27 member states over the period 2016–2022. Our empirical results demonstrate that FD have a negative influence on economic SDGs but positive influence on social and environmental SDGs. The result further shows that FD positively influences DE. DE was found to positively influence economic and social sustainability. Contrary, we find that DE does not significantly influence environmental sustainability. Finally, we find that that DE plays a mediating role between FD and SDGs.

From the theoretical perspective our findings contribute to the burgeoning literature in several ways. First, the results add to the body of research on the relationship between fiscal federalism, DE, and SDGs from the perspective of developed economies (Fang & Fang, 2023; Kopina & Kopin, 2019; Pasichnyi et al., 2019; Pu et al., 2023), by highlighting the crucial role of fiscal federalism and DE in influencing countries drive to sustainability. This new research is novel and important considering that although there are several studies conducted on how countries could achieve sustainable development (Fang & Fang, 2023; Vărzaru et al., 2023), few studies have paid attention to analyzing how the interplay between fiscal federalism influence the different measures of sustainability. Second, the mediating effect of DE in the relationship between fiscal federalism and sustainability is examined in this research. While the direct effect of DE on sustainability has received enough scholarly attention, we considered how it mediates the relationship between FD to impact the three main dimensions of sustainability. This study therefore broadens our understanding of the mechanism through which FD works to impact sustainability in developed economies. Third, this study contributes broadening our understanding of the fiscal federalism and Resource Dependency theories, as we have demonstrated how FD influence DE, this resonates with the fiscal federalism theory which emphasizes the division of responsibilities and financial relations among different levels of government to improve economic efficiency and achieve various public policy objectives (Udeagha & Breitenbach, 2023). Additionally, our result has shown that external resources, such as DE, positively impact organizational behavior and sustainability outcomes (Nandi et al., 2021; Wang et al., 2022). This is in line with the resource dependency theory which suggests that local governments and organizations, are dependent on external resources to fulfill their objectives. These resources include financial, technological, human, and political capital (Deslatte & Stokan, 2019; Khieng & Dahles, 2015). Therefore, DE, characterized by the abundance of digital resources, can potentially enhance the capacity of local governments to promote SDGs (Joseph et al., 2019). From a practical standpoint, we recommend policy makers to effectively coordinate and align national and sub-national policies with the objectives of the SDGs. This will necessitate cooperation, information-sharing, and joint decision-making among various tiers of governments to address common SDGs challenges. The finding that DE positively mediates the relationship between FD and SDGs suggests that policymakers should consider exploiting digital technologies within FD frameworks to enhance SDGs. Policymakers should consider implementing digital infrastructure projects and promoting digital inclusion initiatives when developing EU fiscal policies.

The remainder of this paper is organized as follows. The next section provides a brief insight into the theoretical literature, empirical and hypothesis development. Section 3 describes the methodology and data sources. Section 4 presents empirical PLS-SEM results. Section 5 details the discussion. Section 6 presents conclusions, theoretical and practical implications, and directions for future research.

2. Theoretical literature

2.1. Theory of fiscal federalism and resource dependency theory (RDT)

Fiscal federalism is a public finance concept that deals with the division of governmental functions and financial relations among units in a government system (Oates, 1968). The term was introduced by the German-born American economist Richard Musgrave in 1959. The objectives of fiscal federalism include ensuring that the overall fiscal stabilization objectives for the national economy are met, providing an acceptable degree of equity between individuals in different regions, and encouraging the efficient use of resources across nations (Tanzi, 1995). Olaide et al. (2022) find a significant impact between fiscal federalism SDGs. However, the study fails to explore the environmental dimension of sustainability, which is emphasized by the theory of fiscal federalism. Additionally, a paper by the Organization for Economic Cooperation and Development (OECD) titled "The multi-level fiscal governance of ecological transition" found a significant influence of fiscal federalism in driving ecological transition, a key element in the United Nations' SDGs agenda (Dougherty & Nebreda, 2023). On the contrary, how fiscal federalism improves environmental sustainability, particularly in the broader EU-based context, remains underexplored.

Resource dependency theory (RDT) examines how organizations depend on external resources and how this dependence affects their behavior and decision-making processes (Pfeffer & Salancik, 2015). Pfeffer and Salancik developed the theory when they published a book titled 'The External Control of Organizations: An RDT Perspective' (Biermann & Harsch, Pfeffer & Salancik, 2015). RDT emphasizes that organizations require external resources to survive and compete in their environment (Biermann & Harsch). RDT posits that resources originate from the organization's environment and that these resources often come from their external environment, which may include other organizations (Drees & Heugens, 2013). In the context of our research, RDT can be used to analyze the impact of DE as a resource for FD and SDGs in EU countries. This theory helps understand how the availability and distribution of digital resources can influence the economic and political dynamics of these countries, as well as the allocation of fiscal responsibilities at different levels of government (Jacobs et al., 2021). The RDT can therefore be connected to fiscal federalism, as organizations and economies depend on external resources, including digital resources and technologies, to achieve sustainable development goals. However, the mediating role of DE on FD and the dimensions of SDGs has not been explored in the literature. This study seeks to bridge this gap.

