

## Article

# Unlocking Sustainable Value through Digital Transformation: An Examination of ESG Performance

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**Abstract:** Digital transformation has already begun to play a significant role in helping EU countries to achieve sustainable values by promoting environmental, social and governance (ESG) efficiency. It is rapidly changing the economic landscape, which leads to changes in all sectors and at all levels. The European Union (EU) has set ambitious goals for sustainable development and climate change mitigation, such as the European Green Deal and the 2030 Agenda for Sustainable Development. The paper aims to test the spatial spillover effect of digitalization on ESG performance for EU countries for 2008–2020. The study applies the spatial Durbin model to check the research hypothesis. The empirical results revealed that the EU exhibits varying levels of ESG performance. Digital transformation has the potential to enhance ESG performance and has shown significant spatial spillover effects. The SDM estimates that a 1% increase in digital inclusion results in a minimal 0.001% increase in the ESG index. The statistically significant positive effects observed in key enablers, digital public services for businesses and citizens, highlight the contribution of digitalization to improving ESG performance. In addition, technological innovation serves as a critical conduit for transmitting digital transformation in the business and public sphere to ESG performance. Given these findings, policymakers are advised to strengthen digitalization efforts to narrow the digital divide, leveraging the digital economy as a potent instrument. Additionally, a dynamic and targeted strategy for digital economic development should be implemented to address ESG performance disparities effectively.

**Keywords:** e-governance; e-commerce; digital economy; sustainable development



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## 1. Introduction

The European Union (EU) has embarked on an ambitious goal toward sustainable development and climate change mitigation with initiatives such as the European Green Deal [1,2] and the 2030 Agenda for Sustainable Development [3–6]. In this transformative era, digital technologies are reshaping the economic landscape at a rapid pace, influencing all sectors and levels of society. As a result, digital transformation is emerging as a crucial enabler for EU countries to unlock sustainable value while promoting environmental, social, and governance (ESG) efficiency [7–10].

Digital transformation holds immense potential for driving sustainable development [11,12]. By harnessing innovative technologies and data-driven solutions, countries can optimize resource utilization [13], reduce carbon emissions [14], and enhance operational efficiency across various sectors [15–17]. For instance, the adoption of smart grids, IoT-enabled energy management systems, and advanced analytics revolutionize the energy sector, facilitating the integration of renewable energy sources and improving energy efficiency [18,19]. Furthermore, digitalization facilitates better the monitoring, reporting, and management of environmental impacts [19–22]. The use of digital platforms and real-time data collection allow measuring and tracking of the country's environmental performance [23], enabling them to identify areas for improvement and implement targeted

sustainability measures [23]. This enhanced transparency and accountability contribute to the achievement of ESG goals. The potential of digital transformation extends beyond environmental sustainability [23,24]. It also supports social and governance objectives within the EU. Digital technologies facilitate inclusive and accessible services, ensuring that vulnerable populations are not left behind in the digital era. Additionally, digital platforms enable better stakeholder engagement, allowing citizens, businesses, and governments to collaborate and address societal challenges collectively [25–30]. ESG performance has gained significant importance as investors and consumers increasingly prioritize sustainable practices and ethical considerations. By integrating ESG factors into their decision-making processes, countries strengthen their reputation, attract investment, and tap into new market opportunities. Digital transformation plays a vital role in facilitating ESG measurement, reporting, and analysis, providing stakeholders with accurate and timely information about countries' sustainable development [31,32].

At the same time, Miśkiewicz et al. [33] confirm that the rapid expansion of digital infrastructure, data centers, and high-tech devices can lead to a significant increase in energy consumption. This may result in higher carbon emissions and a strain on limited natural resources. Furthermore, the constant upgrading of digital devices and the disposal of obsolete electronics contribute to the growing problem of electronic waste [34,35]. The improper disposal and recycling of e-waste can lead to environmental pollution and health hazards. The automation and digitization of various processes can result in job losses and workforce displacement. Workers who are not equipped with the necessary digital skills [36–44] may find it challenging to transition into new roles, leading to social and economic challenges.

In this case, it is topical to identify the effect of digitalization on ESG performance for countries to develop the appropriate policy for intensifying the positive effect of digitalization on promoting sustainable values. This paper aims to test the spatial spillover effect of digitalization on ESG performance for EU countries in the period of 2008–2020. The study fills the theoretical gaps in promoting sustainable values by developing an approach for assessing the digitalization effect on ESG performance based on applying the spatial Durbin model, which highlights the interconnected nature of digitalization and its influence on ESG outcomes, emphasizing the importance of considering regional dynamics and the diffusion of digital initiatives when evaluating and enhancing ESG performance.

The paper has the following structure: the Literature Review analyses the theoretical landscape of links between digitalization and the ESG performance of the country; Materials and Methods describes the applied instruments and methods to test the research hypotheses and explain the selected variables and sources; Results describes the results of the analysis of the links between digitalization and ESG performance of the country; Discussion and Conclusion outlines the core results of the research, policy implications, limitations, and further directions for research.

## 2. Literature Review

The linkage between the sustainable development goals (SDGs) and digital inclusion is centered on the idea that access to digital technologies and the internet play a vital role in achieving sustainable development [45–47]. Digital inclusion refers to ensuring that everyone has equal access to and can effectively utilize digital technologies, such as computers, the internet, and mobile devices [47]. ICT has a direct impact on economic growth by driving productivity [48], innovation, and efficiency across various sectors. It enables the creation of new industries [49,50], improves business processes [51], and enhances competitiveness [48–50]. The adoption and use of ICT tools, such as digital infrastructure, telecommunications, and e-commerce, lead to increased productivity and GDP growth.

