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Responsible digitalization through digital technologies and green practices

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Abstract

Although digital technologies grant documented operational and economic benefits, they can activate unwanted consequences for the environment and society. This research investigates these issues by exploring how firms can create a portfolio of technologies to perform corporate social responsibility (CSR) goals and then achieving responsible digitalization. The latter is defined as the firms' capacity of adopting digital technologies without underperforming in terms of CSR. Accordingly, we investigate the relationships between digital technologies and CSR to discover the firms' capacity to achieve responsible digitalization targets. Furthermore, we explore how the use of some green practices allows firms to increase the chances of achieving responsible digitalization goals.

KEYWORDS

corporate social responsibility, digital technologies, green practices, regression analysis, responsible digitalization

1 | INTRODUCTION

The adoption of digital technologies has been both fashionable and attractive in recent years due to the potential benefits of their use and the role they play in the digital world (Frank et al., 2019; Ivanov et al., 2016). All transformations and technological revolutions, especially those occurring after the 1950s, have brought great prosperity, progress, and value. However, firms require further analysis to better understand such rapid and increasing trends, specifically whether the transformation occurring through digital technologies provides real advantages and concrete market opportunities along with social and environmental benefits. In any case, firms must perform a comprehensive analysis of the strategic behavioral changes required to properly select and use digital technologies, an accurate estimation of their economic outcomes, and a careful assessment of the implications for the entire eco-system (Ivanov et al., 2016; Saberi et al., 2019). In the past, several unintended consequences have followed the industrial transformation and revolutions, including climate change and global warming, pollution, and the increasing presence of plastic in oceans, to mention a few. Therefore, the current digital transformation could have similar effects if left unchecked.

The implementation of digital technologies requires a comprehensive analysis of their adoption, including the complex regulatory, tax, auditability, risk, and compliance implications linked to global business (Cole et al., 2020) and extended to the environmental and social spheres (Liu & De Giovanni, 2019). Restrictive legislation, reputational pressure, corruption, misleading information and products, human rights and gender violations, unknown working conditions, and security are only some of the factors firms should consider when selecting their portfolio of digital technologies. In this sense, De Giovanni (2021) coined the concept of *responsible digitalization*, which is exemplified by the firms' capability to achieve their Corporate Social Responsible (CSR) goals by adopting digital technologies. Accordingly, firms should not restrict their focus on digital technologies as merely boosters of enhancing economic performance, but they should carefully evaluate the digital technologies' implications in terms of environmental effects and social targets.

As empirically shown in De Giovanni (2021), digital technologies can harm both the social and the environmental spheres. For example, a farmer who invests in robotics can achieve positive benefits for the environment by reducing production waste and the energy used. However, recent estimates show that a crop-harvesting robot can replace up to 30 human workers. Therefore, robotics can generate important social "rebound effects" that any digital transformation process cannot disregard. Similarly, Industry 4.0 technologies can ensure a lower scrap rate, high saturation of manufacturing equipment, low waste, and superior energy efficiency (Müller et al., 2018). However, production systems using robotics and big data can become highly capital-intensive, which can result in overall higher energy consumption (Indri et al., 2018). In fact, the use of big data requires data centers to consume around 200 terawatt hours annually, which is greater than the total energy consumption of some countries (e.g., Argentina, Ukraine, Thailand), half of the electricity used for transport worldwide, and around 1% of the global electricity demand (Lovell, 2018). According to the described frameworks, digital technologies can have an uncertain and questionable effect on CSR, which requires an accurate and rigorous analysis of both benefits and drawbacks. The adoption of Artificial Intelligence (AI) systems allows firms to proactively mitigate global supply chains risks and disruptions. For example, AI systems extrapolate information from the eco-system, identify possible sources of delay, and proposes alternative solutions to nullify such inconveniences (De Giovanni, 2021). For example, the identification of a potential strike of a port labor force induces the AI system to suggest moving goods by plane rather than by boat. Although this option ensures on-time deliveries and consumer satisfaction, it also induces important environmental damages, since transportation by plane implies higher emissions than transportation by boat. Therefore, firms achieve responsible digitalization when the adoption of digital technologies guarantees the Triple Bottom Line (i.e., economic, social, and environmental outcomes) and consequently CSR goals.

We insert our contribution within this framework and investigate whether the adoption of a portfolio of digital technologies allows firms to pursue CSR targets. Therefore, we contribute to the recent debate of how firms can effectively reach CSR goals (Ben-Amar et al., 2021). With our design, the portfolio of digital technologies is composed of AI systems, Internet of Things (IoT), Intelligent Transport Systems, and Big Data. Furthermore, we consider CSR as a second-order factor measured by economic performance, environmental initiatives, and social effects. By investigating the relationship between digital technologies and CSR, we contribute to the literature by investigating whether firms can achieve responsible digitalization. Furthermore, we explore the benefits that firms can obtain when implementing environment-based strategies exemplified by green process innovation, energy-efficient solutions, green packaging and recycling materials, circular economy, and safety risk practices. We thus investigate whether these practices can enhance responsible digitalization. In this sense, our findings not only contribute to the academic literature by creating additional knowledge regarding the concept of responsible digitalization, but they also offer new insights for managers and practitioners.

