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The Coupling and Coordination Degree of Digital Business and Digital Governance in the Context of Sustainable Development

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Abstract: The inexorable march of technological advancement, particularly within the digital domain, continues to exert a profound influence on global economies, societies, and governance frameworks. This paper delves into the intricate coordination between digital business and digital governance against the backdrop of sustainable development. By introducing an index system to gauge the levels of digital business and governance, this study assesses their coupling coordination using a coupling coordination model. Through this level of coordination, this paper assesses their respective contributions to the sustainable development objectives of EU countries through panel-corrected standard error (PCSE) estimates. The paper's findings underscore several key conclusions: (1) Notable upswings are evident in the composite indices for digital business and digital governance growth. Among these, the index of digital business has demonstrated the most pronounced surge. Furthermore, digital business has experienced a distinct upward trajectory in recent years. (2) Although observable, the rise of the coupling degree is restrained, with an overall coupling degree that remains relatively low. The coupling progression has transitioned from a stage of low-degree coupling to that of primary coupling, with EU countries demonstrating fluctuating rising trends in their coupling degrees, marked by conspicuous regional disparities. (3) Over the examined period, the extent of coordination between digital business and digital governance substantially impacts the Sustainable Development Goals (SDG) index. Focusing on the interplay and harmonization between digital business and governance offers a novel pathway toward attaining the objectives of the Sustainable Development Goals.

Keywords: e-commerce sales; e-commerce turnover; e-commerce web sales; digital economy; sustainable development

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1. Introduction

The global commitment to achieving the Sustainable Development Goals (SDGs) by 2030 represents a shared dedication to addressing the world's most pressing challenges, from poverty reduction to environmental sustainability. Within this global commitment, the European Union (EU) stands as a prominent advocate for sustainable development. Scholars [1–5] have outlined that analyzing the roles of digital business and governance within the context of EU countries is not only essential but also in alignment with the EU's proactive stance on achieving the SDGs [4,5]. One viewpoint [6–10] emphasizes the potential for enhanced efficiency and economic growth resulting from digitalization, highlighting their positive impact on sustainable development. The digital sector contributes significantly to job creation, serves as an innovation hub, and enables efficiency gains across various industries. Facilitating cross-border trade and e-commerce, digital platforms support the EU's economic integration, while the digital transformation of traditional sectors ensures their adaptability and resilience. Additionally, digital technologies empower small- and medium-sized enterprises (SMEs), fostering inclusivity and a diverse business ecosystem. The emergence of FinTech further reshapes the financial sector, making it more accessible and responsive. Recognizing the transformative power of digitalization, the EU continues to invest in policies and initiatives to support a thriving digital economy. Digital governance is integral to the EU economic landscape, serving as the foundational framework guiding effective government digitalization. This strategic approach establishes clear policies and regulations, fostering innovation and ensuring economic competitiveness by encouraging the adoption of emerging technologies. Digital governance prioritizes the accessibility and inclusivity in digital service delivery, addressing the digital divide and promoting social and economic cohesion. Moreover, it plays a pivotal role in upholding data privacy and security through regulations like the General Data Protection Regulation (GDPR), building trust in digital systems and services. By contributing to the efficiency of government service delivery, supporting continuous improvement, and adapting to evolving technologies, digital governance plays a critical role in driving the EU's economic resilience and growth in the digital era. However, critics [11–16] argue that these gains often come at the expense of job displacement, potentially exacerbating income disparities and hindering social progress. Another perspective [17–21] lauds data-driven decision-making for its ability to inform better policies, but it raises concerns about privacy erosion. The balance between data access for governance and safeguarding personal privacy can be a source of debate regarding the extent to which digital governance advances sustainable development [22–28]. In addition, digitalization requires affordable knowledge [29,30], infrastructure [31–34], and new management approaches [35–37]. Moreover, while the coupling of digital business and digital governance can foster innovation [38–40], it may also contribute to digital divides. Some regions or demographics benefit from this innovation, while others may be left behind, potentially exacerbating the inequalities within and among countries, a contentious issue within the context of Sustainable Development Goal 10 [41–43]. Furthermore, digital governance's promotion of environmental sustainability is not without controversy, as the production and disposal of electronic devices contribute to e-waste, a growing environmental concern [44–47]. Scholars [48–50] argue that the environmental benefits of digitalization are offset by the negative impact of e-waste. The global connectivity facilitated by digital governance and business can be seen as fostering international cooperation, but it can also be criticized [51–53] for perpetuating a form of "digital colonialism", where powerful nations or corporations dominate the digital landscape, potentially exploiting less developed regions and undermining local governance and development [51–53]. While digital governance enhances monitoring and accountability [54,55], it also raises concerns about surveillance and government overreach. Striking a balance between effective governance and individual freedoms remains a subject of ongoing debate and can influence the perceived impact digital governance on sustainable development. The impact of digital business and digital governance on sustainable development is a complex issue with diverse and occasionally controversial perspectives. While it presents numerous opportunities, it also poses challenges and trade-offs that necessitate careful consideration and ongoing discussion. It is required for the detailed exploration of how the digital business and digital governance realms interact and align in different national settings, uncovering the nuanced challenges and opportunities that arise in the EU. It is necessary to elucidate the intricacies of the coupling and coordination of digital business and digital governance, providing clarity on their varying degrees across EU countries and their implications for advancing the Sustainable Development Goals. Coupling signifies the depth of interconnection and mutual reliance between digital business and digital governance within the complex landscape of contemporary technological ecosystems. This concept delves into the intricate web of relationships where the activities, processes, and strategies of digital business are intricately linked with the policies, regulations, and operational frameworks established by digital governance. The degree of coupling reflects how closely these two domains are integrated, highlighting the extent to which changes or advancements in one sphere have implications for the other. Coordination, on the other hand, extends beyond mere interdependence and encapsulates the strategic alignment and harmonization of efforts between digital business and digital governance. It emphasizes the collaborative orchestration of initiatives, policies, and practices to achieve shared objectives and common goals. Effective coordination ensures that the dynamism and innovation fostered by digital business align seamlessly with the regulatory frameworks and public service objectives established by digital governance. This synchronization is essential for navigating the evolving landscape of technology, fostering sustainable growth, and mitigating potential conflicts or disruptions. While coupling elucidates the depth of their interconnectedness, coordination underscores the need for a strategic partnership to navigate the challenges and opportunities presented by the ever-evolving digital landscape. In achieving a delicate balance between coupling and coordination, organizations and governments can foster an environment in which technological advancements drive progress, innovation is nurtured, and broader socio-economic goals are met harmoniously. This study's refined research question emerges: how do the dynamics of digital business and digital governance vary across European countries, and what implications do these variations hold for the pursuit of the Sustainable Development Goals (SDGs) within the region? In this case, this paper aims to analyze the coordination between digital business and digital governance against the backdrop of sustainable development. This study fills the research gap on the theoretical framework to attaining the SDGs by developing approaches based on (1) the entropy method to estimate digital business and digital governance; (2) a coupling coordination model to estimate the coupling and coordination degree between digital business and digital governance; and (3) the panel-corrected standard error model to justify the impact of the coupling and coordination degree of digital business and digital governance on the Sustainable Development Goals index.