2.2. Empirical literature and hypothesis development

2.3. Nexus between fiscal decentralization and sustainable development

The concept of FD has been a subject of empirical research in recent decades, particularly in relation to its impact on economic, social, and environmental sustainability (Ter-Minassian, 2015). While SDGs encompass these three dimensions, FD can influence them through various channels, such as intergovernmental transfers, local tax revenue, and investment in local assets and social contributions (Ajeigbe et al., 2023; Park, 2022). It is argued to be an important source of income for local governments, as it can support local public services and infrastructure (Goerl & Seiferling, 2014; Martinez-Vazquez et al., 2017). In addition, FD at the local level is considered an essential component of the SDGs (Petrovito et al., 2023). Researchers have widely studied the impact of FD on SDGs and have found mixed evidence on this relationship (Mainali et al., 2022; Sima et al., 2023). FD can increase local tax revenue and investment in local assets (Zhao et al., 2022; Miranda-Lescano et al., 2023) leading to a more efficient allocation of resources and promoting local economic, social, and environmental development (Udeagha & Breitenbach, 2021). However, other researchers found insignificant effects of FD on economic growth in Germany, the UK, the USA, Australia, and Canada (Guerrero et al., 2022; Zahra & Badeeb, 2022). Based on previous research, we expected a direct positive relationship between FD and the three SDGs dimensions. Hence, we hypothesize as follows:

H1a: *Fiscal decentralization has a direct positive influence on economic sustainability in the EU.*

H1b: *Fiscal decentralization has a direct positive influence on social sustainability in the EU.*

H1c: *Fiscal decentralization has a direct positive influence on environmental sustainability in the EU.*

2.4. The relationship between fiscal decentralization and digital Economy

FD can encourage local governments to invest in ICT infrastructure and digital skill development as they have a better understanding of the specific needs and priorities of their communities (Almunawar et al., 2022; Kwilinski et al., 2023; Martinez-Vazquez et al., 2017). Decentralized decision-making can foster innovation and experimentation in the use of digital technologies for public services and citizen engagement (Helbing et al., 2023; Secinaro et al., 2022). Local governments may be more responsive to the needs of their citizens if they have greater control over fiscal resources and decision making (Manaf et al., 2023), which can lead to improved e-government services and more effective digital skills training programs. A growing body of empirical research supports a connection between FD and DE. For example, Yan and Lyu (2023) and Martínez et al. (2022) found that FD is positively associated with e-government adoption and digitalization in the Chinese and OECD regions, respectively. More recently, research on the influence of FD on DE found that FD can enhance e-government adoption by increasing public sector investments in ICT infrastructure and training programs in the United Arab Emirates and beyond (Al Sayegh et al., 2023; Yan et al., 2023). However, limited attention has been paid to the direct impact of FD on DE (in the context of e-governance, digital skills usage, and institutions providing ICT training) in the European Union (Adam & Dzang Alhassan, 2021). Based on this understanding, we expect FD to have a positive direct influence on DE. Hence, we hypothesize as follows:

H2: *Fiscal decentralization has a direct positive influence on the digital economy in the EU.*

2.5. The role of digital economy for Sustainable Development Goals

DE has been identified as a key driver of SDGs with the potential to contribute to economic, human, and social development (Goulart et al., 2022; Zhang et al., 2022). By leveraging digital tools and infrastructure, governments, businesses, and individuals can collectively address challenges and promote positive outcomes in terms of economic, social, and environmental sustainability (Zhang et al., 2023). Similarly, Song et al. (2022) and Wang et al. (2023) find that DE plays a crucial role in conserving tax sources, expanding the tax base, and improving fiscal revenues, thereby reducing corruption. Likewise, DE improves settlement and well-being by facilitating communication and social engagement (Gennari et al., 2023). This can enhance the overall quality of life and social cohesion. However, the impact of DE on the environment and society is a complex issue that has not been extensively explored (Yi et al., 2022; Zhang et al., 2022). Zhang et al. (2022) and Luo et al. (2023) argue that DE can promote fiscal efforts, green innovation, and digital transformation. These linkages are important for the development of renewable energy and sustainable technological solutions. However, it presents challenges, including e-waste and energy consumption (Srivastav et al., 2023). These findings underscore the need for a balanced approach to harness the potential of DE for the SDGs. Based on previous research, we expect a significant relationship between DE and SDGs. Hence, we hypothesize as follows:

H3a: *The digital economy has a direct positive influence on economic sustainability in the EU.*

H3b: *The digital economy has a direct positive influence on social sustainability in the EU.*

H3c: *The digital economy has a direct influence on environmental sustainability in the EU.*

2.6. Gauging the mediating role of digital economy on fiscal decentralization and Sustainable Development Goals

DE plays a significant role in promoting prosperity and sustainable economic activities, particularly in the context of FD (Chen et al., 2024; Zhang & Qian, 2023). DE improves economic efficiency, expands the tax base, and increases fiscal revenue (Guo et al., 2023; Zhang et al., 2023). This position is further supported by the potential of DE to contribute to environmental and social sustainability (Xu et al., 2022; Huang et al., 2023). FD, particularly decentralized revenue, has a positive impact on environmental improvement, suggesting synergy between FD and environmental regulations (Kuai et al., 2019). Consequently, the relationship between FD and environmental sustainability is complex and non-linear

(Shan et al., 2021). These studies have highlighted the relationship between FD and sustainability. In contrast, studies have paid limited attention to the mediating role of DE on FD and economic, social, and environmental SDGs concurrently. Therefore, we assume that DE mediates the relationship between FD and the dimensions of sustainability. Hence, we hypothesize as follows:

H4a: Digital economy mediates positively between fiscal decentralization and economic sustainability in the EU.

H4b: Digital economy mediates positively between fiscal decentralization and social sustainability in the EU.

H4c: Digital economy mediates positively between fiscal decentralization and environmental sustainability in the EU.