To pursue the objective of our study, we used a sample of 157 firms and carry out an empirical analysis composed of four steps: 1. Identification of the CSR pillars, 2. Definition of CSR and digital technologies, 3. Responsible digitalization by exploring the nature of digital technologies' impact on CSR, and 4. Adoption of environment-based practices to enhance responsible digitalization. We develop an exploratory factor analysis to carry out the first two points. In step 3, we then run a set of linear and non-linear regression analyses to establish the best relationship between digital technologies and CSR. Finally, in step 4, we use the model outcomes obtained in step 3 and run some moderation analyses to investigate the responsible digitalization improvements resulting from the adoption of environmental-based practices.

Our results show that firms can achieve responsible digitalization when building a portfolio of digital technologies composed of Artificial Intelligent Systems, IoT, Intelligent Transport System, and Big Data. There exists a linear relationship between digital technologies and CSR in which economic performance has greater importance than environmental attitudes and social interactions. While the non-linear models show an insignificant relationship, the linear relationships between digital technologies and CSR can be improved when firms implement green process innovations, adopt energy-efficient solutions, and use both green packaging and recycling materials. These practices allow firms to boost the responsible digitalization levels. Finally, neither circular economy nor safety risk procedures induce higher responsible digitalization, resulting in effective practices to achieve other targets.

This paper is structured as follows. In Section 2, we review the literature and identify the research hypotheses to be tested. In Section 3, we describe the data collection process, while in Section 4 we report the empirical results and discuss the findings. Finally, Section 5 concludes and lists both limitations and future extensions.

2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Considering the numerous theories developed to explain the concept of Corporate Social Responsibility (CSR) (Garriga & Melé, 2004), it is not easy to find a unique definition. However, all definitions converge on five fundamental dimensions: the stakeholder, social, economic, voluntariness, and environmental dimensions (Dahlsrud, 2008). Among firms and organizations, the CSR concept has been internalized according to three of those five dimensions, the economic, environmental, and social dimensions (Epstein, 2017). These three pillars become the key ingredients of the Triple Bottom Line (TBL), which is a term coined by John Elkington in the early 1980s and referred to the firms' capacity to achieve successful economic, environmental, and social performance, and represents a proxy to measure CSR. Therefore, the TBL is an antecedence of CSR; the latter has broader targets that also include legal, ethical, and philanthropic responsibility (De Giovanni & Vinzi, 2014). According to Norman and MacDonal (2004), firms committing themselves to the TBL principles make a real, verifiable, and trustable commitment toward CSR.

The implementation of digital technologies can represent the potential to take a further step toward CSR. To explain the links between CSR and digital transformation, De Giovanni (2021) coined the concept of *responsible digitalization* to describe firms' capacity to identify and implement the digital technologies to perform the TBL and achieve CSR goals. By developing a simulated SC framework, he evaluates the benefits that an Artificial Intelligence (AI) system provides in terms of improving profits (economic dimension), emissions (environmental dimension), and consumers' access to goods (social dimension). Interestingly, De Giovanni (2021) finds that AI seldom leads to responsible digitalization, since the environmental and the social pillars are challenging targets that digital technologies do not necessarily contemplate.

To our knowledge, De Giovanni (2021) is the only research inspired by the concept of responsible digitalization. Rather, the literature has sponsored the adoption of digital technologies to promote a limited batch of performance dimensions, showing the existence of certain trade-offs and requiring the creation of new digital capabilities. To demonstrate this issue, Dalenogare et al. (2018) investigate the relationships between digital technologies and performance, discovering that none of the digital technologies can improve all performance dimensions simultaneously; hence, firms should first select their targets and then decide on the digital technologies to implement. For example, Big Data can have contrasting effects on performance: operational performance can be considerably improved, while social performance exemplified by product customization, quality, and time-to-market can deteriorate (De Giovanni, 2021). The responsible digitalization helps firms in driving the corporate digital responsibility process, which is defined by Lobschat et al. (2021) as the acquisition of a set of norms and values that guides the firms' decisions and behaviors and contributes to new managerial styles and culture. Responsible digitalization is then an antecedent of corporate digital responsibility since a digital technology that is not in line with CSR goals cannot become a set of norms and values constituting the corporate digital responsibility.

Liu and De Giovanni (2019) study the economic, environmental, and social benefits linked to investments in I4.0 technologies, focusing on Robotics and IoT. They discover an eco-innovation paradox that arises when investing in digitalization. Digital technologies, in fact, increase firms' capacity to abate the emissions linked to the production process. At the same time, a high number of consumers can access the product, thereby requiring additional production cycles. This access leads to an increase in total emissions, thus generating a stagnation of the environmental performance. This result is in line with the debate in the SC literature over I4.0 and environmental performance. For example, digital technologies can ensure a lower scrap rate, high saturation of manufacturing equipment, low waste, and superior energy efficiency (Müller et al., 2018; Stock & Seliger, 2016). However, production systems using robotics and Big Data can become highly capital-intensive, which could result in overall higher energy consumption (Grau et al., 2017; Indri et al., 2018). Furthermore, the use of Big Data requires data centers to consume around 200 terawatt-hours annually, which is more than the energy consumption of some countries (e.g., Argentina, Ukraine, Thailand), half of the electricity used for transport worldwide, and around 1% of the global electricity demand (Lovell, 2018). Currently, data centers contribute approximately 0.3% to the overall carbon emissions, while the ICT sector accounts for more than 2% of global emissions (Jones, 2018). Finally, the adoption of I4.0 technologies aims to increase productivity over the SC (Saucedo-Martínez et al., 2018; Zhong et al., 2017). Nevertheless, the presence of outdated production and logistics systems can result in increasing emissions and pollution, with a strong detrimental effect on the environment (Nagy, 2019). Accordingly, digital transformation through I4.0 technologies can require a systematic change in SCs, including green investments in terms of products, processes, and SC networks (de Sousa Jabbour et al., 2018a, 2018b).