Digital inclusion can enhance the access to educational resources, online learning platforms, and digital skills training, thereby improving educational opportunities and outcomes for individuals, especially in underserved communities (which is coherent with

SDG4 and the social effect within ESG performance). Kuzior [52] and Zaloznova et al. [53] confirm that digitalization promotes economic empowerment by providing access to online job opportunities, entrepreneurial resources, and digital tools for small businesses, contributing to job creation and economic growth (which is coherent with SDG8: Decent Work and Economic Growth and the social and economic effects within ESG performance). Prior studies [54] outline that digitalization provides equal access to modern infrastructure, technology, and innovation, fostering inclusive and sustainable industrialization. It is relevant to SDG 9: Industry, Innovation, and Infrastructure and allows for attaining the economic and ecological effects within ESG performance. Mahmood et al. [55] emphasize that increasing ESG performance requires relevant digital solutions. Based on the petroleum industry, scholars [55] show that digital technologies allow a decline in carbon dioxide emissions by 43% and improve the well-being of workers. Applying confirmatory factor analysis and structural equation modeling, scholars [56] confirm the close relationships between ESG performance and Industry 4.0. An earlier study [57] shows that the beneficial impact of disclosing ESG information to stakeholders promotes corporate governance and facilitates the organization's technological and environmentally friendly digital transformation in China. Macchiavello and Siri [58] outline the close relationship between green FinTech and attaining sustainable development goals. In addition, scholars [59] highlight that green FinTech could catalyze the extension and implementation of green innovations.

Clark et al. [60] found that digitalization promotes transparent and accountable governance, citizen engagement, and access to justice through digital platforms, enhancing democratic processes and institutions. It is coherent with SDG 16: Peace, Justice, and Strong Institutions and the social and economic effects within ESG performance. Scholars [61] have explored the development of e-government in European countries, focusing on its socioeconomic and environmental aspects. Applying the TOPSIS method and based on the empirical results, they confirm the significant statistical connections between the e-government and comprehensive indicators encompassing environmental, social, and economic aspects. These findings highlight the clear and favorable influence of digitized administrative procedures on sustainable development. Moreover, scholars [61–65] provide evidence that investments in digital infrastructure and government e-services yield numerous long-term advantages and directly contribute to all three domains crucial for ensuring the sustainability of contemporary progress. Past studies [66–68] prove that enterprises with e-commerce and web sales are expected to adhere to ethical business practices and promote transparency. They can ensure fair trade, responsible sourcing, and respect for labor rights throughout their supply chains [67]. By providing clear and accurate information about products, services, and their environmental and social impacts, these enterprises contribute to transparency and accountability. Scholars [66–68] prove that digital technologies reduce inequalities by providing marginalized groups, including women, rural communities, and persons with disabilities, with equal access to information, services, and opportunities (SDG10: Reduced Inequalities and social effects within ESG performance). Erturk and Purdon [68] outline that by promoting digital inclusion, countries harness the power of technology to bridge gaps, empower individuals and communities, and ensure that no one is left behind on the way toward sustainable development. It requires addressing barriers such as infrastructure limitations, affordability, digital literacy [69–71], and gender disparities to create an inclusive digital society that benefits all. Earlier studies [72–75] show that digitalization boosts international collaboration [72], knowledge sharing [73–75], and capacity building [76,77], enabling partnerships and innovation [78] to accelerate progress toward ESG performance.

Scholars empirically confirm that ICT plays a pivotal role in driving economic growth [79], promoting sustainable development, and improving ESG performance. Leveraging ICT tools and technologies effectively and inclusively contributes to achieving the SDGs and enhancing environmental, social, and governance outcomes. Furthermore, considering Ghouse et al. [80], digital inclusion contributes to sustainable development by enabling a more efficient resource management, reducing environmental impacts, and supporting

the transition to a carbon-free economy [81]. Scholars [82–84] have confirmed that smart grids, energy management systems, and IoT-based solutions optimize energy consumption, reduce greenhouse gas emissions, and enhance sustainability performance, aligning with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) and ecological effects within ESG performance. In addition, the studies prove that companies with e-commerce and web sales catalyze the reduction in environmental impact and support climate action. By enabling digital transactions and reducing the need for physical infrastructure [83,84], transportation, and paper-based documentation, these companies are conducive to declining carbon emissions and conserving resources. The results of the analysis of the existing theoretical landscape show that most studies have focused on investigating the direct link between digitalization and ESG performance in attaining sustainable development. Therefore, this paper aims to analyze digitalization’s spillover effect on the ESG performance of a country. Several empirical studies [85–91] have investigated the spatial spillover effects of digitalization on ESG performance. For instance, researchers [85–88] have shown that countries with higher levels of digitalization tend to exhibit positive spillover effects on neighboring countries, particularly in terms of environmental performance. The diffusion of digital technologies and knowledge transfer can lead to increased environmental awareness, resource efficiency, and sustainable practices across borders [89,90]. Similarly, digitalization has been found to have positive social and governance spillover effects, fostering social connectivity, inclusive governance, and participatory decision-making processes [91]. Considering the above, the following hypothesis is proposed:

**Hypothesis 1.** *Digitalization has a spatial spillover effect on the ESG performance of a country.*

### 3. Materials and Methods

#### 3.1. Data and Sources

Based on earlier studies [7,10,24,56,57], this study used the ESG performance index as the explained variable, which contains three subindexes: ecological, social and government effects. The raw data for the ESG performance index are taken from environmental, economic, and ecological indicators by the World Data Bank experts [92]. Considering the direction of impact, all effects are divided into inhibitors and stimulators within each subindex (Table 1). Entropy methods [93] are applied to estimate the ESG performance index. The timeframe of this study is 2008–2020, and the subject of this research is EU countries (the 27 EU member states).