This paper has the following structure: the literature review explores previous studies related to digital business, digital governance, and sustainable development, to identify gaps where this research can contribute; the materials and methods section describes the data sources and datasets used in the study, explains the research methods and analytical techniques employed, justifying the chosen methodology to check the research hypothesis; the results section contains the research findings, with a primary focus on the coupling and coordination degree of digital business and digital governance and their impact on the SDGs; the discussion section interprets and analyzes the results within the context of sustainable development, explores the implications of the coupling and coordination degree on the Sustainable Development Goals, and examines any unexpected findings or emerging patterns; the conclusions section summarizes the main findings of the research, offers insights into the broader implications of the study, policy implications, research limitations, and directions for further investigations.

2. Literature Review

The rapid advancement of digital technologies and their pervasive integration into various aspects of economic development has brought about significant changes in how businesses operate and how governments manage their affairs [56–59]. The studies [56–58] outline that digital business refers to the use of digital technologies, strategies, and tools to conduct and optimize various business processes, operations, and models. It involves leveraging digital innovations such as e-commerce, digital marketing, data analytics, and automation, to enhance efficiency, customer experiences, and overall business performance in the contemporary digital landscape. Scholars [60–62] define digital governance as encompassing the use of digital technologies and data-driven approaches to facilitate and improve the processes of governance via digital public services within organizations, for citizens, and for businesses. It involves the application of technology for decision-making, policy implementation, and citizen engagement, with a focus on transparency, accountability, and the efficient use of digital resources to achieve governance objectives. Scholars [63–66] have shown that the coupling and coordination of digital business and digital governance have become critical factors that have profound implications for sustainable development.

Scholars [60–62] have outlined that government digitalization enhances the delivery of digital public services for citizens and businesses, making services more accessible and efficient. This contributes to the SDGs related to quality education, healthcare access, and reducing inequality, as it can improve the access to information, healthcare services, and educational resources. Based on empirical findings, scholars [67] have outlined the necessity of creating a favorable environment for private sector investment and strengthening digital infrastructure. This allows for boosting the attainment of the SDGs. Prior studies [67–70] confirm that digitalization promotes transparency and accountability in governance, which is crucial for achieving SDG 16 (peace, justice, and strong institutions). Digital platforms for government activities can reduce corruption, improve the rule of law, and enhance good governance [71–74]. At the same time, researchers [6,75,76] have highlighted that government digitalization stimulates economic growth and innovation, supporting SDGs related to economic development, decent work, and industry, innovation, and infrastructure (SDGs 8 and 9). Miskiewicz R. [32], by offering digital public services, showed that governments reduced the need for physical paperwork and travel, which has a positive impact on the SDGs related to environmental sustainability (e.g., clean energy and climate action—SDGs 7 and 13). Thus, Miskiewicz R. [32] confirmed that countries with higher levels of e-governance tend to achieve greater progress in SDG7 (affordable and clean energy). The research also highlights the positive influence of e-governance on renewable energy growth, emphasizing its strategic importance for SDG attainment within the EU [32].

Studies [75,77–79] have shown that digital businesses and e-commerce play a pivotal role in driving economic growth by opening up new markets and generating employment opportunities. The digital economy fosters innovation, which not only spurs economic development but also has a direct impact on reducing poverty, in line with SDGs 1 and 8 [80–82]. Palakshappa and Dodds [83] outline that digital businesses have the potential to foster more sustainable consumption patterns, thereby making valuable contributions to the SDGs centered on responsible consumption and production (SDG 12). Gregori and Holzmann [84] confirmed a similar conclusion; that through the reduction of waste and resource consumption, digital businesses align with objectives related to more sustainable and environmentally friendly practices. In addition to promoting sustainable consumption, the digital realm offers platforms for e-learning and expands access to quality education [85–88]. This is a crucial component for achieving the SDGs dedicated to education (SDG 4), as digital technologies facilitate broader educational opportunities [89–91]. Furthermore, scholars [91–94] have shown that the digital economy, by facilitating digital entrepreneurship and leveling the playing field, can effectively contribute to reducing economic inequalities, in line with the SDGs that aim to diminish disparities within and among countries (SDG 10).

Other studies [95–97] outline that the impact of the coupling and coordination degree of digital business and digital governance on sustainable development is a multifaceted matter, encompassing diverse and occasionally contentious viewpoints. Proponents [98–100] argue that this integration enhances economic efficiency, contributes to innovation, and fosters data-driven decision-making. However, this integration is also met with concerns, including potential job displacement, privacy issues, and the digital divide. Additionally, questions are raised about its environmental impact [101,102], global implications [103–105], and the trade-offs between monitoring and accountability versus surveillance and government overreach [106,107]. Based on the above, this study tests the following hypothesis:

Hypothesis 1: *The coupling and coordination degree of digital business and digital governance affect the attainment of the Sustainable Development Goals.*

3. Materials and Methods

Based on previous studies [108–110], to examine the impacts of the coordination between digital business and digital governance on the Sustainable Development Goals (SDG) index, the following econometric model was specified:

$$SDG_{it} = a_0 + b_1 Coord_{it} + b_2 X_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (1)$$

where SDG_{it}—the dependent variable representing the Sustainable Development Goals (SDGs) index for country i at period t; $Coord_{it}$—the explanatory variable denoting the level of coordination between digital business and digital governance; X_{it}—the set of control variables; a_0—unit-specific fixed effects; b_1, b_2—the coefficients of the explanatory and control variables, respectively; μ_i, μ_t—country- and time-specific factors, respectively; and ε_{it}—error term.