The debate regarding the impact of I4.0 technologies is much stronger and more groundbreaking when considering the social sphere in which it takes place. The current implementation of I4.0 is most likely seen as a threat (Horváth & Szabó, 2019), leading to changes in working conditions and wages, a lack of skilled workforces, the risk of losing jobs, workforce mobility, and the need for training programs (Basl, 2017; Bauer et al., 2015; Müller & Voigt, 2018). Therefore, it is necessary to reshape the current organizational strategies and paths for implementing digitalization projects aimed at CSR. According to the described framework, I4.0 technologies can have an uncertain and questionable effect on CSR, which requires an accurate and rigorous analysis of both the benefits and the drawbacks of such a system. In fact, the current state-of-the-art suggests that firms and SCs invest in I4.0 technologies to exploit financial incentives linked to government policies with CSR that remains a second-order target. Therefore, this research seeks to create knowledge and theory on this subject by developing the following research hypothesis:

> **H1.** Firms achieve responsible digitalization by exploiting the positive impact of digital technologies on Corporate Social Responsibility.

According to the Norman and MacDonal (2004), sustainability plays a key role in achieving CSR. While digitalization is the latest revolutionary trend, sustainable practices have served as the drivers to reach CSR for many decades along with traditional drivers like stakeholder orientation, governance, and CSR incentives (Ben-Amar et al., 2021). Therefore, firms undergoing digital transformation must integrate the related technologies within green strategies and environmental practices. Surely, firms seeking to achieve CSR goals must undertake a set of green practices, which are then a definitive prerequisite (Babiak & Trendafilova, 2011). In fact, digitalization can be responsible when digital platforms, systems, and technologies are used to pursue CSR targets, which are induced by low energy consumption through digital applications for proactive maintenance and production planning, low emissions through an efficient impact of processes, suppliers, and operations, high societal objectives through security, privacy, and identity protection, and appealing economic yields achieved by using secure systems, transactions, and platforms.

All of these goals are potentially feasible when adopting effective green practices (De Giovanni & Cariola, 2020).

The literature has provided a warning regarding the impact of green practices to achieve CSR goals through digitalization. However, research in this field is still rare. For example, robotics application technologies help manufacturing systems handle repetitive jobs and enables continuous systems to achieve economies of scale and efficiency (Bochmann et al., 2017). All robotics equipment includes sensors, intelligence to make autonomous decisions, and collaborative operations with humans (cobots) for improved productivity, quality, and lead times (Pfeiffer, 2016). However, robotics needs investment in process innovation and adjustments of production processes, which should be inspired by green principles and targets; furthermore, robotics can create social issues, leading to a non-responsible situation. Finally, the use of robotics could require the additional use of energy, which alerts firms regarding the need to use sustainable energy sources.

Similarly, Automated Guided Vehicles (AGV) and Intelligent Transport Systems accomplish efficiency and effective transportation tasks through their versatility (Lu et al., 2017). By integrating AGV with (RFID) applications, firms benefit from smart AGV systems that autonomously optimize the decision-making process (e.g., the material routes), improve the traditional guidance methods (e.g., optical line), communicate with other parties in real time, determine performance, interact easily with users, and enable reconfigurable manufacturing systems (Mehami et al., 2018). However, AGV increases several operational risks linked to physical constraints: perfectly even floors to remove all possible vibrations harming the connections, electrical conductivity systems to ensure proper charges, and clean spaces to avoid light and dust that obscure the AGV's sensors. Accordingly, firms might require ad hoc investments in safety systems to avoid these risks.

Although the relationships between digital technologies and performance have been addressed in the literature, a research gap exists regarding whether digital transformation uses proper sustainable drivers and practices to achieve CSR targets. The recent survey by Machado et al. (2019) reveals that there is a very negligible number of published papers linking digitalization technologies and sustainability. These papers focus mostly on single technology applications at the firm level while disregarding the full sphere of CSR, the links and synergies among digital technologies, and the impact of sustainability. The existence of this research gap clarifies the position of this research, which seeks to develop knowledge around the concept of responsible digitalization, exemplified by adopting digital technologies to achieve CSR targets using green drivers.

For these reasons, we formulate the following research hypothesis:

> **H2.** Do green practices accelerate the achievement of responsible digitalization?

To address this question, we focus on six green practices: *investment in green production process innovation, use of green packaging, application of recycled materials, adoption of safety risk procedures, implementation of circular economy systems, and adoption of energy-efficient solutions*.