**Table 1.** Variables for assessment of ESG performance.

Variables	Meaning	Impact
Social performance		
Fertility rate, total (births per woman)	The average number of children born per a woman. Higher fertility rates can be seen as a stimulator for social development, as it may indicate a younger and potentially growing population	↑
Gini index	Higher values indicate greater inequality, which hinders social development	↓
Government expenditure on education	Higher government expenditure on education suggests a greater commitment to investing in human capital, which boosts social development	↑
Income share held by lowest 20%	A lower share suggests a higher level of income inequality, which can be considered an inhibitor	↓
Labor force participation rate	A higher rate indicates greater economic engagement and stimulates social development	↑
Life expectancy at birth	A positive indicator of social well-being and development	↑
Mortality rate, under 5	Restricts social development and well-being	↓
People using safely managed sanitation service	Access to safe sanitation services promotes public health and can be seen as a stimulator for social development	↑
Population ages 65 and above	A higher value restricts development due to strain on social security systems and healthcare	↓
School enrollment, primary	Higher rates indicate increased access to education, which is a stimulator for social development	↑
Unemployment	A lower unemployment rate stimulates social development, as it indicates a higher level of economic participation and well-being	↓

Table 1. Cont.

Variables	Meaning	Impact
Environmental performance		
Agricultural land	Sustainable agricultural practices and land management can help increase agricultural productivity while minimizing environmental impact	↑
Agriculture, forestry, and fishing, CO <sub>2</sub> emissions	It stimulates the environmental performance when sustainable practices are implemented.	↑
Energy intensity level of primary energy	Pollution reduces the environmental performance Continued efforts to improve energy efficiency will reduce energy consumption and contribute to environmental sustainability. Growth of energy intensity decreases environmental performance.	↓
Food production index	Improving agricultural practices, including sustainable farming techniques and reduced food waste, contributes to increased food production while minimizing environmental impact	↑
Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	High levels of water stress decrease environmental performance within ecosystem degradation, water scarcity and drought, saltwater intrusion and land subsidence	↓
Methane emissions	Implementing measures to reduce methane emissions from various sources, such as agriculture and waste management, contributes to environmental sustainability	↓
Nitrous oxide emissions	Efforts to reduce nitrous oxide emissions, particularly from agricultural activities, can contribute to environmental sustainability	↓
Population density	Encouraging sustainable urban planning and development practices can help manage population density and minimize environmental impacts	↓
Forest area	Increasing forest area and promoting sustainable forest management practices positively influences environmental performance	↑
Renewable energy consumption	Promoting renewable energy sources will reduce reliance on fossil fuels and contribute to increased environmental sustainability	↑
Governance performance		
Control of Corruption	Lower control of corruption indicates governance issues and can be considered an inhibitor to good governance	↑
GDP growth	Higher value reflects a healthy economy and can stimulate good governance through economic development and resource availability	↑
Research and development expenditure	Higher value reflects commitment to innovation and knowledge creation, stimulating good governance	↑
Individuals using the Internet	Higher value indicates digital connectivity and access to information, which can stimulate transparency and participation in governance	↑
Proportion of seats held by women in the national parliaments	Higher rate of women in the national parliaments promotes gender equality and diversity in decision-making processes, stimulating good governance	↑
Political stability and absence of violence/terrorism	Higher levels of political stability and higher incidence of violence/terrorism stimulate good governance	↑
Net migration	Positive net migration indicates favorable conditions that attract talent and contribute to economic and social development	↑
Ratio of female to male labor force participation rate	Higher rate signifies inclusive policies and promotes good governance	↑
Regulatory quality	High value indicates adequate regulatory frameworks and enforcement	↑
Rule of law	Strong adherence to the rule of law promotes stability, accountability, and fairness	↑
School enrollment, primary and secondary, gender parity index	It promotes education equity and inclusivity, stimulating good governance	↑
Government effectiveness	Government effectiveness suggests efficiencies in public administration	↑
Voice and accountability	Voice and accountability suggest engagement of citizen in governance	↑

Note: ↑—stimulator; ↓—inhibitor.

Digital inclusion, key enablers, and digital public services for businesses and citizens have wide-ranging impacts on ESG performance [52–55]. These impacts span social equality, economic development, environmental sustainability, governance transparency, resource efficiency, social empowerment, and overall well-being. By leveraging digital technologies and ensuring inclusive access to digital services, organizations and societies enhance their ESG performance across multiple dimensions. Considering this and prior studies [19,22,33,36], this research applies the following explanatory variables for assessment digitalization.

Digital inclusion refers to ensuring equal access to and participation in digital technologies and services. It promotes equal opportunities and reduces the digital divide, ensuring that marginalized groups have access to digital resources [33,36]. This enhances social equality, empowers individuals and communities, and positively contributes to the social dimension of ESG performance. Access to digital technologies and skills enables individuals and businesses to participate in the digital economy [19,22]. This can drive eco-

conomic growth, create job opportunities, and support sustainable development, positively impacting the economic dimension of ESG performance [22,33]. In addition, it facilitates the adoption of digital tools for remote work, teleconferencing, and e-learning, reducing the need for physical travel and infrastructure. This can contribute to lower carbon emissions, resource conservation, and environmental efficiency, positively influencing the environmental dimension of ESG performance [22,33].

Key enablers represent the infrastructure, policies, and regulations necessary for digital transformation [33,36]. Effective policies and regulations encourage the use of digital technologies for energy management, smart grid systems, and sustainable resource management [33,36]. Key enablers promote eco-friendly practices and technologies, contributing to the environmental dimension of ESG performance. It enhances governance structures, promotes transparency, and facilitates access to information.

Digital public services streamline administrative processes, improve service delivery, and reduce paperwork. This can lead to resource optimization, cost savings, and improved efficiency, positively impacting the economic dimension of ESG performance. Digital public services, such as e-health, e-government, and online education, enhance access to essential services, improve healthcare outcomes, and support lifelong learning [19,22,33,36]. Ensuring robust data protection, privacy regulations, and cybersecurity measures in digital public services enhances trust and confidence in digital systems. This promotes data privacy, safeguards personal information, and positively impacts the governance dimension of ESG performance.