2.7. Emerging research gaps

The existing literature provides insights into various aspects of the relationship between FD, DE, and SDGs, but there appears to be a notable gap regarding the specific mediating role of DE in the context of the EU. While Chen et al. (2024) identified a positive correlation between FD and the growth of DE in China, they did not explore the subsequent impact on the SDGs or focus on the EU context. Similarly, while Adam & Dzang Alhassan (2021) empirically demonstrate the relationship between (ICTs and the SDGs, they do not specifically address the mediating role of DE in the FD-SDGs nexus. Furthermore, the literature suggests that DE can be a catalyst for achieving SDGs, as indicated by the role of digital finance in promoting financial inclusion, a key enabler for many SDGs (Dikshit & Pandey, 2021). However, the direct link between FD, DE, and achievement of SDGs within the EU remains underexplored. Additionally, while Vaques (2020) discussed the EU's efforts to integrate SDGs into its policies and the potential of the European Green Deal, it did not specifically address the mediating role of DE (Vaques, 2020). In summary, while there is a body of research on the individual relationships between FD, DE, and SDGs, there is a notable gap in the literature regarding the mediating role of DE in the relationship between FD and SDGs within the EU. This gap justifies further research to explore how DE can influence the effectiveness of FD in achieving SDGs in the EU context (Adam & Dzang Alhassan, 2021; Chen et al., 2024; Dikshit & Pandey, 2021; Vaques, 2020).

Based on the literature, this study outlines FD as an independent variable, DE as a mediating variable, and SDGs as a dependent variable, and merges them to display the conceptual framework, as shown in (Figure 1).

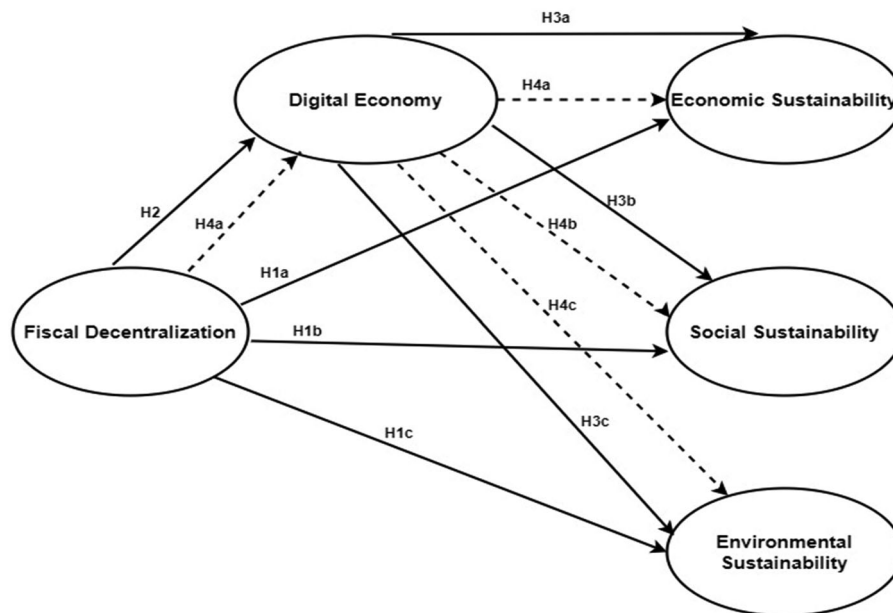


Figure 1. Conceptual model.

Source: (The Authors).

Note. Dashed lines represent the mediating effects and direction.

3. Methodology

3.1. Design and data collection

This study explored the research problem and the theoretical research gap using an exploratory approach. Based on the research gap in the literature, this study outlined a theoretical framework for the flow of research and defined hypotheses to test the proposed association among the constructs. In the next stage, the characteristics of the dataset were assessed using a descriptive technique. Data were obtained using a secondary data collection technique. The data collected were quantitative and curated into a panel dataset. The data represent the EU-27 member states, and the number of observations realized was 144. Data are available open access and are extracted from European Union sources, such as the European statistics database (Eurostat, DESI), the Organization for Economic Cooperation and Development (OECD), and the Government Finance Statistics Database (GFS) from 2016 to 2022, which are country-level data composed of information on FD, DE, and SDGs. Data were extracted for Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Austria, Finland, Sweden, Cyprus, the Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania. Finally, the study reports the results to clarify the possible associations among the constructs.

3.2. Variables description

This study examines the relationship between FD, DE, and SDGs, which necessitates a robust theoretical framework that integrates these concepts. Fiscal federalism theory, as outlined by Slavinskaitė et al. (2019), provides a foundation for understanding the allocation of financial powers and responsibilities across different levels of government (Ajeigbe et al., 2023). These are divided into first- and second-generation models, which offer insights into the efficiency and effectiveness of FD (Dougherty & Nebreda, 2023). Resource dependency theory, which is not explicitly discussed in the provided papers, typically examines how organizations or governments manage and depend on resources that they do not entirely control (Biermann & Harsch). To establish a clear theoretical framework, we explored how FD influences the capacity of local governments to manage resources and address targets set by the SDGs. The framework considers the principles of fiscal federalism, such as subsidiarity, efficiency, subnational expenditure, revenue, and intergovernmental transfers, as well as how these principles affect the ability of decentralized entities to respond to resource dependencies and pursue SDGs objectives. The relationship between FD, DE, and SDGs is further elucidated by examining how decentralized financial authority impacts local governments' resource allocation decisions, which, in turn, affects their ability to meet SDGs targets. SDGs emphasize the need to balance economic growth, environmental protection, and social equity (Harris, 2000; Lorek & Spangenberg, 2014). Measuring SDGs with economic, social, and environmental sustainability provides a holistic assessment of a country's overall well-being and ability to meet the needs of the present without compromising the ability of future generations to meet their own needs (Costanza et al., 2016; Engelman, 2013). For instance, a decentralized government with greater control over its resources may be better positioned to invest in sustainable practices that align with SDGs. Conversely, resource dependency may limit the capacity of local governments to achieve these goals, necessitating a framework that also considers the constraints imposed by external resource controls. The use of DE is justified as digital technology, and the Internet is a significant driver of socioeconomic and environmental progress (Dahlman et al., 2016). It has emerged as a key enabler of sustainable development. By leveraging digital tools such as e-governance, digital skills, and ICT training, governments, businesses, and individuals can collectively address challenges and promote positive outcomes across economic, social, and environmental dimensions (Oloyede et al., 2022; Wang et al., 2023). Details of the variables measuring each concept is described in (Table 1) below.