To estimate regression Equation (1) and ensure the robustness of the data analysis, a comprehensive methodology involving various diagnostic tests was employed. These tests were pivotal in determining the most suitable estimation technique for the dataset. The methodology included the following steps: (1) A series of unit root tests, including Im, Pesaran, IPS, and Augmented Dickey–Fuller (ADF) tests, were conducted to assess the stationarity of the variables in the dataset. These tests are essential for determining whether the variables exhibit nonstationary behavior, which could impact the accuracy of the regression results. (2) The Pesaran test was applied to investigate the potential cross-sectional dependence among observations across different entities within the dataset. Understanding cross-sectional dependence is crucial for capturing the complex relationships present in the data. (3) Cointegration tests, such as the Pedroni, Westerlund, and Kao cointegration tests, were employed to explore the existence of long-term relationships among the variables. Identifying cointegration is crucial for understanding the equilibrium relationships and is particularly relevant in economic and financial analyses. (4) The variance inflation factor (VIF) was calculated to assess the extent of multicollinearity in the model. This step helped in identifying the variables that might be highly correlated, which can affect the stability of the coefficient estimates and the interpretation of results. (5) The Wooldridge test for autocorrelation in the panel data was performed to assess the presence of autocorrelation in the error terms. (6) A correlation matrix was generated to visualize the pairwise correlations between the variables. This analysis was crucial for detecting potential issues with multicollinearity and gaining insights into the interactions between different variables.

Upon meticulously executing the analytical procedures, this study employs the panel-corrected standard errors approach. This decision stems from the acknowledgment that panel data can be susceptible to various challenges, including cross-sectional dependency, autocorrelation, and heteroscedasticity. Recognizing the limitations of traditional econometric techniques, such as pooled ordinary least squares (OLS), fixed effects, and random effects, is paramount. These conventional methods may yield inconclusive or inappropriate conclusions when applied to panel data, as they often fail to adequately address the complexities and nuances inherent to this type of dataset. The panel-corrected standard errors approach, on the other hand, is specifically designed to mitigate the issues associated with panel data. It accounts for cross-sectional dependency, autocorrelation, and heteroscedasticity, offering a more robust and reliable way to estimate and draw meaningful conclusions from the dataset. By adopting this approach, this study aims to overcome the limitations of traditional methods and ensure that the results obtained are valid, insightful, and well suited to the characteristics of the panel data under examination.

The evaluation of the level of coordination between digital business and digital governance considers various dimensions. Government digitalization focuses on the government's integration and proficient use of digital technologies in its operations and service delivery. It involves a meticulous examination of crucial facilitators, such as policies, regulations, and infrastructure, that play a pivotal role in advancing digitalization efforts. Furthermore, it assesses the accessibility and adoption of digital public services by businesses and citizens, serving as a tangible measure of the government's commitment to digital transformation. Based on the previous studies [32,45], this dimension is delineated by key indicators: (a) Key Enablers (*KE*) assess the policies, regulations, and infrastructure, which are vital for fostering a digital environment, encouraging innovation, and ensuring robust digital infrastructure. (b) Digital Public Services for Businesses (*DPb*) evaluate the availability and quality of digital services, streamlining business operations, reducing bureaucracy, and enhancing compliance. (c) Digital Public Services for Citizens (*DPc*) signify a government's dedication to enhancing its citizens' quality of life through user-friendly digital services, including healthcare, education, and public welfare, ultimately enhancing citizen engagement and satisfaction.

Digital business concentrates on evaluating the integration and impact of digital technologies within the business sector. It involves an in-depth analysis of the extent to which businesses engage in e-commerce activities, the proportion of enterprises generating significant e-commerce sales, and the prevalence of businesses utilizing digital platforms for sales transactions. These indicators offer valuable insights into the level of digitalization of business operations and the broader digital economy of a nation. Based on the prior studies [41,45], this dimension is elaborated through the following key indicators: enterprises with e-commerce sales (*E*1); enterprises with e-commerce sales representing at least 1% of their turnover (*E*2); and enterprises with web-based sales conducted via websites, applications, or online marketplaces (*E*3).

The entropy method is applied to calculate government digitalization and digital business and economy. The studies [63,111] outlined that the entropy method considers the relative importance of criteria or indicators by allowing for the assignment of weights. This ensures that not all criteria are treated equally, and their importance is considered when calculating the overall entropy for each alternative. In the first stage, the normalization of all data is provided. This allowed us to transform the data into a standardized format (Formula (2)), often between 0 and 1, where 0 represents the worst possible performance or outcome, and 1 represents the best [63,111].

$$Z_{ni} = \frac{z_i - z_{min}}{z_{max} - z_{min}} \quad (2)$$

where z_{max}, z_{min}—the maximum and minimum value of z_i; i = 1, 2, 3. . ., n and Z_{normi}—normalized value of z_i.

In the next stage, applying Formulas (3) and (4), this study calculated the entropy weight (ω_i) for the relevant variables within government digitalization and digital business and economy, respectively.

$$\omega_i = \frac{1 - p_i}{\sum_{i=1}^{n}(1 - p_i)} \quad (3)$$

where p_i—the values of entropy.

$$p_i = -\frac{1}{\ln(n)} \sum_{i=1}^{n} \frac{1 + Z_{ni}}{\sum_{i=1}^{n} 1 + Z_{ni}} \times \ln(\frac{1 + Z_{ni}}{\sum_{i=1}^{n} 1 + Z_{ni}}) \quad (4)$$

The next stage aims to calculate the entropy weight index for government digitalization (GD_i) and digital business and economy (DB_i) (Formulas (5) and (6), respectively).

$$GD_i = \sum_{i=1}^{n} \omega_{igd} Z_{ngdi} \quad (5)$$

$$DB_i = \sum_{i=1}^{n} \omega_{idb} Z_{ndbi} \quad (6)$$

where ω_{igd}, ω_{idb}—the entropy weight of the relevant variables for government digitalization and digital business, respectively; Z_{ngd}, Z_{ndb}—normalized data for government digitalization and digital business and economy, respectively.

