

# Digital Transformation and ESG Investing as the Driving Force for Sustainable Development

Athanasios Nasis<sup>1</sup>, Ioanna Siouziou<sup>2</sup>, Kanellos Toudas<sup>3</sup>

<sup>1</sup>Department of Economics, National and Kapodistrian University of Athens, Athens, Greece

<sup>2</sup>School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece

<sup>3</sup>Department of Agricultural Business Administration and Supply Systems Management, Agricultural University of Athens, Athens, Greece

Email: [athanasios.nasis@hotmail.com](mailto:athanasios.nasis@hotmail.com)

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## Abstract

The digital revolution is clearly shown to have reshaped industries, economies, and societies all over the world. The digitalization that took place in relation to the enterprises' operations increased the complexity of the entrepreneurial environment, as digital services have consisted communication and data sharing much easier. Recent developments like AI, IoT, big data have enabled significant changes to the production processes and structure of enterprises, while the co-ordination of their activities have not stayed intact. Today, the globe has faced a series of topics of growing concern such as protection of environment, workplace diversity, right of stakeholders and transparency. These challenges have been confronted by organizations incorporating environmental, social, and corporate governance (ESG) factors and digital transformation in their innovation business strategies. Digital technologies increase as the consumption of energy becomes vast, and high generation of electronic waste leads to environmental degradation. Knowing the connection between digital transformation and E.S.G. factors is important as can be seen from these changes. There is enjoyment of enhanced financial performance and resilience by companies that have demonstrated good ESG performance. This has made the connection between the two variables a concerned research area since it sheds light on the key considerations toward attaining the best performance level. The research is meant to investigate the relationship between digitalization and ESG factors using a research sample with countries from different regions. Quantitative research data collection was done by world bank while statical analysis was performed using the methodology of OLS regression. The study gives empirical insights into the improvement of the area, letting the major stakeholders know strategies that would lead to the best performance of individual industries and government departments in the different regions.

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## Keywords

Digital Transformation, Sustainability, ESG Factors

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### 1. Introduction

The growing emphasis on managing climate change and uncertainty in the business environment has transformed the aspect of sustainability into a concept that modern-era institutions and firms should address. The current architecture of sustainability, which is based on Environmental, Social, and Governance (ESG) factors, is a key priority for all companies. These developments have integrated the aspect of digitization, particularly investing in AI research and development, as a key aspect of economic growth that has transformed environmental interventions and concerns.

Today, investors and stakeholders review and examine the ESG and digital transformation aspects of firms to gain an understanding of the activities of the organizations and how they invest resources in sustainability (Wan Mohammad et al., 2018). For instance, the environmental issues that are considered important include the protection of the environment, adherence to practices that do not pose a threat to climate change, and the effects of business operations on the environment. On social aspects, stakeholders evaluate issues such as equality, treatment of workers, and workplace diversity, amongst others (Wan Mohammad et al., 2018). Governance aspects include the independence of board members, the rights of shareholders, and transparency (Lavin & Montecinos-Pearce, 2021). The idea of ESG as a concern for companies first emerged in 2006 as a United Nations Principles for Responsible Investment (UNPRI) report (Kim & Yoon, 2022). Since this time, many institutions around the world have advocated for individual firms to disclose and evaluate their ESG compliance. In addition, governments have enforced specific laws and policies requiring organizations to report on ESG, such as Directive 2014/95/EU by the European Union which requires big corporations to report on non-financial activities and procedures (Ortiz-Martínez et al., 2022).

Digital transformation empowers ESG investing by enhancing ESG data collection and analysis. Digital tools can be used to gather and analyze vast amounts of ESG data thus enabling more informed investment decisions. In addition, Digital transformation empowers ESG investing by the development of sustainable solutions. On the other hand, ESG investing can drive digital transformation by the funding of green innovation (Fang et al., 2023). ESG and Digital transformations are powerful forces for sustainable development. They have a mutually reinforcing relationship. Digital tools can enhance ESG practices whereas ESG investing can drive the adoption and development of sustainable digital technologies.