Scholars [93–98] outline that green investment and trade openness have positive impacts on the ESG performance of a country. Green investment supports environmental sustainability, social development, and responsible governance, whereas trade openness can drive economic growth, foster social and cultural exchange, and influence environmental outcomes. However, it is important to manage the environmental impacts associated with trade openness to ensure a balanced and sustainable approach to ESG performance. Considering the abovementioned factors, this study applies two control variables: trade openness (TO) and green investment (GFDI).

Prior studies [93–96] confirm that including trade openness (TO) as a control variable helps account for the economic environment and global integration of a country. It can provide insights into how digitalization influences trade patterns, market access, and the potential impact on SDGs related to economic growth, employment, and industry development.

Digitalization and green investment (GFDI) have complementary effects on ESG performance [96–98]. For instance, digital technologies enhance the efficiency and effectiveness of green projects, facilitate the data collection and monitoring of environmental indicators, and enable sustainable practices across various sectors. Incorporating green investment allows us to understand the specific impact of digitalization on ESG performance beyond the combined effect of both factors.

The descriptive values of the independent and control variables are shown in Table 2.

**Table 2.** Descriptive statistics of the data for the selected variables for EU countries 2008–2020.

Symbols	Description	Meaning	Source	Mean	SD	Min	Max
DI	Digital inclusion	Refers to the equitable access and effective use of digital technologies and resources by individuals and communities	Eurostat [99]	72.643	15.183	26.340	96.750
eGovke	Key enablers	Elements or factors that facilitate and support the successful implementation and utilization of digital technologies and initiatives.		58.218	25.664	5.0	101.321
eGovbuss	Digital public services for businesses	Online services provided by public authorities to facilitate interactions between businesses and government entities		64.629	18.054	16.0	100.786
eGovcit	Digital public services for citizens	Online services provided by public authorities to individuals		49.001	20.348	12.0	89.0
GFDI	Green investment	Investments made in developing new projects or initiatives with the aim of contributing to climate finance		9145.863	15,734.580	3.0	84,826.0
TO	Trade	Degree to which a country engages in international trade activities	World Data Bank [92]	127.369	66.632	45.419	380.104

### 3.2. Model Development

The nature of the EU data suggests that the observations might not be independent, indicating the potential presence of spatial dependency. This spatial dependency in the data is influenced by various factors, such as geographical proximity, economic interactions, shared policies, cultural influences, and spillover effects. Due to this spatial dependency, the assumption of independence among observations is violated, leading to the need to consider spatial relationships in the analysis. Importantly, ordinary regression methods assume independence among observations, and this spatial dependency challenges that assumption. Consequently, it can result in inefficient standard errors and introduce uncertainty in modeling, given the unknown nature of spatial interaction effects.

This study applies *Moran's I* test, as proposed by Moran [100], to investigate the potential spatial effects of ESG performance. *Moran's I* test allows for the estimating of spatial autocorrelation, addresses the nonindependence of observations, has policy implications, and provides statistically valid and robust results.

$$Moran's\ I = \frac{n}{W} \times \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2} \tag{1}$$

where *Moran's I* measures the spatial autocorrelation; *n* means the number of observations or regions in the dataset; *W* is the sum of the weights in the spatial weights matrix, which represents the spatial relationships among regions; *w<sub>ij</sub>* means the weight between region *i* and region *j* in the spatial weights matrix; *x<sub>i</sub>*, *x<sub>j</sub>* are the values of the variable of ESG performance for regions *i* and *j*, respectively; and  $\bar{x}$  is the average value of ESG across all regions.

*Moran's I* coefficient ranges from  $-1$  to  $+1$ . A value higher than 0 indicates a positive spatial autocorrelation, meaning that similar values tend to cluster together (high ESG performance countries are surrounded by high ESG performance regions). A value less than 0 indicates negative spatial autocorrelation, where dissimilar values tend to cluster together (high ESG performance countries are surrounded by low ESG performance countries). A value close to zero indicates no significant spatial autocorrelation.

This study applies the spatial autoregressive model (SAR), spatial error model (SEM), and spatial Durbin model (SDM) to examine the relationship between digitalization and ESG performance at the country level:

Spatial autoregression model (SAR)

$$ESG_{i,t} = \lambda WESG_{i,t} + X_{i,t}\beta + \varepsilon_{i,t} \tag{2}$$

where *ESG* represents the ESG performance level of the EU countries; *W* is the spatial weight matrix; *X* is the  $n \times k$  data matrix of independent variables;  $\lambda$ ,  $\beta$  are coefficients of spatial impacts; and  $\varepsilon$  is the error term.

Spatial error model (SEM)

$$ESG_{i,t} = X_{i,t}\beta + \mu, \quad \mu = \rho Mv_{i,t} + \varepsilon_{i,t} \tag{3}$$

where *M* is the spatial weight matrix and  $\mu$  is the function of unexplained error (residuals).

Spatial Durbin model (SDM)

$$ESG_{i,t} = \lambda WESG_{i,t} + X_{i,t}\beta + WX_{i,t}\delta + \varepsilon_{i,t} \tag{4}$$

where  $WX_{i,t}$  are the spatially weighted regressors.