The thresholds for GD_i and DB_i are from 0 (low-level) to 1 (high-level). Based on the findings from previous studies [63], the level of coordination between the weighting factors is computed using Formula (7):

$$Coord_i = \sqrt{C_i \times T_i} = \sqrt{\left(\frac{\prod_{i=1}^{n} f_i}{\left[\frac{\sum_{i=1}^{n} f_i}{n}\right]^n}\right)^{1/n} \times \left(\sum_{i=1}^{n} q_i \times f_i\right)^{1/n}}, \quad (7)$$

where C_i is the numerical value of coordination; T_i is the quantitative value of the coordination level for government digitalization and digital business; q_i is the weighting factor = 0.5; f_i is the level of government digitalization and digital business; and n is the number of indicators.

The coupling degree between the components is categorized into four distinct levels, delineated by specific threshold values. A coupling degree falling within the range of 0.75 to 1 is classified as "High", while values between 0.5 and 0.75 are considered "Above average". A coupling degree ranging from 0.25 to 0.5 is labeled as "Below average", and values between 0 and 0.25 are denoted as "Low".

Referring to the studies [6,9], this investigation used the following set of control variables that could significantly affect the attainment of the SDGs within government digitalization and the digital business and economy:

- Trade openness, often measured as the ratio of a country's total trade (exports plus imports) to its GDP, provides insights into how integrated a country is with the global economy. A high degree of trade openness suggests that a nation is actively participating in international trade, which can positively impact its economic growth and development. Studies [112–117] show that enhanced trade leads to increased income, job creation, and the transfer of new technologies, ultimately contributing to economic prosperity. These economic benefits, in turn, can facilitate a country's ability to invest in healthcare, education, infrastructure, and other essential sectors, aligning with several SDGs, including those related to poverty reduction, economic growth, and industry innovation.
- GDP per capita is a key indicator of a country's economic well-being, representing the average income of its citizens [118–120]. A higher GDP per capita implies greater resources available for social and infrastructure development. Countries with higher GDP per capita often find it more feasible to allocate funds to healthcare, education, clean energy, and other SDG-related initiatives. This indicator is particularly relevant for the SDGs addressing poverty reduction, access to quality education, good health and well-being, and reduced inequalities.
- Environmental regulation measures a country's commitment to environmental sustainability, which is central to several SDGs, particularly those focusing on responsible consumption and production, climate action, life below water, and life on land. Strong environmental regulations signify that a country is taking steps to mitigate pollution, conserve natural resources, and combat climate change [121–123]. These actions are crucial for safeguarding the environment for future generations and aligns with the SDGs that address environmental and ecological concerns.

To explore the impact of the coordination level between digital business and digital governance on the SDGs index, panel data spanning from 2013 to 2020 are utilized, encompassing 22 EU countries. The selection of this time frame is based on data availability for the variables under analysis. The description of the chosen variables is provided in Table 1.

Table 1. Variable Descriptions.

Variables	Mean	Standard Deviation	Minimum	Maximum
GDP	35,528.690	24,286.830	8969.149	123,678.700
TO	126.612	65.624	54.868	380.104
EnvReg	0.695	0.268	0.200	1.500
KE	59.605	24.547	5.000	100.857
DPb	64.420	17.719	16.000	100.786
DPc	49.039	19.911	12.000	89.000
E1	19.644	8.079	5.500	46.800
E2	17.126	7.923	3.300	42.800
E3	11.482	5.022	3.267	27.900

4. Results

The empirical results presented in Table 2 provide insights into the state of government digitalization in a selection of European countries. This analysis aims to quantify and compare the level of digitalization in these nations based on a set of relevant indicators. The data include the mean (average), standard deviation (variability), minimum, and maximum values for each country, which explore the degree of digitalization and the variability within the sample.

Table 2. The empirical results for the calculation of government digitalization.

Country	Mean	SD	Min	Max	Country	Mean	SD	Min	Max
Austria	0.348	0.081	0.231	0.486	Latvia	0.089	0.042	0.024	0.144
Croatia	0.383	0.082	0.281	0.525	Lithuania	0.437	0.051	0.374	0.542
Czechia	0.537	0.054	0.453	0.613	Luxembourg	0.242	0.044	0.163	0.295
Denmark	0.486	0.083	0.370	0.648	Netherlands	0.455	0.044	0.376	0.513
Estonia	0.227	0.079	0.095	0.330	Poland	0.215	0.049	0.169	0.302
Finland	0.489	0.078	0.402	0.602	Portugal	0.211	0.051	0.120	0.286
France	0.333	0.061	0.244	0.408	Romania	0.098	0.124	0.030	0.402
Germany	0.468	0.104	0.330	0.616	Slovakia	0.252	0.048	0.162	0.292
Hungary	0.175	0.052	0.111	0.262	Slovenia	0.249	0.075	0.094	0.351
Ireland	0.783	0.141	0.590	0.998	Spain	0.303	0.080	0.187	0.436
Italy	0.076	0.051	0.004	0.151	Sweden	0.662	0.117	0.527	0.878

The mean values represent the central tendency toward government digitalization within each country. A higher mean value indicates a higher level of digitalization. It should be noted that Ireland (0.783) and Sweden (0.662) have the highest mean values, suggesting a more advanced level of digitalization in their governmental systems. On the other hand, Italy (0.076) and Romania (0.098) exhibit much lower mean values, indicating a relatively lower level of digitalization in their government services and infrastructure. Furthermore, Ireland and Sweden, with relatively high mean values, also exhibit higher standard deviations (0.141 and 0.117, respectively). This indicates that while they have high overall digitalization, there is still variability or diversity in their digitalization levels across various areas. In contrast, countries such as Italy and Romania, with lower mean values, have lower standard deviations (0.051 and 0.124, respectively). This suggests a more consistent, albeit lower, level of digitalization across different aspects of their government services.

Considering the findings in Table 3, Estonia (0.843) has the highest mean value, indicating a relatively advanced digital business environment. Other countries, such as Denmark (0.735) and Austria (0.728), also exhibit high mean values, implying a robust presence of digital business and economy within their borders. Conversely, countries such as Romania (0.107) and Hungary (0.246) have substantially lower mean values, reflecting a relatively lower level of digital business and economic development.

Table 3. The empirical results for the calculation of digital business and economy.