The interest in Digital transformation factors has substantially transformed the strategies of companies from profit maximization into an awareness of social interests, environmental protection, and corporate governance (Kwilinski et al.,

2023b). Organizations that focus on digital transformations like AI have an increased awareness of sustainability, and they are subsequently able to incorporate ethical business approaches. This implies that compliance with digital transformation can help companies gain a competitive advantage whereas failure to comply constitutes a significant risk. Undoubtedly, there are strong justifications for ESG and digital transformation sustainability practices as they are known to add value to companies (Lavin & Montecinos-Pearce, 2021). Digital transformation of AI holds immense potential to revolutionize various fields and help solve global challenges (Moro-Visconti, 2022). The digital revolution is transforming countries and companies. AI imposes several benefits to companies easy accessibility to data and computing power, increased efficiency, and democratization of AI. On the other hand, data privacy and security become a challenge faced by digitalization.

Interestingly, evidence indicates that companies have different levels of ESG compliance and reporting (Chvatalová & Simberova, 2011), which suggests that there are distinct approaches and levels of understanding. This observation can be attributed to the lack of clarity on the association between ESG factors and organizational performance which has resulted in a lack of motivation to make ESG and sustainability normal business practices as compared to financial reporting (Chvatalová & Simberova, 2011). This study investigates the relationship between digital transformation in the field of AI and ESG issues, together with a discussion of the research findings and critical analysis.

## 2. Literature Review

A sustainable environment is critical for global challenges. One of the key motivations for companies to engage in ESG practices and sustainability is to demonstrate compliance in the market which then translates to higher financial returns (Khandelwal et al., 2022). However, there is no clear link between ESG and organizational performance since the literature features conflicting results. Digital technologies like Artificial Intelligence (AI), and IoT, among others, are consistently revolutionizing industries. Digital transformation can contribute to sustainability in various ways, including environmental, social, and economic aspects.

ESG investing considers a company's social, environmental, and governance practices alongside financial performance (Iazzolino et al., 2022). Companies that have robust ESG practices may manage risks better and attract long-term investors than those without ESG. The primary goal of a majority of companies is to increase their market share and financial value in the long term (Alsayegh et al., 2020).

Several studies have established that there is no significant relationship between ESG factors or sustainability and the financial performance of companies. In a study of UK firms that assessed key indicators for the environment, employment, and community activities, the researchers concluded that there is a negative relationship between stock returns and environmental performance for a 12 to 36-month period

(Brammer et al., 2006). Similar results were reported in another study involving 54 Malaysian companies where the results indicated that there is no significant relationship between individual and combined aspects of ESG and company profitability or value. Still, the same study indicates that the combined score of ESG has a significant effect on the cost of capital (Wan Mohammad et al., 2018).

Further, 22% did not lean towards either side or reported a mixed relationship. A different study that analyzed the impact of ESG disclosure on firm performance, based on return on assets (ROA) and earnings before interests and taxes (EBIT), among Italian firms during 10 years reported a positive relationship between ESG factors and the financial indicators (Pulino et al., 2022). Specifically, the study found that the environment and social pillars positively influence corporate performance, whilst governance aspects did not have any effect (Pulino et al., 2022).

Recent technological developments like AI resulted to a digital transformation of enterprises. An increasing factor of corporate value has been found on digital transformation. Aspects such as organizational capital, corporate governance quality, the quality of published information, and the age of the enterprise's Initial Public Offering (IPO) have been identified as shaping factors of the value occurring due to digital transformation. The digital technology is significantly influenced by socioeconomic factors such as income, education and infrastructure quality. Wealthier regions have greater access to digital technologies compared to poorer regions (Mardikyan et al., 2015). Organizational capital, corporate governance and firm information quality are aspects that have to be carefully considered from enterprises in order for them to enjoy the benefits of digital transformation (Zareie et al., 2024). The digital transformation contributes to unequal participation in the global financial system, with regions lacking access to digital platforms missing out on financial inclusion opportunities (Mardikyan et al., 2015).