Figure 1 captures and summarizes our research goals.

3 | DATA AND SAMPLING

3.1 | Survey design and sample description

To test our research hypotheses, we designed a survey to collect information about the respondents (e.g., industry and company type), the investments in Industry 4.0 technology, the implemented green practices, and the CSR goals. The questionnaire has been pre-tested through a pool of experts (professors, Ph.D. students, professionals, managers) from whom we asked for feedback about wording, readability, and completeness. Consequently, the survey was modified and improved accordingly.

The data collection process began by subjecting the survey to an initial sample of 1200 firms' managers. We chose to interview professionals who are active in this domain. They were contacted via email. Within 2 weeks, we received the majority of the responses. In the meantime, we extended our investigation by contacting them by phone. Overall, we obtained a total of 157 usable observations, excluding those removed as invalid. This represents about 12% of the entire population of companies that we targeted (1200). More than half of the organizations had an average sale turnover of more than 100 million (52%) and a workforce of more than 200 employees (53%).

The data collected was primarily from European and American companies, 73% and 16%, respectively. Most of the interviewees are supply chain managers (52%), working mainly for manufacturing companies (36%) and retailers (23%). The results reveal a heterogeneous industrial panorama with the Food and Beverage (22%) and the Fashion & Apparel (12%) sectors predominating. A more detailed representation of the distribution of the respondents and the composition of the sample characteristics are illustrated in Table 1.

Several approaches were used to assess the "non-response bias." The first approach consisted of comparing early and late respondents (i.e., first and second to third surveys). A one-way analysis of variance (ANOVA) found no significant differences between the early and late responses for all items. These findings support the conclusion that "non-response bias" is not a significant concern. Moreover, we checked for non-response bias by using the demographic variables company type, size, number of employees, and average turnover. Once again, we found no significant differences between the groups. As an example, we have taken the variable *company type* and created two groups, one composed by manufacturers and wholesalers and once composed of distributors, suppliers, and retailers. We run an ANOVA using these two groups and the traditional Fisher's F-test, whose corresponding probability are: 0.156 for profits, 0.733 for ROI, 0.668 for saving costs, 0.836 for energy cost, and 0.625 for environmental impact. These results highlight that the two groups have the

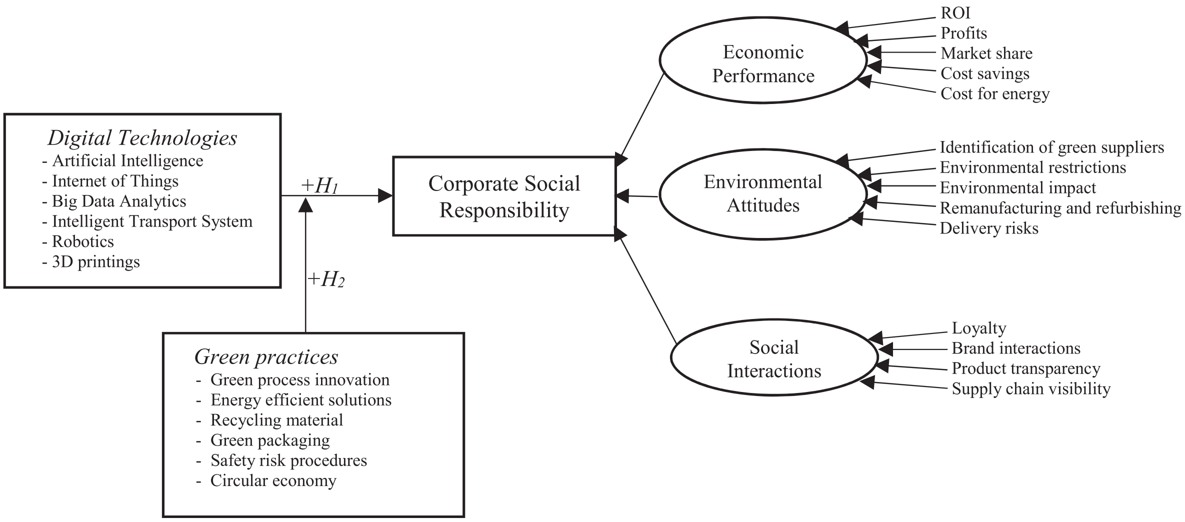

FIGURE 1 Research design

same means. The same results have been obtained for all other variables and using the other descriptive statistics.

All items included in the questionnaire were measured using a 7-point Likert scale, indicating the level of agreement with a certain question (where 1 = not at all in agreement and 7 = full agreement). Therefore, we conducted the analysis at the original items' scale and then moved to the scores after computing the second-order factor for CSR.