Country	Mean	SD	Min	Max	Country	Mean	SD	Min	Max
Austria	0.728	0.125	0.525	0.896	Latvia	0.762	0.065	0.637	0.838
Croatia	0.261	0.070	0.169	0.358	Lithuania	0.534	0.075	0.404	0.632
Czechia	0.432	0.110	0.275	0.585	Luxembourg	0.591	0.131	0.423	0.798
Denmark	0.735	0.080	0.570	0.823	Netherlands	0.652	0.131	0.442	0.830
Estonia	0.843	0.061	0.775	0.931	Poland	0.362	0.049	0.311	0.457
Finland	0.753	0.035	0.710	0.801	Portugal	0.635	0.046	0.558	0.687
France	0.554	0.086	0.418	0.658	Romania	0.107	0.049	0.064	0.180
Germany	0.477	0.069	0.390	0.603	Slovakia	0.333	0.155	0.148	0.544
Hungary	0.246	0.115	0.125	0.405	Slovenia	0.512	0.083	0.397	0.623
Ireland	0.556	0.042	0.507	0.598	Spain	0.539	0.095	0.390	0.671
Italy	0.422	0.097	0.292	0.556	Sweden	0.725	0.062	0.619	0.818

Estonia, which has the highest mean value, exhibits a relatively low standard deviation (0.061), indicating a relatively consistent high level of digital business and economic development across different areas. In contrast, Slovakia (0.155) and Luxembourg (0.131), despite having higher means, have higher standard deviations, indicating greater variability or disparities in digital business and economic activities within their borders.

The empirical results (Table 4) show that Sweden, with the highest maximum value (0.953), demonstrates areas of strong coupling between government digitalization and digital business and economy. This suggests that certain regions or sectors within Sweden have achieved a high level of synergy between government digitalization efforts and digital economic development. Countries with lower maximum values, Italy (0.698) and Romania (0.694), indicate that their coupling is relatively weaker, even in the regions or sectors where it is most prominent.

Table 4. The findings for calculating the coupling between government digitalization and digital business and economy.

Country	V	Mean	SD	Min	Max	Country	V	Mean	SD	Min	Max
	C	0.933	0.023	0.892	0.955		C	0.586	0.121	0.360	0.712
Austria	T	0.731	0.069	0.635	0.831	Latvia	T	0.651	0.040	0.581	0.701
	D	0.825	0.044	0.758	0.891		D	0.616	0.083	0.466	0.704
	C	0.972	0.035	0.908	1.000		C	0.993	0.005	0.986	0.999
Croatia	T	0.565	0.054	0.513	0.665	Lithuania	T	0.696	0.039	0.639	0.749
	D	0.741	0.040	0.699	0.808		D	0.831	0.023	0.798	0.865
	C	0.984	0.024	0.936	1.000		C	0.900	0.074	0.769	0.983
Czechia	T	0.695	0.043	0.651	0.759	Luxembourg	T	0.644	0.040	0.598	0.709
	D	0.826	0.033	0.781	0.871		D	0.760	0.020	0.719	0.779
	C	0.977	0.014	0.954	0.993		C	0.983	0.013	0.965	0.999
Denmark	T	0.780	0.046	0.713	0.858	Netherlands	T	0.742	0.056	0.640	0.811
	D	0.873	0.029	0.833	0.923		D	0.853	0.029	0.799	0.884
	C	0.800	0.096	0.613	0.898		C	0.960	0.030	0.903	0.994
Estonia	T	0.731	0.036	0.672	0.787	Poland	T	0.536	0.033	0.490	0.583
	D	0.764	0.061	0.642	0.834		D	0.717	0.025	0.684	0.761
	C	0.974	0.015	0.954	0.990		C	0.857	0.054	0.763	0.918
Finland	T	0.788	0.031	0.752	0.836	Portugal	T	0.650	0.032	0.582	0.688
	D	0.876	0.023	0.848	0.910		D	0.746	0.039	0.667	0.795
	C	0.966	0.019	0.937	0.992		C	0.938	0.061	0.824	0.998
France	T	0.664	0.050	0.577	0.717	Romania	T	0.306	0.101	0.221	0.531
	D	0.800	0.033	0.747	0.837		D	0.529	0.075	0.452	0.694
	C	0.991	0.009	0.974	1.000		C	0.967	0.031	0.901	0.999
Germany	T	0.686	0.044	0.643	0.781	Slovakia	T	0.536	0.081	0.394	0.645
	D	0.824	0.028	0.797	0.884		D	0.717	0.052	0.628	0.783
	C	0.986	0.014	0.960	1.000		C	0.926	0.057	0.787	0.961
Hungary	T	0.451	0.090	0.348	0.578	Slovenia	T	0.614	0.063	0.496	0.696
	D	0.664	0.062	0.589	0.751		D	0.753	0.058	0.625	0.818
	C	0.984	0.013	0.966	0.999		C	0.957	0.013	0.936	0.977
Ireland	T	0.817	0.049	0.741	0.890	Spain	T	0.646	0.068	0.537	0.744
	D	0.896	0.023	0.860	0.927		D	0.785	0.047	0.709	0.853
	C	0.632	0.238	0.230	0.820		C	0.997	0.004	0.989	1.000
Italy	T	0.494	0.075	0.386	0.595	Sweden	T	0.832	0.048	0.764	0.910
	D	0.553	0.152	0.302	0.698		D	0.910	0.027	0.873	0.953

Note: V—variable; D—value of coupling; C—the numerical value of coordination; T—the quantitative value of the coordination level for government digitalization and digital business.

Sweden (whose mean value of D is 0.910), Denmark (whose mean value of D is 0.873), and Finland (whose mean value of D is 0.8759) exhibit relatively high mean values, suggesting a substantial interrelationship between government digitalization and the digital business and economic sectors (Table 3). Italy (0.1520) and Romania (0.0754) have the highest standard deviations, implying that there are variations in the coupling strength within these countries, possibly across different regions or sectors. Conversely, Luxembourg (0.0203) and Sweden (0.0269) have lower standard deviations, suggesting a more consistent coupling strength across different areas.

The results of testing for stationarity are shown in Table 5. The findings of the Levin–Lin–Chu test indicate that all selected variables are stationary. However, the Im–Pesaran–Shin and Phillips–Perron tests for Coord, GDP, TO, and EnvReg are not significant. This suggests that these tests did not provide enough evidence to conclude stationarity. The results of the CIPS test confirm stationarity for all variables but are not as strong as those of the Levin–Lin–Chu test.