The research of George & Schillebeeckx (2022) examined the manners through which the environmental and health crises in combination with digitalization increased tensions in several fields, such as geopolitics, organization, market, for multinational enterprises (MNEs). According to their findings, institutional pluralism results to an increased complexity of the worldwide environment. Productive work has foreseen significant developments in relation to its organization that generated challenges for the structuring and coordination of MNEs activities. The understanding of value creation is broadened by changing consumer and investor expectations, a development that results to changes in business models. Occurring tensions prompt MNEs to reassess the framing, formalization and realization of their corporate purpose. Furthermore, a requirement for MNEs to evolve into actors orientated towards achieving a purpose is recognized.

Digitalization and environmental sustainability demonstrate an ambiguous relationship. Several digital technologies demonstrate a potential of diminishing the distance between different countries. On the other hand, relevant applications have an increased demand for energy and resources necessary for the

production of hardware and the use of relevant applications. There is not yet a worldwide framework that handles opportunities and threats of digital technologies in relation to sustainability. They propose the adoption of a Digital Green Deal that would include solid, sector-wide environmentally friendly policies for digitalization on every governance level (Santarius et al., 2023). According to their approach, such a deal would firstly and mainly aim to increase policy coherence. Towards this direction, measures servicing environmental objectives are proposed to be incorporated to current digital policy initiatives, while policies are proposed to be focused on addressing threats and opportunities of digital technologies in order to promote developments orientated towards sustainability.

The main relationships among the notions of digital transformation, open innovation and sustainability. Particular attention is paid on identifying their conceptual framework and investigating the effect that digital transformation poses on sustainability and open innovation (Robertson & Lapina, 2023). According to the findings of the study, digital transformation is a factor that enables and enhances sustainability and open innovation. Furthermore, digital transformation is found to potentially pose a negative impact to the environmental dimension of sustainability.

### 3. Methods and Materials

The relationship between ESG and Digital transformation is crucial for achieving sustainable development. This study has employed the secondary data analysis method. The approach involves working with data that has already been collected and analyzed. In this context, the data on ESG and AI research has been collected, analyzed, and visualized by the World Bank. The method involved accessing the World Bank databank to select the data and the matching visualizations for this analysis.

There were research variables for this project. These included CO<sub>2</sub> emissions, patent applications, and investments in AI research and development. The three variables were selected since they demonstrate the commitment of the countries toward attaining ESG sustainability. CO<sub>2</sub> emissions relate to the aspect of the environment while patent applications reflect the social and governance aspects. AI research and development links to the aspect of digitalization and offers insights into growth areas in the global community. 191 countries in Europe, America, Central Asia, Middle East, Africa Region were included in the research. The 191 countries included Qatar, Kazakhstan, Russian Federation, Poland, Czech Republic, Bosnia and Herzegovina, Ukraine, Bulgaria, Germany, Slovenia, Greece etc. Data collection involved accessing the World Bank Databank website and selecting the indicators. The results of the collection were then interpreted based on the presented series of data. The independent criteria for the analysis were the ESG performance. The present study follows a quantitative research approach. More precisely, two econometric models were applied in order to identify potential relationships between three aspects of ESG (CO<sub>2</sub> emissions, and two variables

related to digital transformation (namely, Research & Development – R&D – expenditure and the number of Patent applications). The time period between 2011–2022 was examined. Data were gathered from the World Bank database. This database was selected since it was of open access. Data analysis was conducted with an OLS regression approach through the SPSS statistical system. The following econometric models were applied:

$$CO_{2i} = PAP_i + RDE_i \quad (1)$$

$$REU_i = PAP_i + RDE_i \quad (2)$$

The following variables were applied to the models:

$CO_{2i}$ :  $CO_2$  emissions;

$RNDC_i$ : Revenue from new digital channels;