4 | METHODOLOGY AND DATA ANALYSIS

The items that define each construct were selected accordingly against the theoretical background and the literature contributions. CSR is measured as a second-order factor. As mentioned earlier, the CSR construct is composed of different ingredients and several dimensions. Therefore, we cannot identify a bath of indicators that measures CSR. Rather, one needs to first measure the various components of CSR, which are represented by the TBL. Specifically, we measure the components economic performance, environmental attitudes, and social interactions as isolated phenomenon and then check their joint contribution in measuring CSR. We have displayed our research framework graphically in Figure 1. To pursue our research targets, we have used a Principal Component Analysis, which aims at summarizing various measures into single components. Hence, we used it for the TBL measures and then also for the CSR and the digital technologies. Overall, we have followed a procedure that consists of four steps:

- *Step 1*. Run a set of Block Factor Analysis on performance-related constructs to create the composite indicators of each first-order factor.
- *Step 2*. Apply the Exploratory Factor Analysis (EFA) to verify the orthogonality between Digital Technologies and CSR.
- *Step 3*. Run a set of regression analyses between Digital Technologies and CSR to investigate H_1 and choose the best fit model.
- *Step 4*. Investigate H_2 by running a set of moderating effect analyses on the best fit model using Green Practices as moderators.

In the following, we explain each of these steps in details.

4.1 | Step 1: Apply the block exploratory factor analysis to the first-order factors

The first objective of this procedure is to define the single constructs linked to the TBL. Therefore, we seek to identify the components linked to economic performance, environmental attitudes, and social interactions. To accomplish our target, we run an Exploratory Factor Analysis using a Principle Component Analysis. In our specific case, we run a Block Exploratory Factor Analysis to measure the TBL pillars as isolated phenomenon and independent of all the rest. Note that this is done because we seek to measure CSR as a second order factor; hence, each TBL component will be first studied through a single Block Exploratory Factor Analysis.

We start the search for the first block by developing the component *Economic Performance* (EcP), which is defined as the firm's ability to generate economic value. Each of the items included in the constructs have been measured by asking the question: "In the last two years, our company has performed in terms of…". Then, we have used the following items: ROI (EcP1), which indicates the firm's ability to profitably allocate its investments; profits (EcP2), which is the ability to create profits; market share (EcP3), which indicates how the firm performs with respect to its competitors; and cost savings (EcP4) as an indicator of the firm's capability to enable efficient practices. Our statistical results indicate that *Economic Performance* has one dimension only, with an associated eigenvalue of 2.454 and explaining 61.339% of the variance. The second eigenvalue scores 0.9,

TABLE 1 Sample description

%	21.7%	11.5%	7.6%	7.0%	4.5%	4.5%	3.8%	3.2%	2.5%	2.5%
#	34	18	12	11	7	7	6	5	4	4
Industry	Food & Beverage	Fashion & Apparel	Medical & Healthcare	Automobile	Mechanic	Energy	Furnitures	E-commerce	Aerospace	Sport
%	52.2%	7.6%	8.3%	1.9%	5.7%	1.3%	5.1%	1.3%	16.6%	
#	82	12	13	3	9	2	8	2	26	
Professionals	SC Manager	Logistics Manager	Operations Manager	Sales Manager	Production Manager	Purchasing Manager	Procurement Manager	Distribution manager	Other	
%	35.7%	19.1%	8.9%	13.4%	22.9%					
#	56	30	14	21	36					
Company type	Manufacturer	Wholesaler	Distributor	Supplier	Retailer					
%	73.2%	15.9%	2.5%	8.3%						
#	115	25	4	13						
Country	Europe	USA	Asia	Other						
%	8.9	25.5%	12.7%	52.9%						
#	14	40	20	83						
Employees	<50	50–99	100–200	>200						
%	7.0%	24.2%	16.6%	52.2%						
#	11	38	26	82						
Sales	<10	10–50	50–100	>100						
%	2.5%	1.9%	1.9%	1.3%	1.3%	1.3%	1.3%	0.6%	19.1%	1
#	4	3	3	2	2	2	2	1	30	157
Industry	Entertainment	Glass	Cement	Telecommunications	Luxury	Beauty & Cosmetics	Electical and electronics	Chemical	Other	
%										1
#										157
Professionals										
%										1
#										157
Company type										
%										1
#										157
Country										
%										1
#										157
Employees										
%										1
#										157
Sales										Total

highlighting the existence of a unique dimension. Therefore, these four measures will form the first block of our research. We exclude the item "Cost of Energy" from the construct, since it has a low loading. This is probably linked to the fact that firms do not have control over the energy cost, which is decided by regulators. Rather, they control the energy consumption.

The second block that we explore links to the construct *Environmental Attitudes* (EA), which summarizes the firm's ability to pursue environmental outcomes. To properly measure this construct, we used the question: "In the last two years, our company has successfully managed the following environmental challenges…:" and collected data on several items. First, identification of green suppliers (EA1) indicates the firms' commitment to create a green supply chain by selecting SC members aligned to the environmental goals. Second, environmental restrictions (EA2) measures the firm's capacity to conduct its business also in the presence of environmental constraints, which can be imposed either internally by business units, suppliers, and partners or externally by legislation and competitors. Third, environmental impact (EA3) indicates, in general terms, the impact of the firms' business activities on the environment. The results of the block analysis show the existence of one factor, whose associated eigenvalue is equal to 1.938 and explains 64.604% of the variance. The second eigenvalue scores 0.9; therefore, uniqueness is ensured for environmental attitudes, which represents the second block for our analysis. Our empirical analysis suggests the exclusion of two indicators: "remanufacturing and refurbishing activities" and "delivery risks". The former is probably too specific to manufacturing firms, while the latter is most likely linked to logistics, which is managed through outsourcing in most cases and then leaves few opportunities to carefully manage all activities.