Table 5. The results of unit root tests (Im, Pesaran, IPS, and Augmented Dickey–Fuller (ADF)) tests.

Variable	Levin–Lin–Chu		Im–Pesaran–Shin		Phillips–Perron		CIPS
	Statistic	*p* Value	Statistic	*p* Value	Statistic	*p* Value	Statistic
Coord	−15.237	0.000	0.810	0.791	0.425	0.336	−2.117
GDP	−10.196	0.000	0.294	0.616	−1.885	0.970	−0.575
TO	−4.949	0.000	−0.609	0.271	−0.622	0.733	−1.748
EnvReg	−3.811	0.000	−3.284	0.001	0.558	0.289	−1.625
ΔCoord	−12.449	0.000	−4.436	0.000	20.054	0.000	−2.421 **
ΔGDP	−25.822	0.000	−2.587	0.005	12.270	0.000	−2.455 *
ΔTO	−19.249	0.000	−2.132	0.017	3.512	0.000	−2.335 *
ΔEnvReg	−5.633	0.000	−3.619	0.000	11.676	0.000	−2.463 *

Note: *, **—statistical significance at 1% and 5%; Coord—coupling coordination between government digitalization and digital business and economy; GDP—gross domestic product per capita; TO—trade openness; EnvReg—environmental regulation; Δ—Coord, GDP, TO, and EnvReg in their first differences.

The results for the differenced variables (ΔCoord, ΔGDP, ΔTO, ΔEnvReg) also indicate that they are stationary, as the test statistics are highly negative and significant. This allows for the next stage of the investigation—the Pesaran test.

Considering the results in Table 6, there is a significant level of cross-sectional dependence among the selected variables. This implies that these variables are not independent, and their values are influenced by common factors or interactions across the cross-sections. For instance, the CD-test statistic values for SDG, Coord, GDP, TO, and EnvReg are all notably high, indicating a substantial presence of cross-sectional dependence.

Table 6. The results of the Pesaran test.

Variable	CD-Test	*p* Value	Mean ρ	Mean abs (ρ)
SDG	30.214	0.000	0.70	0.72
Coord	24.043	0.000	0.56	0.69
GDP	30.631	0.000	0.71	0.73
TO	13.761	0.000	0.32	0.49
EnvReg	12.724	0.000	0.30	0.41

The results of the Kao test (Table 7) indicate that, for the Modified Dickey–Fuller t and Augmented Dickey–Fuller t statistics, the p values are greater than the common significance level of 0.05 ($p > 0.05$). This suggests that there may not be sufficient evidence to support cointegration based on these statistics. However, the Dickey–Fuller t statistic, the unadjusted modified Dickey–Fuller t, and unadjusted Dickey–Fuller t statistics, all have *p* values less than 0.05 ($p < 0.05$), indicating some potential evidence of cointegration.

Table 7. The empirical results of the cointegration test.

Kao Test	Statistic	*p* Value	Pedroni Test	Statistic	*p* Value
Modified Dickey–Fuller t	1.322	0.093	Modified Phillips–Perron t	6.183	0.000
Dickey–Fuller t	−3.194	0.001	Phillips–Perron t	−21.235	0.000
Augmented Dickey–Fuller t	2.424	0.008	Augmented Dickey–Fuller t	−14.761	0.000
Unadjusted modified Dickey–Fuller t	−2.288	0.011	**Westerlund**	**Statistic**	***p* Value**
Unadjusted Dickey–Fuller t	−6.121	0.000	Variance ratio	2.382	0.009

In contrast to the Kao test, the results of the Pedroni test consistently suggest the presence of cointegration. All statistics exhibit highly significant p values ($p < 0.05$), indicating strong evidence of cointegration. The Modified Phillips–Perron t and Phillips–Perron t statistics reveal particularly low p values ($p < 0.001$), further supporting the existence of cointegration.

The results of the multicollinearity test are displayed in Table 8. The variance inflation factor (VIF) for all variables in the dataset is less than 5, indicating the absence of multicollinearity issues within the sample.

Table 8. The empirical calculations of the variance inflation factor (VIF).

Variable	VIF	1/VIF
Coord	1.430	0.697
GDP	1.350	0.742
TO	1.130	0.883
EnvReg	1.080	0.925
Mean VIF	1.250	

The results of the Wooldridge test for autocorrelation in the panel data (Table 9) suggest that autocorrelation is present in the variables being tested. The low p values associated with the F-statistics indicate strong evidence against the null hypothesis, indicating the existence of autocorrelation.

Table 9. The results for autocorrelation, applying the Wooldridge test.

Variable	F-Statistics	Prob > F
SDG	70.414	0.000
Coord	62.169	0.000
GDP	190.497	0.000
TO	51.996	0.000
EnvReg	13.195	0.002

The first row in Table 10, with a "Delta" value of 2.244 and a p value of 0.025, indicates a statistically significant difference in the slopes of the groups being compared. The second row, with a "Delta" value of 3.664 and a p value of 0.000, also signifies a highly significant difference in slopes between the groups. These results suggest the presence of slope heterogeneity in the regression model under examination, implying that the relationship between the variables and the dependent variable varies significantly across different groups or entities within the panel dataset.

Table 10. The results of testing slope heterogeneity.

	Delta	*p* Value
Delta	2.244	0.025
Adjusted delta	3.664	0.000

Table 11 displays the pairwise correlations between the variables under investigation. The SDGs display moderate positive correlations with Coord and EnvReg, indicating that higher SDG scores are associated with increased Coord and more stringent EnvReg.

Table 11. The findings for pairwise correlations between SDG, Coord, GDP, TO, and EnvReg.

	SDG	Coord	GDP	TO	EnvReg
SDG	1.000				
Coord	0.504	1.000			
GDP	0.423	0.494	1.000		
TO	0.346	0.160	0.189	1.000	
EnvReg	0.558	0.292	0.154	0.127	1.000

Additionally, Coord is positively correlated with the Gross Domestic Product (GDP), suggesting that better coordination is associated with a higher economic output. The relationships between GDP and the other variables, as well as between Trade Openness (TO) and Environmental Regulations (EnvReg), are relatively weak.