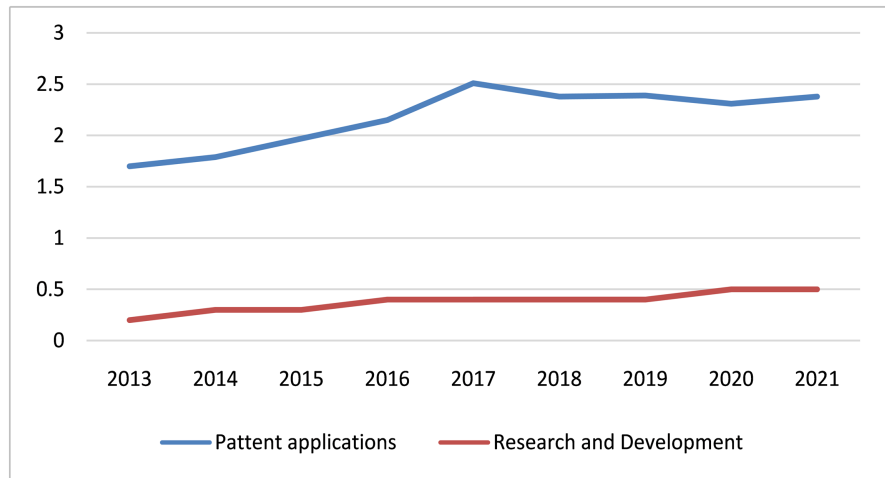
$PAP_i$ : Number of patents' applications;

$RDE_i$ : R&D Expenditure.

## 4. Results

Developments in the field of digital transformation reveal a deep connection with ESG concerns. In terms of digital transformation in the field of AI, this study indicates that countries around the world have invested in the sector. Specifically, the world witnessed an increase in investments from \$1.24 billion in 2013 to \$14.81 billion in 2021. Also, the research shows that digital technology like AI can lead to various impacts in the transformation of countries and companies. From the research, it is found that companies prioritizing ESG are likely to invest in digital solutions creating positive feedback for sustainability. These changes highlight the important role digital transformation plays in modern society as more countries have focused on increasing their innovations. According to [Kwilinski et al. \(2023a\)](#), developments in the field of digital transformation have contributed to an increase in the rate of economic development, innovation, and competitiveness.

ESG scores for Europe, America, Central Asia, Middle East, Africa Region show an inconsistent trend over the past 10 years. The number of patent applications by residents shows fluctuating trends over the years. There is a significant variability since some of the countries have not recorded their values for either indicator. In 2019 and 2020, there was a slight decrease in patent applications compared to the previous years, possibly indicating a temporary slowdown or change in innovation activity. However, the trend seems to stabilize or even slightly increase in subsequent years, suggesting a resurgence in innovation efforts. R&D expenditure as a percentage of GDP demonstrates a generally increasing trend over the 10 years. The trend indicates a growing investment in innovation and technological advancement. The data shows a gradual rise in R&D spending from 2014 to 2021, indicating a sustained commitment to research and innovation activities. The percentage of GDP allocated to R&D has surpassed 2% in recent years. The allocation indicates a significant dedication of resources to drive innovation and technological progress ([Figures 1-4, Tables 1-5](#)).



**Figure 1.** ESG performance (Source: (World Bank, n.d.)).

**Table 1** indicates the scoring of the data based on patent applications. The analysis shows the scores of the country in terms of their recognition of creative and intellectual property rights. The variable demonstrates the aspect of governance.