The model selection process involved assessing the test results described by LeSage and Pace [101]. To capture both the dynamic and spatial effects, a fixed-effects dynamic spatial panel model is employed, allowing for the identification of the temporal and

spatiotemporal lags that capture the impacts of various factors on ESG while accounting for disequilibrium shocks:

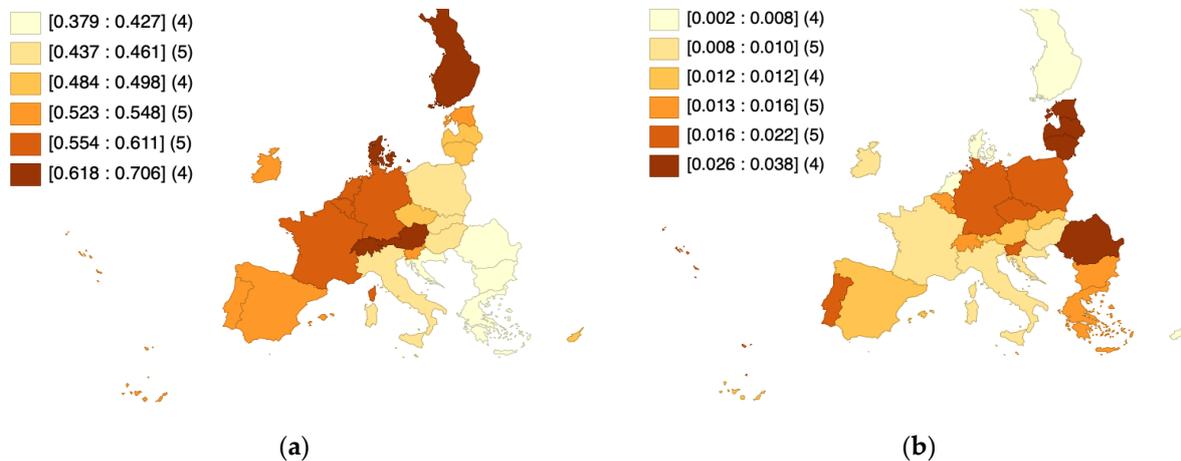
$$ESG_{i,t} = \alpha_i + \tau ESG_{i,t-1} + \rho \sum_{j=1}^N W_{ij} ESG_{i,t} + \beta_1 Digital_{i,t} + \beta_2 TO_{i,t} + \beta_3 GFDI_{i,t} + \lambda_1 \sum_{j=1}^N W_{ij} Digital_{i,t} + \lambda_2 \sum_{j=1}^N W_{ij} TO_{i,t} + \lambda_3 \sum_{j=1}^N W_{ij} GFDI_{i,t} + \pi_{it} \tag{5}$$

$$\pi_{it} = \sigma \sum_{j=1}^N W_{ij} \pi_{it} + \varepsilon_{i,t} \tag{6}$$

where  $\alpha_i$  is a fixed-effect parameter;  $\sum_{j=1}^N W_{ij} ESG_{i,t}$  and  $\sum_{j=1}^N W_{ij} Digital_{i,t}$ ,  $\sum_{j=1}^N W_{ij} TO_{i,t}$ ,  $\sum_{j=1}^N W_{ij} GFDI_{i,t}$  are the endogenous and exogenous spatial impacts prospectively;  $Digital_{i,t}$  is the level of country digitalization expressed by DI, eGovke, eGovbuss, eGovcit;  $\rho, \beta_1 \dots \beta_3, \lambda_1 \dots \lambda_3$  are coefficients of different kinds of spatial impacts; and  $\varepsilon_{i,t}$  is a residuals term.

**4. Results**

In the first stage, this study checks the spatial connection distributions of the mean and standard deviation of ESG performance within EU countries (Figure 1).



**Figure 1.** Spatial distribution of ESG performance within (a) mean values and (b) standard deviation.

The results (Figure 1a) show that the highest average value of ESG in the interval of 0.2–0.71 for 2011–2020 is observed in the following countries: Austria, Sweden, Finland, and Denmark. These countries could serve as examples for others in terms of their successful practices and policies in promoting environmental sustainability, social responsibility, and good governance. At the same time, Romania, Bulgaria, Greece, and Croatia have the lowest ESG values (0.38–0.43). This highlights the need for targeted interventions and policies in these countries to improve their ESG performance and align with sustainable development goals. However, the fluctuation of ESG has a different pattern compared to the mean value (Figure 1b). Thus, the value of ESG has lower volatility in Greece, Finland, and Denmark. This suggests that these countries have been able to maintain more stable and consistent ESG performance over the analyzed period. Examining the policies, practices, and initiatives implemented in these countries can provide valuable insights for others looking to enhance their ESG stability and reduce fluctuations. The following EU countries have huge fluctuations in ESG values: Latvia, Lithuania, Romania, and Estonia. These countries may benefit from focused efforts to identify the underlying factors contributing to these fluctuations and to implement measures to enhance stability and improve their overall ESG performance.

The Moran scatterplot allows the relationship between a value and the average value of its neighbors for the same variable to be checked. The findings (Figure 2) of Moran’s I show that most countries are in the 1st and 3rd quadrants. Thus, the 1st quadrant means that countries with high ESG values are surrounded by countries with high ESG values:

France, Austria, Belgium, Sweden, Germany, Denmark, Spain, Portugal, Luxembourg, and the Netherlands.

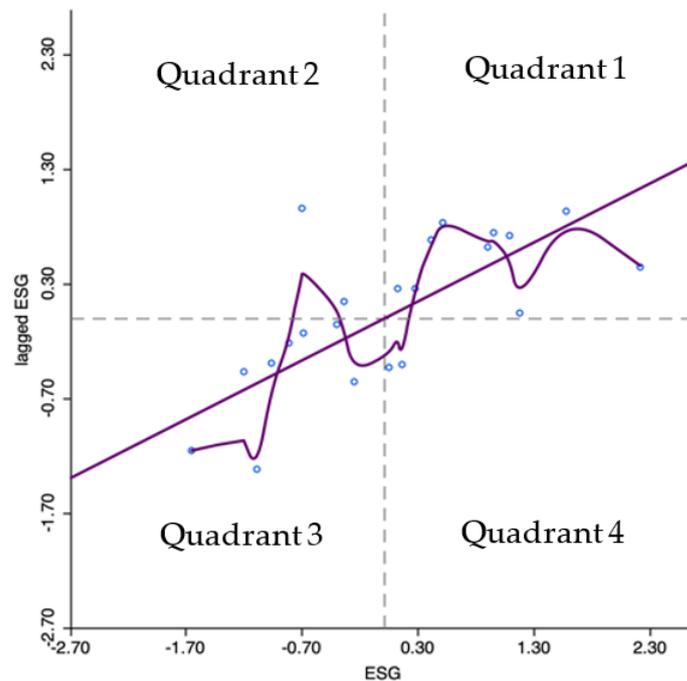


Figure 2. Visualization of Moran’s I plot of ESG performance.