Based on the outputs of the diagnostic tests presented in Tables 4–9, it is evident that the sample data exhibit issues related to cross-sectional dependency, autocorrelation, and heterogeneity. With the presence of cross-sectional dependency, autocorrelation, and heterogeneity within panel data, the panel-corrected standard errors (PCSE) approach is a more appropriate choice for several reasons. This method effectively addresses cross-sectional dependency by adjusting standard errors, ensuring the independence of observations within cross-sections. Moreover, it accounts for autocorrelation by correcting the errors across time, maintaining the validity of the statistical tests. Table 12 provides a summary of the results obtained through the panel-corrected standard errors, fixed effects, and random effects approaches.

Table 12. The findings for PCSE, FE, and RE approaches.

Variables	PCSE	FE	RE
Coord	0.054 * (0.0097)	0.037 * (0.0073)	0.038 * (0.0074)
GDP	0.022 * (0.0028)	0.041 * (0.0067)	0.035 * (0.0058)
TO	0.027 * (0.0039)	0.035 ** (0.0135)	0.036 ** (0.0139)
EnvReg	0.022 * (0.0051)	−0.001 (0.0036)	0.001 (0.0037)
const	4.279 * (0.0330)	3.963 * (0.0693)	4.031 (0.0603)
Number of observations	176	154	154
R-squared	0.999	0.432	0.429
rho	0.655	0.963	0.948
Wald chi2	1193.59	24.37	97.60
Prob > chi2	0.000	0.000	0.000
Hausman Test chi2	–	2.41	
Prob > chi2	–	0.6604	

Note: *, **—statistical significance at 1% and 5%; standard errors in parentheses.

The results obtained from the panel-corrected standard errors (PCSE) approach reveal that the level of coordination between digital business and digital governance significantly bolsters the Sustainable Development Goals (SDGs) index. Specifically, the coefficient associated with the level of coordination indicates that a one-unit increase in the Coord indicator corresponds to a 5.4% upsurge in the SDGs index. Importantly, this coefficient is statistically significant at the 1% level, particularly among European Union (EU) countries. The elevation of the SDGs index is a consequence of concerted efforts to integrate digital technologies into both public and private sector operations. The close collaboration between digital business and government within EU nations has paved the way for streamlined digital services, improved governance, and more efficient processes. As a result, citizens and businesses benefit from heightened access to digital public services, while adherence to regulatory requirements becomes more streamlined, fostering economic growth and environmental sustainability. This synergy ultimately contributes to the attainment of the SDGs, underscoring the pivotal role of digital coordination in advancing sustainable development. Furthermore, the estimation results demonstrate a positive and statistically significant impact of GDP per capita on the Sustainable Development Goals (SDGs) index. According to the computed findings, a one-unit increase in GDP per capita leads to a 2.2% improvement in the SDGs index across the sampled economies. This observed effect of GDP on the SDGs index aligns with the empirical evidence from previous studies. This positive GDP impact reflects the pivotal role that economic prosperity plays in advancing sustainable development. As GDP per capita increases, it signifies improved living standards, increased access to resources, and a greater financial capacity to invest in initiatives that align with the SDGs. This, in turn, contributes to the overall enhancement of the SDGs index, highlighting the interconnectedness of economic well-being and the pursuit of sustainable development objectives. Additionally, the regression analysis reveals that trade openness exerts a positive and significant influence on the Sustainable Development Goals (SDGs) index. This finding is consistent with the results of a study conducted by [46,75,93]. The positive impact of trade openness on the SDGs index underscores the potential benefits of international trade for advancing the Sustainable Development Goals. This suggests that countries actively engaged in global trade activities tend to experience improved economic growth, increased access to diverse resources, and enhanced opportunities for collaboration and innovation.

In addition, the results obtained from the fixed effects and random effects models show that the level of coordination between digital business and digital governance significantly enhances the Sustainable Development Goals (SDGs) index. Specifically, the coefficient linked to the level of coordination suggests that a one-unit increase in the Coord indicator corresponds to a substantial 3.7% increase in the fixed effects model and 3.8% in the random effects model. Nonetheless, the EnvReg indicator exhibits varying effects on the SDGs index in the fixed effects and random effects models, although it is important to note that this coefficient lacks statistical significance.

In this study, a robust check was conducted using the alternative estimated approach, namely the two-stage least squares (2SLS) method, which efficiently solves the endogeneity issue. Additionally, research and development (R&D) were incorporated into Model (1). Table 13 reveals the results derived from 2SLS estimations. The p-value from the under-identification test (K-P rk LM) exhibits significance at the 1% threshold, whereas the statistical measure for the weak identification test (K-P rk Wald F) surpasses the critical value noticeably. Additionally, the Durbin–Wu–Hausman (DWH) test's p-value substantiates the presence of endogeneity. The outcomes of these three assessments collectively support the appropriateness of applying the 2SLS method to address endogenous issues.

Table 13. The findings of the 2SLS approach.

Variables	2SLS
Coord	0.047 * (0.0085)
Control variables	Yes
const	4.134 * (0.0564)
Number of observations	176
K-P rk LM	18.101
K-P rk Wald F	19.343
DWH test	121.596

Note: *, —statistical significance at 1%; standard errors in parentheses.

Furthermore, as depicted in Table 13, the calculated coefficient for the coordination between digital business and digital governance is positive. This observation reaffirms the primary findings of this research, emphasizing that the coordination between digital business and digital governance substantially enhances the Sustainable Development Goals (SDGs) index.

5. Discussion

The results presented in this study provide a comprehensive overview of government digitalization and its impact on digital business and economy, as well as their coupled influence on the Sustainable Development Goals (SDGs) across a selection of EU countries. Previous investigations [6–10,75,77] in different global contexts have shown that digitalization is instrumental in improving government services, transparency, and accessibility. The results align with these findings, highlighting the advanced digitalization in countries such as Ireland and Sweden. However, the results of this analysis indicate that even highly digitalized countries exhibit variability, suggesting that digitalization efforts must be consistent across different areas. This variation could be attributed to the focus on specific aspects of government digitalization. The obtained results from the analysis of digital business and economy validate previous research highlighting the importance of fostering a conducive environment for digital innovation. Estonia, Denmark, and Austria stand out, which is consistent with studies [75,93], showcasing successful ecosystems for digital businesses and startups. The need to promote digital business and economic growth is particularly evident in countries such as Romania and Hungary, aligning with prior investigations [75,93].