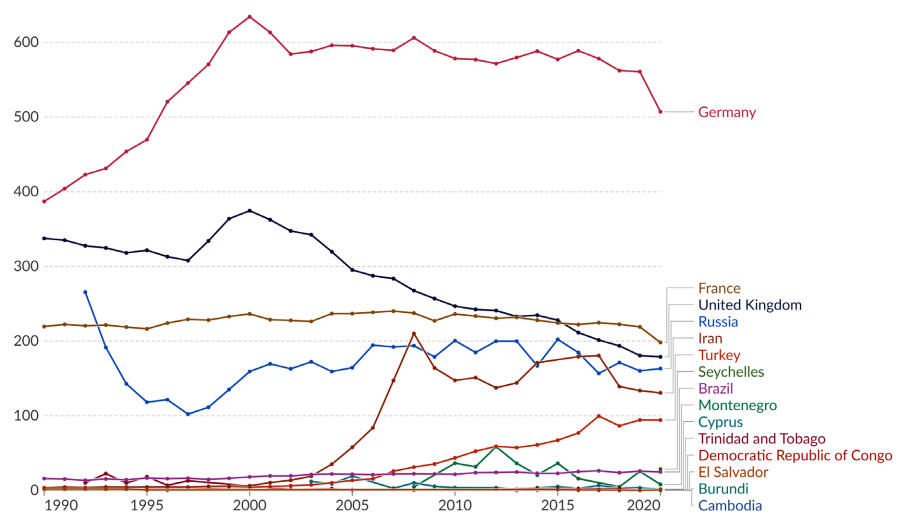
**Figure 3** indicates the CO<sub>2</sub> emissions. It indicates the emissions coming from burning fossil fuels and the use of cement in construction activities. **Table 2** indicates the highest and lowest scoring countries.

The R-Squared index has a value of 0.875, implying that the model explains 87.5% of the independent variable. The Durbin-Watson index has a value of 1.975, which is between the acceptable range of 1.5 - 2.5, implying that the model has nearly zero autocorrelation.

**Table 1.** Highest and lowest scoring countries (Source: (World Bank, n.d.)).

Highest	Value	Lowest	Value
1) Germany	46.24	106) El Salvador	3
3) Russia Federation	24.92	107) Burundi	2
3) India	16.28	108) Guyana	2
4) France	14.30	109) St) Lucia	2
5) UK	12.86	110) Malta	2
6) Iran	11.9	111) Buhtan	1
7) Italy	8920	112) Cambodia	1
8) Türkiye	7156	113) Kuwait	1
9) Brazil	4980	114) Lao BDR	1
10) Canada	4348	115) Samoa	1

### Annual patent applications per million people



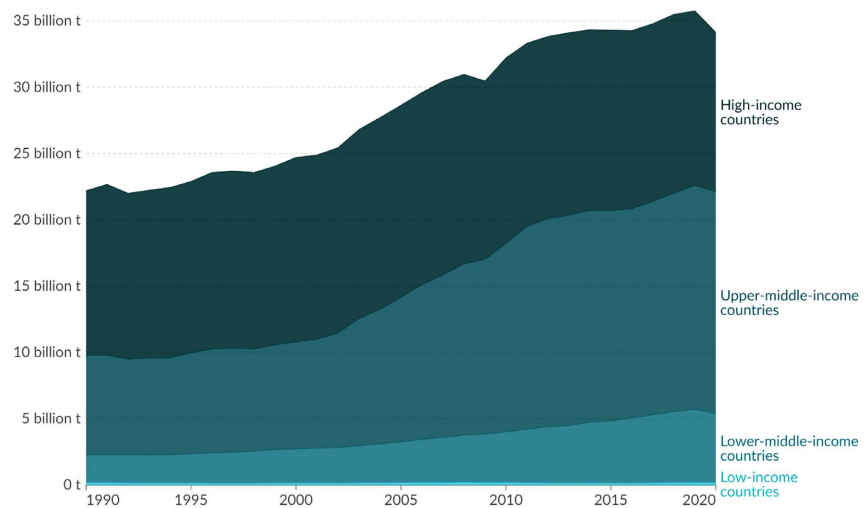
Data source: World Bank (2023); United Nations (2022) OurWorldinData.org/research-and-development | CC BY  
 Note: Patents are assigned based on the residence country of the first-named applicant.

**Figure 2.** ESG Scores based on patent applications (Source: (World Bank, n.d.)).

### Carbon dioxide emissions by income level, 1990 to 2020



Global carbon dioxide (CO<sub>2</sub>) emissions, by World Bank income group.