The 3rd quadrant contains countries with lower ESG values and is surrounded by countries with lower ESG values. The 3rd quadrant includes the following countries: Croatia, Hungary, Bulgaria, Greece, Romania, Slovakia, Lithuania, Latvia, and Poland. This confirms the positive spatial autocorrelation. The 4th quadrant (low value is surrounded by high value) contains Estonia and Slovenia. The second cluster (high value is surrounded by lower value) contains Czechia and Italy. The results allow for outlining the cluster effects, which means that countries with similar ESG values are likely to be located in closed areas.

To evaluate the presence of spatial relationships, a nonspatial panel model was employed as a point of comparison with the spatial panel model. The outcomes presented in Table 3 reveal that augmenting digital inclusion, fortifying key enablers, expanding digital public services for businesses, and offering digital public services for citizens have statistically significant positive effects on ESG. These findings suggest that the adoption of digitalization initiatives and the leveraging of digital technologies and services can contribute to enhanced ESG performance. The growth of Digital increases ESG performance by 0.390 in the model with digital inclusion, by 0.089 in the model with eGovke, by 0.137 in the model with eGovbuss, and by 0.165 in the model with eGovcit. All results are statistically significant with a probability of 0.000.

Table 3. Pooled OLS estimator.

Depend Variable: ESG	DI		eGovke		eGovbuss		eGovcit	
	coef.	prob.	coef.	prob.	coef.	prob.	coef.	prob.
Digital	0.390	0.000	0.089	0.000	0.137	0.000	0.165	0.000
TO	−0.002	0.850	0.048	0.005	0.036	0.057	0.018	0.053
GFDI	0.038	0.000	0.044	0.000	0.044	0.000	0.043	0.000
const	−2.615	0.000	−1.568	0.000	−1.724	0.000	−1.694	0.000
R-squared	0.699		0.563		0.531		0.659	
Adj R-squared	0.697		0.557		0.524		0.655	

To examine the persistence of the observed effects in geographic space, a spatial model was employed for verification and assessment. The first two rows of Table 4 compare the spatial autoregressive (SAR) model with the spatial Durbin model (SDM) and the spatial error model (SEM) with the SDM. For each digitalization variable (DI, eGovke, eGovbuss, eGovcit), the chi-square test statistic ( $\chi^2$ ) and its corresponding p value (all equal to 0.000) indicate that there is strong enough evidence to reject the null hypothesis, suggesting that the SDM is a more suitable model than both the SAR and SEM for analyzing the relationship between ESG and Digital. The results of the Hausman test, reported in the third row of Table 4, reveal significant chi-square test statistics ( $\chi^2$ ) and corresponding p values (0.001, 0.031, 0.045, and 0.000). These findings strongly reject the null hypothesis, suggesting that the fixed-effects spatial Durbin model (SDM) is the appropriate model to detect the impact of digitalization on ESG.

**Table 4.** Test for model selection.

Depend Variable: ESG	DI		eGovke		eGovbuss		eGovcit	
	$\chi^2$	p Value						
SAR versus SDM	62.05	0.000	44.12	0.000	40.78	0.000	23.47	0.000
SEM versus SDM	54.71	0.000	49.69	0.000	50.51	0.000	30.16	0.000
Hausman test	24.02	0.001	15.39	0.031	14.38	0.045	33.87	0.000

The results of the SDM models (Table 5) suggest that digitalization has a positive impact on ESG, with varying degrees of significance depending on the specific independent variables (DI, eGovke, eGovbuss, eGovcit) included in each model. The coefficient for the main effect of DI is 0.048 (significant at 0.002), indicating a positive impact of digitalization on ESG. It suggests that policies and initiatives aimed at promoting digital inclusion contribute to improving ESG performance. The EU should focus on enhancing digital accessibility, bridging the digital divide, and ensuring equal opportunities for individuals and businesses to access and utilize digital technologies. This can include measures such as improving internet infrastructure, providing affordable access to digital services, and promoting digital literacy and skills development.

**Table 5.** Results of SDM.

Depend Variable: ESG	DI		eGovke		eGovbuss		eGovcit	
	coef.	prob.	coef.	prob.	coef.	prob.	coef.	prob.
Main								
Digital	0.048	0.002	0.011	0.010	0.020	0.042	0.030	0.000
TO	−0.006	0.792	−0.019	0.486	−0.011	0.664	−0.035	0.193
GFDI	0.006	0.810	0.006	0.002	0.005	0.003	0.005	0.008
Wx								
Digital	0.125	0.000	0.028	0.000	0.048	0.000	0.033	0.001
TO	−0.005	0.838	0.080	0.014	0.054	0.103	0.047	0.170
GFDI	0.004	0.166	0.004	0.082	0.007	0.003	0.006	0.008
Spatial rho	0.077	0.093	0.110	0.150	0.047	0.043	0.190	0.009
Variance sigma2_e	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000

Note: Wx—spatially weighted regressors.

However, the coefficients for TO and GFDI are not statistically significant, suggesting that trade openness and green field investment do not have a significant impact on ESG in this model. It is important to note that trade openness could still have indirect effects on ESG performance. Policymakers should consider integrating sustainability criteria into trade agreements and promoting sustainable practices within international trade. This can include measures to encourage environmentally friendly production processes, the responsible sourcing of raw materials, and the adoption of sustainable supply chain management practices. In addition, the EU should create an enabling environment for green investment

by offering incentives for sustainable investments, promoting green technologies and innovation, and ensuring transparent and accountable governance frameworks to monitor and regulate environmental impacts.