3.3. Data analysis technique

This study applied a quantitative approach to extract panel data for the European Union from the European statistics database (Eurostat, DESI), the OECD, and GFS, and processed them through partial least square structural equation Modelling (PLS-SEM) to report the findings and establish associations

Table 1. Variable description.

Variables	Description	Source
E-governance index (med)	Assess the availability and index of e-government services of countries, reflecting the level of digitalization in governance.	Ali et al., 2018
Digital skills usage (med)	Measure the population's digital skills. Individuals who use the internet at least once a week for business or personal activities.	Dahlman et al., 2016
Ins. Providing ICT training (med)	Institutions who provided training in ICT to their personnel.	Dahlman et al., 2016
Intergovernmental transfers (Indep)	Assess the extent of financial transfers between different levels of government, indicating fiscal decentralization mechanisms.	Bahl & Johannes, 1994
Local Tax revenue % of GDP (Indep)	Share of subnational government revenue over the total general government revenue generated as a % of GDP.	Martinez-Vazquez et al., 2017
Investment in Local assets (Indep)	Net/gross investment in nonfinancial assets.	Petrovito et al., 2023; Wenjuan & Zhao, 2023
Social contributions at local level (Indep)	Social contributions, share of general government (SC).	Petrovito et al., 2023
GDP per capital (Dep)	The indicator is calculated as the ratio of real GDP to the average population of a specific year.	Nakatani et al., 2022
Employment rate (dep)	The indicator measures the share of the population aged 20 to 64 which are employed.	Pieper, 2000
Human capital Development (dep)	Consider indicators of tertiary education and skill development as factors influencing the mediating role of digital transformation.	Nakatani et al., 2022
HDI (dep)	Index of life expectancy, education, and per capita income indicators.	Jin & Jakovljevic, 2023
Settlement per capital (dep)	This indicator captures the amount of settlement area used for buildings, industrial and commercial areas, infrastructure, and sports grounds.	O'Regan et al., 2009
Corruption perception index (dep)	The indicator is a composite index based on a combination of surveys and assessments of corruption based on how corrupt a country's public sector is perceived to be.	Dočekalová & Kocmanová, 2016
Green gas Emission (dep)	The indicator measures total national emissions from all sectors	Rehman et al., 2021
Environmental goods and services (dep)	Defined as that part of a country's economy that is engaged in producing goods and services that are used in environmental protection and resource management activities.	Hervani et al., 2017.

Source: (The Authors)

among constructs. PLS-SEM is a helpful and authentic procedure to validate the research framework, establish associations among constructs suitable for predictive and formative studies, handle complex models and small sample sizes, and easily test hypotheses (Hair et al., 2021; Rehman & Prokop, 2023). Mathematically, the PLS-SEM equation is denoted as (see, Zawojcka, 2010):

$$z_k = \beta_0^{(k)} + \sum \beta_i^{(k)} z_i + v_k \quad (1)$$

where z_k is the outcome variable thus the various dimensions of sustainable development, $\beta_0^{(k)}$ represents the constant term, $\beta_i^{(k)}$ denotes the regression coefficient, v_k represents the residual error term.

3.4. Robustness check

We first initiated the robustness check by testing for potential nonlinearities using the quadratic effect. We followed Svensson et al. (2018) and conducted two confirmatory tests. We first used Ramsey's (1969) RESET (Table 6) on the latent variable scores extracted after we module the original concepts PLS-SEM

Table 2. Assessment of endogeneity test using the Gaussian Copula approach.

Test	Construct	Coefficient	P values	Number of segments		
Gaussian copula of model 1 (endogenous variables; Econ SDGs)	^c Econ SDGs	0.270	0.705	AIC	1 2020.10	2 2080.89 2070.60
Gaussian copula of model 2 (endogenous variables; Social SDGs)	^c Social SDGs	−0.112	0.875	AIC ₃	2400.10	2090.89 2095.62
Gaussian copula of model 3 (endogenous variables; Env SDGs)	^c Env SDGs	0.415	0.745	CAIC	2450.60	2160.11 2186.56

Note: c indicates the copula term in the model; AIC: Akaike's information criterion; AIC₃: modified AIC with factor 3; CAIC: consistent AIC.

algorithm. The results of bootstrapping with 5000 samples indicate that FD and SDGs ($F(3,489) = 1.55$, $p = 0.304$) nor the partial least regression of DE on FD and SDGs ($F(3,490) = 0.56$, $p = 0.620$) is subject to nonlinearities. Next, we included interaction terms to represent the quadratic effects between (1) FD and SDGs (2) DE on FD and SDGs. The results of bootstrapping for the 5000 samples and using no sign changes indicate that neither of the nonlinear effects is significant (Table 4). We therefore conclude that the linear effect model is robust.