Data source: Global Carbon Budget (2023) OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

**Figure 3.** CO<sub>2</sub> emissions (Source: (World Bank, n.d.)).

**Table 2.** Highest and lowest scoring countries (Source: (World Bank, n.d.)).

Highest	Value	Lowest	Value
1) Qatar	31.38	182) Sierra Leone	0.13
2) Kuwait	21.47	183) Madagascar	0.12
3) Bahrain	20.73	184) Rwanda	0.11
4) United Arab. Emirates	19.06	185) Chad	0.10

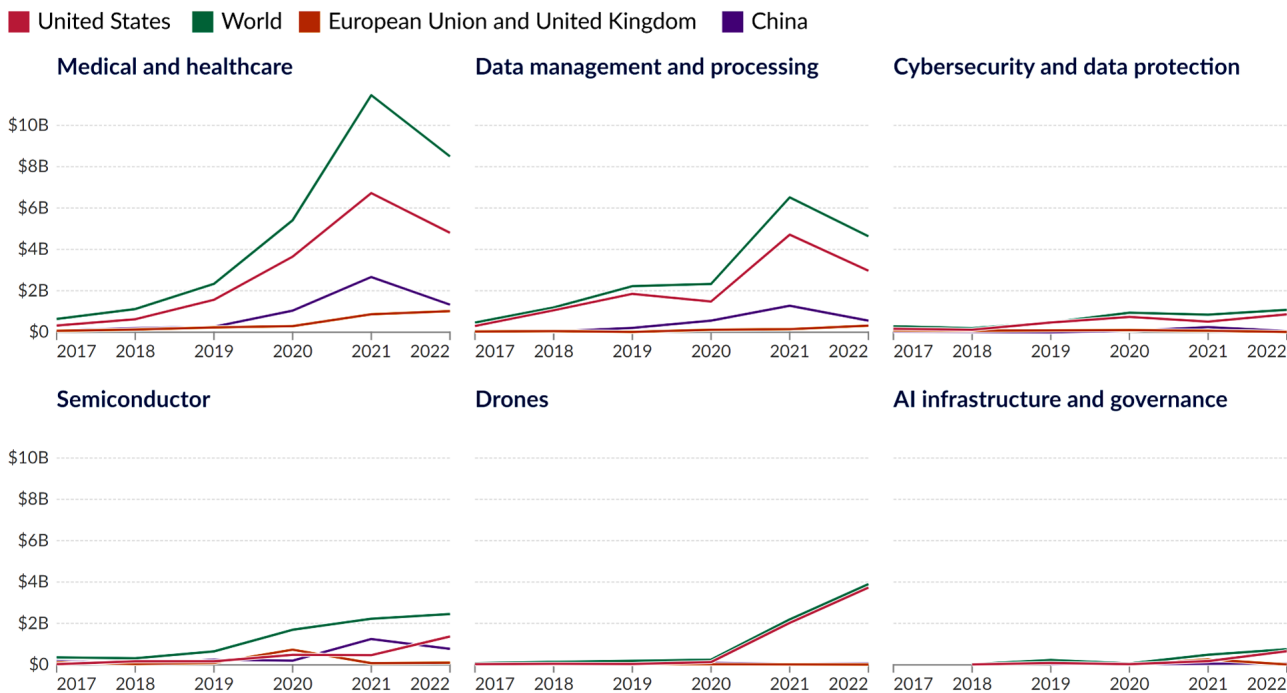
**Continued**

5) Brunel Der	17.36	186) Malawi	0.09
6) Oman	16.38	187) Niger	0.09
7) Australia	15.87	188) Burundi	0.06
8) Canada	15.63	189) Central Africa	0.04
9) Luxemburg	15.33	190) Somalia	0.04
10) United States	15.22	191) Congo	0.03

## Annual private investment in artificial intelligence, by focus area



Includes companies that received more than \$1.5 million in investment. This data is expressed in US dollars, adjusted for inflation.



Data source: Quid via AI Index (2024); U.S. Bureau of Labor Statistics (2024) OurWorldinData.org/artificial-intelligence | CC BY  
 Note: Data is expressed in constant 2021 US\$. Inflation adjustment is based on the US Consumer Price Index (CPI).