On the other hand, eGovke has a positive and significant impact on ESG with a coefficient of 0.011 (significant at 0.010) and a significant positive effect on GFDI. This suggests that the EU should focus on developing and implementing digital platforms and services that facilitate business operations, promote sustainability practices, and enhance collaboration between businesses and government entities.

Furthermore, both eGovbuss and eGovcit exhibit a positive impact on ESG, with both TO and GFDI showing significant positive associations. This suggests that investing in digital public services for citizens contributes to improving the overall ESG performance. The EU should prioritize the development of user-friendly digital platforms and services that enable citizens to access essential public services, participate in decision-making processes, and engage in sustainable behaviors. It could include enhancing online platforms for e-government services, digital channels for citizen engagement, and initiatives promoting digital inclusion among marginalized and vulnerable groups.

In all models (Table 5), the coefficients for the main effect of Digital in the  $Wx$  term are significant and positive, indicating a positive spatial spillover effect. This suggests that higher levels of digitalization in neighboring regions positively affect the ESG performance of the targeted region. The spatial rho values in all models are positive and statistically significant, suggesting the presence of spatial autocorrelation in the data. This implies that there is a spatial pattern or clustering in the relationship between digitalization, trade openness, green field investment, and ESG performance. The variance of  $\sigma^2_e$  represents the error variance in the model, capturing the unexplained variation in the dependent variable (ESG) not accounted for by the independent variables. In all models, the  $\sigma^2_e$  variance values are small and statistically significant at 0.000. This indicates a low level of unexplained variation, suggesting that the models effectively capture the relationships between the independent variables and ESG performance.

The regression results presented in Table 6 demonstrate a significant and positive effect of the lagged value of ESG on the current value of ESG, underscoring the persistence of ESG performance over time. This finding emphasizes the need for sustained efforts and long-term strategies in fostering and maintaining a positive ESG performance. By recognizing the lasting influence of historical ESG practices, stakeholders can better understand the importance of continuous commitment to sustainable practices and policies. The variable DI (Digital Inclusion) exhibits a statistically significant yet relatively modest positive effect on ESG. This suggests that initiatives aimed at improving digital inclusion can contribute favorably to ESG outcomes. More precisely, the dynamic SDM model estimates that a 1% increase in DI results in a minimal 0.001% increase in the ESG index. These findings align with prior studies [102,103], providing further validation of the significance of digital inclusion in advancing ESG objectives. The statistically significant positive effects observed in the variables eGovke (Key Enablers), eGovbuss (Digital Public Services for Businesses), and eGovcit (Digital Public Services for Citizens) highlight the contribution of digitalization to improving ESG performance. These findings suggest that the digitalization of key enablers and the provision of digital public services for businesses and citizens play a crucial role in fostering positive ESG outcomes. One plausible explanation for these positive impacts is that digitalization enhances the efficiency, transparency, and accessibility of ESG-related processes and information. By leveraging digital platforms and services, organizations can streamline the reporting and monitoring of environmental practices, facilitate stakeholder engagement, and empower individuals and businesses to make more sustainable choices. The EU has been actively promoting digitalization across various ESG domains [104]. However, to fully realize the potential positive impacts on ESG, further improvements in digitalization strategies and infrastructure are necessary. Government interventions aimed at enhancing ESG performance should prioritize refining digitalization strategies and infrastructure to effectively leverage digital technologies and services. It allows us to boost progress in ESG areas and contribute to a more sustainable and inclusive future.

**Table 6.** Results of dynamic SDM.

Depend Variable: ESG		DI		eGovke		eGovbuss		eGovcit	
		coef.	prob.	coef.	prob.	coef.	prob.	coef.	prob.
Main	L.ESG	0.908	0.000	0.725	0.000	0.773	0.000	0.749	0.000
	Digital	0.001	0.019	0.003	0.076	0.019	0.076	0.005	0.018
	TO	0.040	0.007	0.051	0.048	0.055	0.030	0.051	0.045
	GFDI	0.002	0.038	0.004	0.011	0.003	0.051	0.004	0.013
Wx	L.ESG	0.082	0.269	0.073	0.486	0.115	0.278	0.129	0.211
	Digital	0.047	0.004	0.005	0.032	0.017	0.016	0.001	0.061
	TO	0.060	0.004	0.041	0.193	0.047	0.134	0.045	0.170
	GFDI	0.002	0.333	0.003	0.029	0.002	0.028	0.003	0.023
	Spatial rho	0.009	0.082	0.055	0.050	0.078	0.037	0.074	0.062
	Variance sigma2_e	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: Wx—spatially weighted regressors; L. ESG—value of ESG with lag.

Additionally, the coefficients of greenfield investment (GFDI) in all dynamic SDM models are found to be significantly positive at the 1% level, indicating a positive association between GFDI and ESG outcomes. Specifically, according to the dynamic SDM model, a 1% increase in GFDI corresponds to a 0.002–0.004% increase in ESG. One possible explanation for these positive impacts is that the allocation of resources toward greenfield investments can promote sustainable practices and technologies, thereby positively influencing ESG performance. Across all models of dynamic SDM, the coefficients associated with the main effect of Digital in the Wx term consistently display statistical significance and a positive direction. These findings provide evidence of a positive spatial spillover effect, indicating that increased levels of digitalization in neighboring regions have a beneficial impact on the ESG performance of the focal region. The results highlight the interconnected nature of digitalization and its influence on ESG outcomes, emphasizing the importance of considering regional dynamics and the diffusion of digital initiatives when evaluating and enhancing ESG performance.

Table 7 presents the direct, indirect, and total effects of digitalization on ESG. The coefficients for both the direct and indirect effects of DI (Digital Inclusion), eGovke (Key Enablers), eGovbuss (Digital Public Services for Businesses), and eGovcit (Digital Public Services for Citizens) on ESG are positive, indicating a beneficial influence. These results support the hypothesis that digitalization has a spatial effect on ESG performance. Notably, the indirect effect coefficients of DI, eGovke, eGovbuss, and eGovcit on ESG are all significant with p values of 0.000, indicating a strong statistical relationship. This finding is in line with prior research [24,64] and suggests that digitalization initiatives focusing on these areas have a significant impact on promoting positive ESG outcomes.