It should be noted that the findings prove that Sweden, Denmark, and Finland demonstrate strong coupling, echoing the focus on collaboration and synergy in these countries. In contrast, the relatively weaker coupling in Italy and Romania corresponds to previous studies [75,93] regarding the challenge of bridging the gap between the government and business sectors in certain regions. This study's findings align with previous research [41,48], reinforcing the positive association between digital coordination, GDP per capita, trade openness, and the SDGs index. This consistency in results across studies [41,76,108] suggests a robust relationship between digitalization efforts and sustainable development. However, a controversial viewpoint arises when considering the relative significance of digital coordination in the broader context of achieving the SDGs [6,8,109]. Some argue that while digitalization contributes positively, it may not be the sole driver of sustainable development. Factors such as education, healthcare, and social policies might carry equal or greater weight in certain contexts. Comparing our results to earlier investigations [118–120] reveals a common thread in emphasizing the importance of GDP per capita and trade openness in advancing the SDGs. These factors consistently appear to be significant contributors to improved living standards, access to resources, and international collaboration. Nevertheless, this study's nuanced findings regarding environmental regulations challenge conventional wisdom. The varying effects of environmental regulations on the SDGs index across different models warrant further exploration and suggest a more intricate relationship that demands deeper scrutiny. While this study corroborates the link between digital coordination, economic prosperity, and sustainable development in line with prior research [41,76,108], it introduces a controversial aspect by underscoring the multifaceted nature of achieving the SDGs. The complex interplay between environmental regulations and the SDGs index demands more comprehensive analysis, pushing for a deeper understanding of the intricate dynamics at play.

6. Conclusions

This research underlines the significance of digitalization in modern societies and economies and emphasizes the need for tailored strategies and robust statistical analyses to make informed decisions. The findings of the PCSE approach confirm the significant role of digital coordination in advancing sustainable development, particularly among EU countries. The results of this research can be instrumental for policymakers, businesses, and researchers interested in the intersection of digitalization, business, and sustainable development in European nations. It encourages governments to prioritize digitalization efforts and collaborate with the private sector to unlock the full potential of digital technologies for achieving the Sustainable Development Goals.

Governments should adopt a comprehensive approach to promote digitalization by investing in and supporting Digital Innovation Hubs (DIHs) to encourage businesses to adopt digital technologies [122]. Establishing incentives or subsidies for businesses participating in DIHs can expedite the development of e-commerce capabilities. Simultaneously, policymakers should actively facilitate Public–Private Partnerships (PPPs), particularly in digital infrastructure, by creating a conducive regulatory environment and offering financial incentives to private entities investing in digital infrastructure that enhances e-commerce. Additionally, governments must prioritize the development and regulation of Data Sharing Platforms to ensure the efficient utilization of data for e-commerce operations while establishing clear guidelines on privacy and security standards to build trust among participating businesses [123,124]. Allocating resources to Smart City Initiatives can further enhance digital infrastructure, potentially increasing the percentage of turnover from e-commerce, and incentives or grants can be provided to businesses operating within smart cities. Furthermore, policymakers should invest in Digital Skills Training Programs to enhance the workforce's ability to engage in web-based sales, collaborating with educational institutions and the private sector to tailor programs to the specific requirements for the digital transformation of sales [125]. Moreover, supporting Green Tech Incubators can address environmental challenges and improve digital public services for citizens by creating incentives for startups and businesses working on solutions with a direct impact on citizens' quality of life [126–128]. Policymakers should also actively encourage the establishment of Cross-Sectoral Platforms to facilitate dialogue between different industries, leading to improved citizen-centric digital services, particularly in areas such as healthcare and public welfare [129].

Enhancing the coupling and coordination degree of digital business and digital governance in the context of sustainable development involves adopting a nuanced approach supported by concrete models.

1. Holistic Ecosystem Integration: Denmark's comprehensive approach to digitalization involves collaboration between the government, businesses, and civil society to create an integrated digital ecosystem. Policymakers can further this integration by focusing on creating a supportive legal and regulatory environment, promoting synergies that bolster sustainable development initiatives.
2. Data Sharing Frameworks for Sustainability: Estonia's development of data-sharing frameworks facilitates cooperation between public and private entities for sustainable development projects. Policymakers should refine data governance structures, ensuring ethical and secure data sharing practices while emphasizing transparency and inclusivity [123,124].
3. Inclusive Innovation Labs: Finland's establishment of innovation labs brings together diverse stakeholders, including marginalized communities, to co-create sustainable

solutions. Policymakers should encourage the establishment of inclusive innovation labs, ensuring representation from various demographic groups, fostering a more holistic approach to digital innovation and governance.

4. Tailored Digital Education Initiatives: Germany's targeted investment in digital education includes programs designed to equip citizens with the skills needed for emerging digital business and governance practices. Policymakers should tailor educational initiatives, considering the specific needs of communities and industries and ensuring a diverse skill set that contributes to a more finely tuned coupling of digital advancements to sustainable development.
5. Citizen-Centric Digital Platforms: The Netherlands' has implemented citizen-centric digital platforms for their participation in decision-making processes related to sustainable development projects. Policymakers should prioritize the development of user-friendly, accessible digital platforms, ensuring that citizens have a meaningful role in shaping the policies and initiatives that contribute to sustainable development.
6. Flexibility in Regulatory Frameworks: Sweden's adaptive regulatory frameworks respond to evolving digital trends, fostering an environment conducive to innovation and sustainable practices. Policymakers should embrace flexibility in their regulations, continuously adapting frameworks to accommodate advancements in digital business while maintaining a strong focus on the Sustainable Development Goals.

The attainment of the Sustainable Development Goals requires a holistic approach that integrates digitalization, digital business, and governance. Policymakers should recognize the interdependencies between these elements and prioritize strategies that strengthen coordination, promote digital business and innovation, and address disparities.

Despite its valuable results, this study has a few limitations. Thus, future investigations will require extending the list of countries studied. This allows for the comparison of different parts of the world and provides more reliable policy implications for attaining the SDGs by improving coupling and coordination between government and business digitalization. In addition, the list of the control variables that could affect the link between the coupling of government and business digitalization and the SDGs should also be extended. Thus, considering the studies [130–132], the qualities of governance, voice and accountability, rule of law, green investment, and innovations, could promote the attainment of the SDGs and significantly affect the digitalization transformation of countries.

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