**Figure 4.** AI innovations and investment (Source: (World Bank, n.d.)).

**Table 3.** First econometric model.

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
				R Square Change	F Change	df1	df2	Sig. F Change	
0.936	0.875	0.834	0.1341321	0.875	21.075	2	6	0.002	1.975

The model is of statistical significance on the 1% significance level, since its p-value is  $0.002 < 0.01$ .

**Table 4.** Descriptive statistics between CO<sub>2</sub> emissions and research and development expenditure.

Model	Sum of Squares	df	Mean Square	F	Sig.	
1	Regression	0.758	2	0.379	21.075	0.002b
	Residual	0.108	6	0.018		
	Total	0.866	8			

b. Predictors: (Constant), research and development expenditure, patent applications.

**Table 5.** Descriptive statistics dependent variable: CO<sub>2</sub> emissions.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta			
1	(Constant)	4.959	5.044		0.983	0.364
	Patent applications	2.526E-005	0.000	0.233	1.266	0.252
	Research and development expenditure	-1.908	0.455	-0.773	-4.195	0.006

A statistically significant relationship between R&D Expenditure and CO<sub>2</sub> emissions is observed at the 1% significance level, because the p-value is 0.006 < 0.01. The relationship is negative, since the coefficient has a negative sign. No statistically significant relationship occurs between Patent applications and CO<sub>2</sub> emissions (**Table 6**).

**Table 6.** Second econometric model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	0.941a	0.885	0.847	0.4065363	0.885	23.119	2	6	0.002	2.123

a. Predictors: (Constant), research and development expenditure, patent applications.

The R-Squared index is equal to 0.885, indicating that the model explains 88.5% of the independent variable. The Durbin-Watson index is equal to 2.123, which falls on the acceptable interval of 1.5 - 2.5, indicating that the model has nearly zero autocorrelation (**Table 7**).

The model is of statistical significance on the 1% significance level, as its p-value is 0.002 < 0.01 (**Table 8**).

A statistically significant relationship between R&D Expenditure and Renewable Energy Consumption occurs at the 1% significance level, as the p-value is 0.003 < 0.01. The relationship is positive, since the coefficient has a positive sign.

**Table 7.** Descriptive statistics dependent variable: Renewable energy consumption.

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.642	2	3.821	23.119	0.002b
	Residual	0.992	6	0.165		
	Total	8.634	8			

b. Predictors: (Constant), research and development expenditure, patent applications.

**Table 8.** Descriptive statistics between R&D expenditure and renewable energy consumption.

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.951	15.287		0.455	0.665
	Patent applications	-3.397E-005	0.000	-0.099	-0.562	0.595
	Research and development expenditure	6.829	1.379	0.876	4.954	0.003

No statistically significant relationship is identified between Patent applications and Renewable energy consumption. The model has already checked absence of multicollinearity using VIF values and for homoscedasticity. VIF value is ( $VIF = 1.249 < 10$ ) so we do not have multicollinearity between variables. In addition, using the Breusch-Pagan method ended up with ( $p = 0.676 > 0.05$ ) so we have no heteroscedasticity.

## 5. Discussion

CO<sub>2</sub> emissions are a critical environmental indicator that reflects a country's contribution to global greenhouse gas levels and its impact on climate change. Among the highest emitters, Qatar Bahrain, Kuwait followed by UAE and US. These high emissions are often linked to heavy industrial activities, reliance on fossil fuels, and energy-intensive economic structures. The Czech Republic (8.30), Netherlands (7.47), Belgium (7.40), Poland (7.37), Germany (7.25), and Ireland (6.77) also show significant emissions, indicating a need for substantial efforts in transitioning to renewable energy sources and enhancing energy efficiency to mitigate their environmental impact. Conversely, countries with the lowest CO<sub>2</sub> emissions per capital in Africa Region, can be attributed to various factors such as less industrialization, lower energy consumption, or a greater reliance on renewable energy sources and lack of investments. Countries from Europe and especially countries from Scandinavian region shows low emissions, for instance, are largely due to their significant investments in renewable energy and strong environmental policies. Reducing CO<sub>2</sub> emissions is essential for addressing climate change, and countries with high emissions must implement aggressive strategies to lower their carbon footprint, while those with low emissions should continue to pursue sustainable practices to maintain their environmental standing.