**Table 7.** Results of direct, indirect and total effects.

Depend Variable: ESG		DI		eGovke		eGovbuss		eGovcit	
		coef.	prob.	coef.	prob.	coef.	prob.	coef.	prob.
LR Direct	Digital	0.045	0.004	0.012	0.004	0.023	0.019	0.033	0.000
	TO	−0.007	0.755	−0.017	0.507	−0.010	0.690	−0.034	0.197
	GFDI	0.000	0.043	0.005	0.002	0.005	0.006	0.004	0.016
LR Indirect	Digital	0.116	0.000	0.032	0.000	0.057	0.000	0.045	0.000
	TO	−0.004	0.871	0.085	0.010	0.059	0.092	0.047	0.214
	GFDI	0.004	0.043	0.004	0.029	0.007	0.007	0.006	0.025
LR Total	Digital	0.161	0.000	0.044	0.000	0.080	0.000	0.079	0.000
	TO	−0.011	0.653	0.068	0.092	0.049	0.245	0.013	0.785
	GFDI	0.003	0.027	0.001	0.005	0.003	0.046	0.002	0.051

Considering the other variables, TO (trade openness) and GFDI (greenfield investment), their coefficients and probabilities indicate mixed results. In general, the coefficients for TO show relatively weak and statistically insignificant effects on ESG. However, the coefficients for GFDI suggest a statistically significant positive impact on ESG, with probabilities ranging from 0.027 to 0.051, indicating the potential importance of greenfield investments in promoting ESG outcomes.

## 5. Discussion

The abovementioned findings provide valuable insights into the complex relationship between digitalization and ESG performance. The evidence strongly suggests that digitalization has a significant and positive direct impact on ESG performance within individual countries. Moreover, the spillover effect observed indicates that the benefits of digitalization extend beyond national borders, positively influencing ESG performance in neighboring countries as well. This interconnectedness highlights the global nature of the impact of digitalization on sustainability and responsible business practices.

The positive spatial effect of digitalization on ESG performance, as supported by studies [45–47,53–56], indicates that as digital technologies advance and become more prevalent in a region or group of countries, the overall sustainability and environmental, social, and governance performance of those countries tend to improve. This finding holds particular promise for international cooperation and collaboration in fostering sustainable development, as countries can potentially work together to harness the benefits of digitalization for a more sustainable future.

However, it is crucial to acknowledge the contrasting results presented by studies [102–104], which propose a U-shaped impact of digitalization on ESG effects. This U-shaped pattern implies that, initially, as digitalization progresses, there may be challenges or negative consequences for certain aspects of ESG performance. These studies might highlight specific concerns related to the rapid adoption of digital technologies, such as environmental impacts, privacy issues, or unequal access to technology, which could affect ESG metrics.

The existence of both positive and U-shaped impacts of digitalization on ESG performance warrants further exploration and examination. It could be indicative of differing circumstances and contexts in which digitalization is deployed, underscoring the need for tailored approaches to sustainability strategies based on a country's unique characteristics, policies, and development stages.

## 6. Conclusions

Based on the aforementioned findings, it can be inferred that digitalization has a favorable impact on Environmental, Social, and Governance (ESG) performance, both directly and through spillover effects. This indicates that as digitalization increases in neighboring countries, it positively influences the ESG performance of all countries involved. These results highlight the interconnectedness and potential benefits of embracing digitalization for sustainable development and responsible business practices globally.

Considering the abovementioned results, the following policy implication could be outlined:

1. Policymakers should prioritize initiatives that aim to bridge the digital divide and ensure equal access to digital technologies and services. This includes providing affordable internet access [12] and digital literacy programs [41]. By promoting digital inclusion, countries can create a more equitable and inclusive digital society [9].
2. Governments should reinforce the development of robust digital infrastructure [19,33], such as high-speed internet connectivity, reliable data networks, and advanced technology platforms. By investing in key enablers, countries can create an enabling environment for digital innovation [17,18], entrepreneurship [23,34], and sustainable economic growth [19,21], ultimately contributing to an enhanced ESG performance.
3. EU policymakers should prioritize the development and expansion of digital public services for businesses and citizens. This includes digital platforms for e-government services [33], online business registration [46,49,51], electronic tax filing, and access to

digital healthcare and education [66,73]. By streamlining administrative processes, reducing bureaucracy, and improving access to essential services, countries can enhance their efficiency, transparency, and sustainability.

4. It is necessary to pursue policies that promote open and inclusive trade practices. This includes reducing trade barriers, facilitating cross-border digital transactions, and fostering international collaboration. It allows the exchange of knowledge [43,44], technology [55], and sustainable practices [48,49] to be boosted, leading to an improved ESG performance through an enhanced global cooperation.
5. EU countries should continue to develop the relevant mechanisms for creating an attractive climate for green investments and sustainable business practices. This involves implementing supportive policies, such as tax incentives, subsidies, and regulations that promote clean energy, resource efficiency, and environmentally friendly technologies [74,102,105–107]. By attracting and incentivizing green investments, the EU could drive the transition toward a low-carbon economy [14,21,66] and promote sustainable development.

Despite the valuable findings, this study could be further advanced in the following aspects. While the paper identifies a correlation between digital transformation and ESG performance, it is important to note that correlation does not imply causation. The study does not establish a causal relationship between digitalization and an improved ESG performance, as there may be other factors at play that contribute to these outcomes. EU countries exhibit varying levels of economic development, digital readiness, and ESG performance. The heterogeneity among countries may introduce additional complexities and nuances that may not be fully captured in the analysis. Further investigations require extending the list of control variables which could have influenced the results. Additionally, it is necessary to conduct sensitivity analyses to assess the robustness of the findings against potential confounding variables.

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