According to Hair et al. (2021), panel data can contain variations in its patterns across different countries and that failing to account for this heterogeneity can lead to biased estimates. Because our data is drawn from various sources and countries, there are compelling reasons to believe that unobserved endogeneity play a role at the country and sector levels and that the effects of FD on DE and SDGs may differ as well. We assessed potential endogeneity based on the Gaussian copulas approach using the latent variables scores of the original model estimation as inputs (Hair et al., 2021). Applying Park and Gupta (2012) approach, we conducted the Kolmogorov-Smirnov test to ascertain variables which potentially exhibit endogeneity and are nonnormally distributed (Sarstedt & Mooi, 2014). The latent variable score of econ, social and env SDGs which serve as dependent variables in the PLS-SEM path models partial regression. The results showed that none of the construct has normally distributed scores allowing us to progress with Park and Gupta (2012) approach. The results in (Table 2) show that none of the Gaussian Copulas (that is Econ, social and env SDGs) is significant ($p \text{ value} > 0.05$). All possible combinations of Gaussian copulas were included, and none were significant. The results of the fit indices for three segments paint a good picture consistent with Sarstedt & Mooi who argued that, whenever AIC₃ and CAIC indicate similar number of segments, the results is appropriate. Hence, endogeneity is not present, which supports the robustness of the structural model (Hair et al., 2021). We further tested the multicollinearity problems using the variance inflation factor (VIF). From the VIF results in (Table 4), the values for VIF are less than 5. Hence, we can conclude that the model does not suffer from multicollinearity. The test conducted above confirms that the robustness test of the model is within the accepted threshold.

4. Results

In the last few years, PLS-SEM has been widely applied in the social science literature for theory formation, establishing associations among variables, and testing hypotheses (Benitez et al., 2020). In the PLS-SEM methodological procedure, measurement and structural models are usually perceived as the main steps in the analysis. The necessary steps, procedures, and threshold values for measurement and structural models are presented in the following sections. We proceed with the results discussions with the descriptive statistics and the normality tests using the Kurtosis and skewness. Table 3 below reports the results, and it shows that FD construct has the lowest mean of score of 68.120, with an associated standard deviation of 14.530. SDGs construct has the highest mean of 3636.458 with a corresponding standard deviation of 9359.251. The DE construct has a mean score of 333.186 and a standard deviation of 188.194. These results suggest that the values of the means, and standard deviations have an inverse relationship, signifying that as the mean scores reduces, the standard deviation score increases. We further examined the normality of the data distribution using the kurtosis and skewness. A set of data is said to be normally distributed if the kurtosis value falls between -7 and 7 , and the skewness value falls between -2 and 2 (see, Hair et al., 2021). The results in (Table 3) demonstrates that all the variables fall within the acceptable normal distribution thresholds described above. Based on these results, it can be concluded that the data for the research is normally distributed.

Table 3. Descriptive statistics – means, standard deviation, Kurtosis and Skewness.

Variables	Mean	Stan. Dev	Variables	Mean	Stan. Dev	Kurtosis	Skewness
FD	68.120	14.530	Intergv-trans	60.180	0.466	2.843	1.506
			Tax rev % of GDP	48.710	0.896	−1.086	0.431
			Invest. assets	85.716	7.624	−1.115	−0.117
SDGs	3636.458	9359.251	Social.cont	77.874	3.739	4.089	1.786
			GDP. Per cap	28398.3	16996.6	1.543	0.708
			Emp. rate	70.153	18.737	1.19	−1.012
			Hum_cap.dev	21.979	7.851	−0.629	0.039
			HDI	50.905	11.556	−0.094	−0.613
			Sett_per cap	104.010	210.90	1.11	0.024
			CPI	205.701	110.910	1.15	2.306
			Gren_gas E	90.110	85.701	3.010	0.405
DE	333.186	188.194	Env_goods	150.510	88.405	1.200	−0.503
			Digit_skill	520.110	55.301	3.201	1.400
			ins_ICT. Train	403.80	201.600	−0.105	−1.408
No. of observations	144		E-Gov	75.650	20.880	−1.204	2.010

Note: FD = fiscal decentralization, SDGs = Sustainable development goals, DE = Digital economy, Intergv-trans = intergovernmental transfer, Tax rev % of GDP = subnational tax revenue as a % of GDP, Invest. Assets = investment in local assets, Social.cont = social contribution at local level, GDP per Cap = Gross domestic product per capita, Emp. Rate = employment rate, Hum_cap.dev = human capital development, HDI = human development development, Sett_per cap = Settlement per capital, CPI = corruption perception index, Gren_gas E = Green gas Emission, Env_goods = Environmental goods and services, ins_ICT. Training = Institutions providing ICT training, E-Gov = e- governance. Source: (The Authors).

Table 4. Factors loading, Cronbach Alpha, discriminant validity, and AVE.

Construct	Dimension	Factors Loading	Cronbach Alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE	VIF
DE	E-Gov	0.839	0.805	0.814	0.886	0.722	1.981
	Digi-skills	0.916					2.520
	Ins-ICT Train	0.789					1.567
FD	Intergov-tra	0.762	0.747	0.812	0.835	0.563	1.480
	Local tax-re	0.880					1.779
	Local asset-investment	0.717					1.436
	Social_Cont.Lo	0.617					1.326
Econ- SDGs	GDP per-ca	0.776	0.887	0.878	0.879	0.605	1.422
	Emp-rate	0.682					1.247
	Human-cap	0.864					1.690
Social-SDGs	HDI	0.896	0.777	0.814	0.875	0.704	3.886
	Sent-per.ca	0.647					1.300
	Per-corrupt	0.945					4.436
Env-SDGs	Green.gas-emission	0.703	0.877	0.887	0.890	0.605	1.049
	Env. Goods_serv	0.846					1.049

Source: (The Authors), Abbreviations; DE, digital economy; FD, fiscal decentralization; Econ- SDGs, economic sustainability. Social SDGs, social sustainability. Env SDGs, Environmental sustainability. Env. Goods_serv, Environmental goods and services.