Finally, we investigate the concept *Social Interactions* (SI), which considers firms' capacity to perform the social-oriented policies implemented by the firm. To properly measure this construct we used the question "In the last two years, our company has targeted to improve the following consumer-based dimensions…" and obtained data on the following items: (1) Loyalty (SI1), which indicates the company's ability to retain its customer base and highlights the increasing consumers' attention on social and ethical policies; (2) Brand interaction (SI2), which measures the company's ability to be close to its consumer and develop interactions during all life-cycle stages; and (3) Product transparency (SI3), which represents the company's attention to making the flow of information related to the production, transportation, and procurement highly transparent and available for consultation during the purchasing and consumption phases. Results show that one factor, whose associated eigenvalue is 1.938, can explain 64.609% of the variance. Therefore, these measures form our third block that links to Social Interactions. We excluded from this construct "supply chain visibility" because of its low loading. This is possibly linked to the difficulties that firms encounter when building visibility to extend targets of loyalty, interactions, and transparency throughout the SC (Table 2).

4.2 | Step 2: EFA on CSR and digital technologies

Upon obtaining the three factors of economic performance, environmental attitudes, and social interactions, we run a second-order factor analysis to identify the Corporate Social Responsibility (CSR) component. We compute the scores associated with each of the three performance-related constructs and run an Explorative Factor Analysis. The latter includes both the CSR and digital technologies. For these two constructs, there is no further second order factor to be analyzed; therefore, we proceed by a traditional Explorative Factor Analysis through a Principal Component Analysis to check for unidimensionality, as displayed in Table 3.

Then, we create the construct of digital technologies by asking the question: "In the last two years, our company invested in the

TABLE 3 Exploratory factor analysis

	CSR	Digital technologies
Economic performance	0.812	
Environmental initiatives	0.810	
Social interactions	0.696	
Artificial intelligence		0.842
IoT sensors		0.752
Big data analytics		0.717
Intelligent transport systems		0.693
Cronbach's alpha	0.826	0.851

TABLE 2 Loadings of the first-order factors

Economic perf.		Environmental initiatives		Social interactions	
Items	Loadings	Items	Loadings	Items	Loadings
ROI	0.773	Identification of green suppliers	0.887	Loyalty	0.868
Profits	0.707	Environmental restrictions	0.864	Brand interaction	0.862
Market share	0.693	Environmental impact	0.637	Product transparency	0.695
Cost savings	0.613	*Remanufacturing and refurbishing*	*0.335*	*Supply chain visibility*	*0.353*
Cost for energy	*0.231*[a]	*Delivery risks*	*0.388*		
Cronbach's alpha = 0.822		Cronbach's alpha = 0.814		Cronbach's alpha = 0.809	

[a]Italic vales are not significant.

following digital technologies…". Therefore, the construct indicates the level of investments in digital technologies and is measured by the following items: artificial intelligence (DT1) and machine learning (DT3), which inform on firms' capacity to learn autonomously from data analysis and situations and improve forecasting, warehouse management, production processes, and security; the technology IoT sensors (DT2), which entails an efficient data collection and exploits it to improve performance; and the Intelligent transportation system (DT4), which indicates the development and implementation of innovative management systems aimed at optimizing transport efficiency. The technology of 3D printing (DT5) allows firms to use the Additive Manufacturing system to make highly customize products using efficient technology, and integrate it with Robotics (DT6) to achieve high levels of efficiency.

The statistical results show that one factor exists for CSR, with an associated eigenvalue of 1.809 and explaining 60% of the variance. Instead, the second eigenvalue scores 0.4, highlighting the existence of unidimensionality. Accordingly, our results show that the CSR is mainly driven by economic outcomes, since economic performance has a loading of 0.812. In contrast, environmental attitudes (EP) and social interactions (SP) have 0.810 and 0.696 values, respectively, meaning that firms put on the top of their targets economic performance, then environmental sphere, and lastly social pillars. Clearly, great economic outcomes serve as a driver to achieve other targets in a sustainable way, as being green and socially responsible is costly.

Regarding the construct Digital Technologies, the Factor Analysis suggests removing 3D printing and Robotics from the component. This is probably linked to the use of these digital technologies in manufacturing activities, while the sample includes firms belonging to other types of activities as well. Hence, our analysis gives one factor, with an Eigenvalue of 2.485 which explains 49.498% of the variance. Accordingly, investments in digital technologies are mainly aimed at AI technologies (loading of 0.842) and IoT sensors (loading of 0.752), followed by Machine Learning (loading of 0.717) and Intelligent Transport Systems (loading of 0.693).

4.3 | Step 3: Digital technologies and CSR—model selection

After finding unidimensionality of digital technologies and CSR in Step 2, we use the related scores obtained by XL-Stat 2021.2.1 to investigate their relationships. Therefore, we run a set of regression analyses to investigate H_1, that is, the impact of digital technology adoption on CSR, where CSR is the dependent variable and digital technologies is the independent variables. In this phase, we cannot really assume any specific type of relationship between digital technologies and CSR, since it can be either linear or non-linear. Hence, instead of assuming a certain relationship, we run a batch of regression analyses composed of a linear regression analysis as well as a set of non-linear regression analysis to search for the best model to explain CSR through digital technologies. All results that we obtain are displayed in Table 4.