Patent applications reflect a nation's innovation capacity and commitment to sustainable development, social welfare, and effective governance. Germany leads with 42,272 applications, indicating strong innovation in green technologies and a robust R&D environment, positively impacting environmental sustainability, social well-being, and governance. Following Germany, the Russian Federation (23,760 applications), France (12,768 applications), the United Kingdom (11,992 applications), and Italy (10,064 applications) also show substantial patent activity. These results suggest advancements in renewable energy, healthcare, and social infrastructure supported by effective intellectual property laws and government policies. In contrast, countries like the Kyrgyz Republic (63 applications), Bosnia and Herzegovina (50 applications), and North Macedonia (47 applications) have low patent numbers. The results show that these nations face challenges in contributing to environmental sustainability, social advancements, and maintaining robust governance structures. Based on these results, high patent activity correlates with positive ESG outcomes, while low activity highlights areas needing significant improvement in sustainable practices, social development, and governance frameworks.

Developments in the field of AI reveal a connection with the ESG concerns. In the research, a statistically significant correlation was found between various ESG indicators and digital transformation metrics. For instance, in terms of artificial intelligence research and development, this study indicates that countries around the world have invested in the sector. Specifically, the world witnessed an increase in investments from \$1.24 billion in 2013 to \$14.81 billion in 2022. These changes highlight the important role AI plays in modern society as more countries have focused on increasing their innovations. The study reveals that the United States had the highest increase in the allocation of AI research and development resources. A similar increase is evident in the UK and the European Union where developments in AI have increased. The transformations communicate a major increase in technology adoption and a consistent focus on product enhancement. China has also turned out to be an important player in AI innovation. This is evident through the numerous development programs that the country has registered.

## 6. Conclusion

The results indicate relationships between ESG and digitalization variables but not a big statistically significant relationship. More precisely, R&D expenditure was identified to be positively correlated with Renewable energy consumption. The increase in R&D expenditure leads to an increase in the use of renewable energy sources. The relationship between ESG and digitalization may not be straightforward. Digitalization might influence ESG factors rather than the other way around, or the relationship could be influenced by external factors, like Covid 19 which had an impact on the investments. The time lag also can affect the data of this research and might miss out on longer term effects. In addition, the lack of

digitalization metrics can be complex and difficult to quantify accurately.

High CO<sub>2</sub> emissions in countries like United Arab Emirates, Qatar and Kuwait highlight the urgent need for transitioning to renewable energy and enhancing energy efficiency to mitigate environmental impacts. On the other hand, lower emissions in countries such as Tajikistan (0.98) and the Kyrgyz Republic (1.38) illustrate the benefits of less industrialization and greater reliance on renewable sources. Patent applications serve as a crucial ESG indicator, with Germany (42,272 applications) leading in innovation, positively affecting environmental sustainability, social welfare, and governance. In contrast, low patent activity in countries like the Kyrgyz Republic (63) and North Macedonia (47) indicates challenges in these areas. The significant rise in global AI investments from \$1.24 billion in 2013 to \$14.81 billion in 2021 underscores the deep connection between AI advancements and ESG concerns. Countries investing heavily in AI, such as the United States, the UK, and China, show increased economic development and competitiveness. These findings suggest that fostering digital transformation and robust ESG practices can drive sustainable development, enhance financial performance, and address global challenges effectively.

The aforementioned results indicate that digitalization enhances the performance of ESG aspects. More precisely, both environmental (reduction of CO<sub>2</sub> emissions, increase of the use of renewable energy sources) and ESG features have been identified to be improving when functions related to digitalization (R&D expenditure, Patent applications) increase. This finding comes in accordance with literature.

Further study can be found on the specific aspects of the identified relationships on a company level. More precisely, it is proposed to study the impact of the aforementioned digitalization variables on a company level. Through this research, that would have the form of a case study, specific details about the precise relationship between digitalization and ESG practicing would be extracted.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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