Table 5. Discriminant validity and HTMT.

	Discriminant validity					HTMT				
	FD	DE	Econ-SDGs	Social-SDGs	ENV-SDGs	FD	DE	Econ-SDGs	Social-SDGs	ENV-SDGs
FD		0.464	0.251		0.821	FD		0.464	0.251	
DE	0.464					DE				
Econ-SDGs	0.251	0.850				Econ-SDGs		0.850		
Social-SDGs		0.556	0.827		0.799	Social-SDGs	0.628	0.556	0.827	0.799
ENV-SDGs	0.879	0.567	0.411			ENV-SDGs		0.567	0.411	

Source: (The Authors).

Table 6. Direct effects (Hypothesis Testing Decision) and normality test.

Relationship	Estimate	SM	SD	p-Values	Decision	R-Square	F-Square	Q-Square	Ramsey's RESET
FD → Eco-SDGs	−0.169	−0.168	0.053	0.001	Rejected	0.566	0.556	0.112	(F (3,489) = 1.55, p = 0.304)
FD → Soc-SDGs	0.221	0.218	0.042	0.000	Supported	0.746	0.162	0.257	
FD → Env-SDGs	0.728	0.476	0.552	0.094	Supported	0.454	0.822	0.403	
FD → DE	0.391	0.392	0.072	0.000	Supported	0.153	0.181	0.142	(F (3,490) = 0.56, p = 0.620)
DE → Eco-SDGs	0.802	0.805	0.042	0.000	Supported	0.566	1.256		
DE → Soc SDGs	0.753	0.755	0.031	0.000	Supported	0.746	1.889		
DE → Env-SDGs	−0.216	−0.109	0.210	0.152	Supported	0.454	0.772		

Source: (The Authors).

4.1. Measurement model

In the statistical algorithm, the measurement model is the initial phase to confirm the authenticity of the factor loading, Cronbach's alpha, composite reliability, average variance extracted (AVE), discriminant validity, cross loadings, and other important measuring factors in the measurement model (Igamo et al., 2024). However, as per the recommended procedure to confirm the statistical outcomes, the values must exist in the following range: the factor loading values must be 0.6 or higher, Cronbach's alpha and composite reliability must be 0.7 or higher, AVE must be ≥ 0.5 , to verify the validity of the measurement model (Hair et al., 2021; Ursachi et al., 2015). At the same time, the study focused on examining the multicollinearity among constructs through the variance inflation factor (VIF) technique, and the results confirmed that there were no issues of multicollinearity in this study, with a criterion score below 5. Hence, the findings show that all necessary factors meet the recommended criteria of the measurement mode, as shown in (Table 4).

In the second step of the measurement model, the study applied the Fornell and Larcker (1981) approach to calculate discriminant validity and HTMT to verify the measurement model. The results show that all diagonal values were higher in the concerned columns and rows, as presented in (Table 5).

4.2. Structural model

After validating the measurement model, the study extends to the second phase of the PLS-SEM analysis procedure to assess the structural model for testing the proposed hypothesis. In the assessment of the structural model, bootstrapping methodology, along with a sample of 5000, was executed to test the hypothesis. In the first step, the study inspected the direct association among the outlined variables, where the results indicated that FD had negative significant effects on economic SDGs ($\beta = -0.169$, $P > 0.05$), FD has positive significant effects on environmental and social SDGs ($\beta = 0.728$, $P > 0.05$) and ($\beta = 0.221$, $P > 0.05$, respectively). Likewise, FD has a significant positive effect on DE ($\beta = 0.391$, $P > 0.05$) among EU countries. Similarly, the study found that DE has a significant positive relationship with economic and social SDGs ($\beta = 0.802$, $P > 0.05$); ($\beta = 0.753$, $P > 0.05$, respectively). In contrast, we found a negative but significant influence of DE on environmental SDGs ($\beta = -0.216$, $P > 0.05$) among European Union countries, as shown in (Table 6 and Figure 2). Second, the indirect associations among the

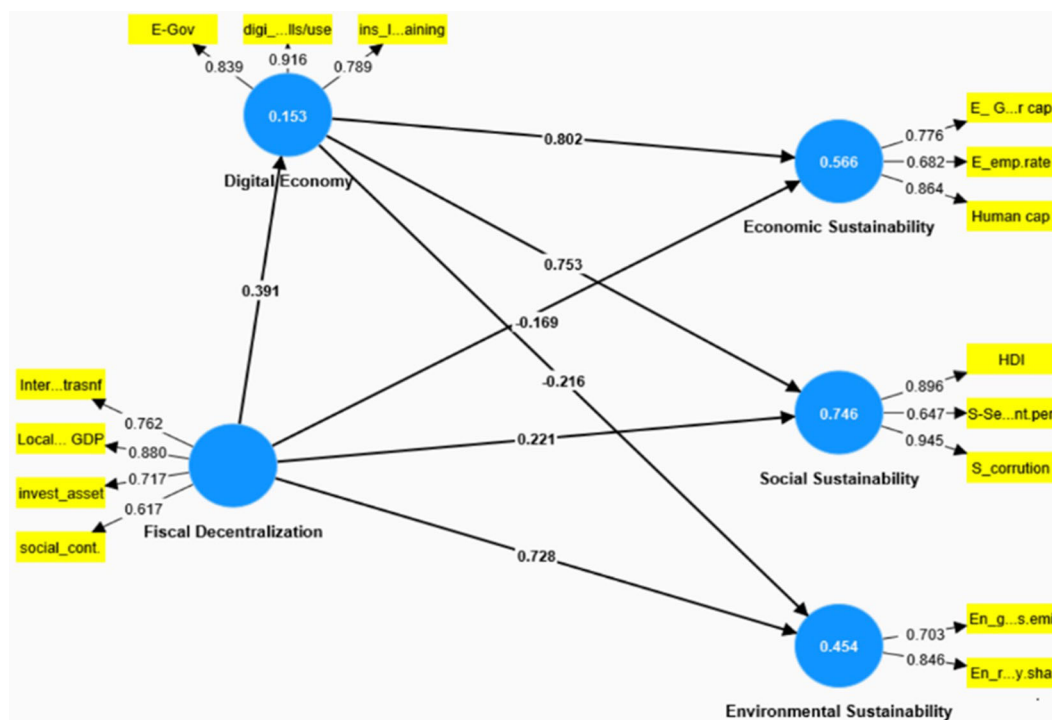


Figure 2. Measurement model.
Source: (The Authors).