We develop our analysis evaluating the Mean Square Error (MSE) and the Akaike information criterion (AIC), which are qualified indicators to compare regression models according to the same dependent variable when non-linear relationships exist. MSE informs on how well the line generated from the developed model fits the data. Instead, AIC evaluates how well a model fits the data it is derived from. Finally, considering that both indicators should be minimized, the linear regression model works better than the others. In fact, the MSE is the lowest, indicating that the linear model implies low errors; furthermore, the AIC indicates that the linear model is more informative than the other models.

In fact, among the proposed models and according to the lower and the upper bounds, the non-linear models result in non-significant coefficient in most of the cases, while the linear model offers $\beta = 0.497$, which is significant with p-value < 0.01. Therefore, we conclude that the linear model induces the best fit between CSR and digital technologies, resulting in an $R^2 = 0.309$.

In greater detail, the relationship between CSR and digital technologies can be exemplified by the regression equation CSR $= 0.497 \times$ Digital Technologies, highlighting that H_1 is supported. Accordingly, the use of digital technologies improves CSR and gives empirical evidence to firms that responsible digitalization is a feasible target. Specifically, the implementation of a portfolio of digital technologies composed of Artificial Intelligence, IoT sensors, Machine Learning, and Intelligent Transportation Systems allows firms to positively influence CSR. Therefore, we can formulate the following proposition:

> **Proposition 1.** *A portfolio composed of digital technologies including Artificial Intelligence, IoT sensors, Machine Learning, and Intelligent Transportation Systems allows firms to achieve responsible digitalization targets by obtaining high levels of CSR, which is measured by economic performance (ROI, profits, market share, and cost savings), environmental initiatives (green suppliers and the environmental restrictions and impact), and social interactions (brand loyalty, contact points, and product transparency).*

4.4 | Step 4: Moderator effects of green practices

After identifying the best fit between digital technologies and CSR, we run some further regression analyses using the six moderating variables representing the adoption of specific green practices: *investment in green process innovation, use of green packaging, use of recycled materials, adoption of safety risk procedures, implementation of circular economy systems, and adoption of energy efficient solutions*. For these items, we asked to the interviewees the following question: "In the last two years, our company has adopted the following green practices:", and the items were measured through a "Yes" or "No" answer. According to the outcomes obtained in Step 3, we refer to a linear model to check for moderating relationships. The motivation for using these moderators relies on the investigation of whether the adoption

TABLE 4 Selection of the regression model

Model	Equation	Coefficients	Lower and upper bounds	MSE	AIC
Linear	$CSR=\alpha+\beta\,Dig.Tech.+\varepsilon$	$\alpha=0$ $\beta=0.497$**	{−0.113, 0.113} {0.277, 0.553}	0.519	−100.452
Exponential	$CSR=\beta_1\,e^{\beta_2 Dig.Tech.}+\varepsilon$	*$\beta_1=-0.047$* $\beta_2=-1.458$*	{−0.153, 0.059} {−2.717, −1.98}	0.616	71.687
Logistics growth	$CSR=\frac{\beta_1\beta_2}{\beta_1\beta_2 e^{\beta_3 Dig.Tech}+\beta_2}$	*$\beta_1=-170.25$* *$\beta_2=-0.046$* *$\beta_3=-1.4567$*	{−0.198.2205.33} {−0.202, −0.109} {−5.505, 2.191}	0.620	−69.68
Quadratic	$CSR=\beta_1 Dig.Tech.^2$	*$\beta_1=0.021$*	{−0. 080, 0.121}	0.662	−61.610
Exponential growth	$CSR=\frac{\beta_1\beta_2}{\beta_1\beta_2 e^{\beta_3 Dig.Tech}+\beta_2}$	*$\beta_1=-170.25$*	{−0.198.2205.33} {−0.202, −0.109}	0.616	−71.64
Power	$CSR=Dig.Tech.^{\beta_1}$	$\beta_1=0$	The algorithm does not converge		

Note: Italic values are not significant.
**p*-value < 0.05; ***p*-value < 0.01.

TABLE 5 Results on H_2

	Green process innovation (H_{2a})	Energy efficient solutions (H_{2b})	Use of recycled material (H_{2c})	Green packaging (H_{2d})	Circular economy (H_{2e})	Safety risks (H_{2f})
CSR × moderator	0.575**	0.505*	0.643**	0.602**	0.468**	0.426**
Main effect of the moderator	*0. 069*	*0.075*	*0.051*	*−0.033*	*0.098*	*−0.077*
Results of H_2 and related t-test	*Supported with z-value = 3.994*	*Supported with z-value = 3.885*	*Supported with z-value = 8.374*	*Supported with z-value = 6. 095*	*Not supported with z-value = 0.126*	*Not supported with z-value = 1.222*

Note: Italic values are not significant.
**p*-value < 0.05; ***p*-value < 0.01.

of green practices can improve the impact of digital technologies on CSR. Therefore, we seek to identify the green practices through which firms can improve their responsible digitalization attitudes. Hence, we seek to consider the joint effect of digital technologies with green practices and check whether the beta-coefficient of the linear regression becomes significantly greater than 0.497, resulting from the presentation of results in Table 5. Hereby, each regression model takes the general form CSR = $\alpha+\beta\times$ digital technologies $\times$ moderator $+\gamma\times$ moderator $+\varepsilon$, with α being the linear coefficient of the regression line, β being the joint coefficient for digital technologies and the moderator, γ being the coefficient for the moderator, and ε being the error.