Table 7. Mediating path results (Indirect Effects Hypothesis Testing).

Relationship	Estimate	SM	SDGs	T-Value	CILL	CIUL	Decision
DE → FD → Eco SDGs → Soc SDGs → Env SDGs	0.314	0.316	0.063	4.994	0.154	0.31	Supported

Note: FD = Fiscal Decentralization, DE = Digital Economy, Eco = Economic, Env = Environmental, Soc = Social, SDGs = Sustainable Development goals.

Source: (The Authors).

Table 8. Goodness of model fit.

	Saturated model	Estimated model
SRMR	0.062	0.062
d_ULS	0.355	0.355
d_G	0.277	0.277
Chi-square	466.775	466.775
NFI	0.871	0.872

Source: (The Authors).

constructs were inspected. The findings revealed that DE ($\beta = 0.314$, $P > 0.05$) played a mediating role between FD and SDGs within the European Union.

The coefficients of determination (R^2), effect size (f^2), and predictive model (Q^2) are presented in Table 5. According to Hair Jr et al. (2021) the range of explanatory power is determined using the standard R^2 which the value of 0.67 indicates a substantial explanatory power, while values of 0.33 and 0.10 are categorized as moderate and weak explanatory power, respectively. Examining Table 5 reveals that the R^2 values for social and economic SDGs were 0.746 and 0.566, respectively, indicating the strong and substantial explanatory power of the model. The Q^2 values were all greater than 0.1, indicating the strong predictive capability of the constructed model (Hair et al., 2021). Additionally, we analyzed the indirect (mediating effect) of DE on FD and SDGs as illustrated in (Table 7).

To evaluate the goodness of model fit, (Table 8) below proved the outcomes as it indicates that SRMR = 0.062, 0.062, NFI = 0.871, and 0.872 were within a satisfactory range. According to the rules, the values of SRMR must be in the range of "0 to 0.08", and NFI must be in the range of "0 to 1.00" to achieve goodness of model fit (Rizwanullah et al., 2021). Hence, the objective of the goodness of fit of the model was accomplished in this research.

5. Discussion

These results suggest that FD has a mixed relationship with the SDGs (Mainali et al., 2022). First, FD is negatively related to economic sustainability, contradicting H1a. The negative relationship between FD and economic sustainability is somewhat surprising, as it contradicts the conventional wisdom that FD can stimulate the SDGs in economies (Kuai et al., 2019). However, this finding is consistent with recent studies that have found that excessive FD can lead to inefficiencies and hinder sustainability in economies (Guerrero et al., 2022; Ligthart & Oudheusden, 2017; Zahra & Badeeb, 2022). In the case of EU countries, it is possible that the negative relationship between FD and economic sustainability is due to the existence of cross-country differences (Saqib, 2022), and on the settled principle that FD can also lead to reduced policy coherence as different local governments may implement conflicting policies (Shan et al., 2021). For example, some local governments may invest in renewable energy sources, whereas others may support the fossil fuel industry. Lack of coherence can hinder economic growth and sustainability. Hence, the findings suggest that the effects of FD on SDGs are contingent on various factors, including the presence of environmental regulations, level of economic development, and governance structure in place.

Second, our findings confirm Hypotheses H1b and H1c, demonstrating that FD has a significant influence on social and environmental SDGs (Shrestha et al., 2023). The positive relationship between FD and social SDGs is consistent with the expectations of proponents of the fiscal federalism theory, who argue that it can lead to better governance and more responsive public services (Shrestha et al., 2023). Likewise, the findings between FD and environmental SDGs suggest that local governments are often more responsive to environmental concerns than central governments (Xia et al., 2022). FD can lead to more efficient resource management and greater emphasis on environmental SDGs at the local level (Zhao et al., 2022). Consistent with the findings of Yan et al. (2023), we confirmed H2, as it shows a

significant positive influence of FD on DE. Thus, FD can promote DE use by encouraging the development of more responsive and user-friendly e-government services. DE, on the other hand, had a significantly positive influence on the two dimensions of the SDGs, except for environmental SDGs. Although our results show a negative relationship between DE and environmental SDGs, it affirms our expectation that the more countries digitalize, the lesser the degradation of the environment (Thanh et al., 2023). This finding is consistent with the position that the digital sector's environmental footprint is expected to triple by 2040, driven by the growth in data consumption and the increasing use of artificial intelligence and machine learning (Wang et al., 2023). Consequently, we confirmed hypotheses H3a, H3b, and H3c. The results between DE and the dimensions of SDGs are consistent with the growing body of literature, suggesting that DE plays a role in promoting SDGs (Gennari et al., 2023; Lu & Zhou, 2023; Song et al., 2022). The findings of this study further confirm H4a, H4b, and H4c, as they prove that DE plays a mediating role between FD and SDGs. We argue that the impact of FD on SDGs is partly dependent on the level of DE in the EU. This is likely because DE can amplify and mitigate the effects of FD on SDGs outcomes, as has been established in China (Xu et al., 2022; Huang et al., 2023). For example, if FD leads to a greater decentralization of environmental policymaking, DE can ensure that FD is accompanied by effective implementation and monitoring (Kuai et al., 2019).

6. Conclusion and policy implication

This study aims to investigate the relationship between FD and SDGs while considering the mediation role of DE, based on insights from the fiscal federalism and resource dependence theories in the EU. The study employed data from the European statistics databases (Eurostat, DESI), the OECD, and the GFS database from 2016 to 2022, and analyzed them through a PLS-SEM model in a quantitative analysis. While it is acknowledged that FD impacts SDGs dimensions, our knowledge about the channels through which it works is underexplored. In this study, we explored the mediating effect of DE on the relationship between FD and SDGs. This result shows that FD has a significantly negative effect on economic sustainability. The results further revealed a significant positive effect of FD on environmental and social SDGs. In addition, FD had a significant positive effect on DE. The analysis further proved that DE has a significant positive relationship with economic and social SDGs. Conversely, our results reveal a negative but significant influence of DE on environmental sustainability. We further demonstrated the mediating role of DE between FD and Sustainability. The results add to the growing literature on the nexus between FD, DE, and SDGs from the perspective of developed economies (Fang & Fang, 2023; Kopina & Kopin, 2019; Pasichnyi et al., 2019; Pu et al., 2023), by highlighting the important role of fiscal federalism and DE in influencing countries drive to sustainability. Second, this study examines the mediating role of DE in the connection between sustainability and FD. Although there has been sufficient research on the direct impact of DE on sustainability, we looked at how it influences the three primary characteristics of SDGs via mediating the interaction between FD. Therefore, this research adds to our understanding of how FD affects SDGs in industrialized economies. The findings of this study make novel contributions that expand existing theories, such as the theory of fiscal federalism and RDT, providing valuable insights into the relationship between FD, DE, and the dimensions of SDGs, which in turn influence economic, social, and environmental sustainability. These findings support the argument that FD has both positive and negative effects on the SDGs. This expands the view in fiscal federalism theory that FD can promote efficiency and responsiveness, but can also create inefficiencies and inequities if not managed effectively (Musgrave, 1956; Mainali et al., 2022). Similarly, we expand the view of fiscal federalism theory to include the role of DE in mediating the relationship between FD and SDGs (Wang et al., 2022). Our findings support the argument that local governments are more likely to adopt sustainable practices if they have access to resources such as digital infrastructure and skills training, consistent with RDT claims that organizations are more likely to adopt practices that are in their own best interests (ElMassah & Mohieldin, 2020). Furthermore, we showed that DE can reduce the resource dependency of local governments and free resources for sustainable development initiatives (Jacobs et al., 2021). This can help develop more effective strategies for promoting the SDGs at the local level.

The findings of this research have valuable practical implications for policymakers and guide governments in defining more interesting strategies to manage FD in a wise manner to successfully achieve

the objectives of the SDGs through the proper implementation of DE on a large scale among societies. This study found that FD can have both positive and negative effects on socioeconomic and environmental sustainability. It is important for policymakers to strike a balance in FD ensuring efficient revenue allocation mechanisms and enhancing fiscal responsibilities, ensuring that local governments have sufficient autonomy to address local needs while maintaining effective oversight and coordination (Faguet, 2014). Consistent with our results on DE and SDGs, governments should prioritize the development of broadband Internet access, e-governance resources, and other digital technologies (Ullah et al., 2021). Investing in digital skills training programs will ensure that citizens and businesses can take advantage of the opportunities presented by DE. Consistent with our findings, policymakers across the EU must tailor their strategies according to the specific needs and conditions of each region by striking a balance between promoting digitalization and minimizing its adverse environmental impacts through regulations and green technology adoption. They should consider factors such as the level of economic development and the availability of digital infrastructure when designing policies (Sarangi & Pradhan, 2020). Finally, local governments can create incentives to adopt sustainable practices, such as providing funding for renewable energy projects or supporting green urban planning initiatives to improve social welfare and environmental quality (Hoppe et al., 2015).

Limitation and future directions

As anticipated, there are certain limitations to this research, the most noticeable of which are as follows. First, it focused on the relationship between FD and SDGs in the context of European countries. Future studies could investigate this model in developing economies to enable comparison. Second, this study examined FD and SDGs mediated by DE, and exploring other mechanisms, such as the role of institutional quality and good governance, can provide more interesting insights in the relevant literature. In addition, this study inspected the data for all European countries in one model, and future studies could investigate the data for each country separately or conduct cross-country studies to provide policymakers with more in-depth information.

Acknowledgments

The authors are grateful to the students Michal Zilvar and Martin Matějček for providing us with feedback on the overall concept and editing of the article.

Authors' contributions

MIG: conception and design, analysis and interpretation of the data and the drafting of the paper; **SOA:** Data curation, writing original draft, Reviewing and Editing; **FF:** Data curation, writing original draft, Reviewing and Editing; **RP:** Supervision, revision and the final approval of this version. All authors agree to be accountable for all aspects of the work.

Disclosure statement

There is no potential or existing conflict of interest in this study.

Funding

The article was supported by the specific research project "Economic Impacts under the Industry 4.0 / Society 5.0 Concept", 2024, University of Hradec Králové, Faculty of Informatics and Management, Czech Republic. This work was also supported by the Student Grant Competition of the University of Pardubice, SGS_2024_013.

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Data availability statement

The study used Secondary data which were obtained from public sites. However, data can be provided by the corresponding author upon reasonable request.

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