To check for the differences in the regression outcomes, we run a *z*-test. According to Clogg et al. (1995), the coefficients resulting from two regression models can be compared by computing the test: $z=\frac{\beta_{model1}-\beta_{model2}}{\sqrt{\sigma^2_{model1}+\sigma^2_{model2}}}$, where *z*-value > 1.645 show a significant difference between the regression coefficients, corresponding to a *p*-value < 0.05.

We display the results of the moderator analysis in Table 5. Hypothesis H_{2a}, whose moderating variable is the presence of green process innovations, is supported, since the regression coefficient $\beta=0.575$ (*p*-value < 0.01) turns out to be higher than the original proposed model with *z*-value = 3.994. Accordingly, firms can exploit the synergies existing between digital technologies and green process innovation to achieve higher levels of CSR. Investing in digital technologies can supply key driving information to pursue CSR. For example, an AI system can identify the source of pollution within a production process and suggest the actions to undertake. Furthermore, IoT sensors can detect increasing temperature levels requiring increasing energy consumption. These cases call for investment in process innovations to mitigate the environmental inefficiency, thus enabling firms to achieve responsible digitalization by corroborating the strengths of digital technologies with green process innovation to leverage their CSR levels.

Along with green process innovation, firms can rely on the adoption of energy-efficient solutions to improve the impact of digital technologies on CSR. Hypothesis H_{2b} is supported with $\beta=0.505$ (*p*-value < 0.01), which is corroborated by a *z*-value = 3.885. The latter indicates that the use of energy-efficient solutions enables firms to target responsible digitalization. While digital technologies provide the opportunity to create business and orientation toward CSR, they also require a huge amount of energy to operate. The current worldwide infrastructures cannot support the entire complexity linked to AI systems, given that the amount of energy requested is huge, and most of the consumption comes from traditional fossil fuel, thereby generating significant ecological problems. In the future, the transition to more efficient infrastructures will certainly speed up the adoption of AI systems, leading to a cleaner digital environment. Similarly, the use of Big Data requires data centers to consume around 200 terawatt-hours annually, which represents more than the energy consumption of some countries (e.g., Argentina, Ukraine, Thailand), half of the electricity used for transport worldwide, and around 1% of the global electricity demand (Lovell, 2018). The adoption of energy-efficient solutions from this perspective thus illustrates an urgent need. Therefore, companies can achieve high levels of CSR when digital technologies are supported through energy-efficiency solutions.

This result is also confirmed by the use recycling materials, which still acts within the production system to enable efficient production. When implementing digital technologies, the use of recycling brings value to this relationship. In fact, H_{2c} is supported with $\beta = 0.643$, *p*-value < 0.01, which gives a *z*-value $= 8.374$. Therefore, recycling material exerts a boosting effect on digital technologies, through which firms have higher changes to perform CSR. Big data can be used to better sort solid waste, resulting in a cheaper and safer recycling process. When applied to production, data can be collected and processed when associated with the patterns, textures, and even brand logos of the material. Artificial intelligence systems and Intelligent Transport Management Systems can use the outcomes from Big Data to identify the regions and rural areas where the recycling material come from and better forecast the amount of recycling material to manage. All of these chances become real when digital technologies are integrated with the use of recycling material, leading to a fair opportunity to perform CSR.

Our empirical analysis shows that Hypothesis H_{2d}, which links to the adoption of green packaging, is supported with $\beta = 0.602$ (*p*-value < 0.01), corresponding to a *z*-value $= 6.095$. Accordingly, the adoption of digital technologies, complemented by the use of green packaging, allows firms to perform in terms of economic pillars, environmental attitudes, and social interactions. For example, the use of Intelligent Transportation Systems, which generally help in planning, executing, and optimizing the physical movements of goods, is highly challenged by the waste created when handling packaging. Instead, the adoption of green packaging removes some of the inefficiencies and the risks linked to logistics. Furthermore, the use of smart sensors applied to recycling packaging leads firms to the implementation of the Internet of Packaging, which allows all stakeholders involved in managing the recycling process to obtain recycling instructions and clear information. Digital technologies applied to recycling packaging further facilitate responsible digitalization, which is exemplified by an increased capacity to achieve CSR goals.

Finally, two of our hypotheses do not reach statistical support. The first hypothesis, H_{2e}, refers to the *return management procedures* that shows a coefficient of $\beta = 0.468$ (*p*-value < 0.01) that, although significant, shows an insignificant improvement with respect to the original coefficient (the *z*-test gives a *z*-value $= 0.126$). Consequently, the effects of AI systems, Intelligent Transportation, IoT, and Big Data on CSR cannot be powered by a circular economy system. This is probably due to the definition of CSR that we have given in this research, which lacks a direct link to circular economy features like recycling, reverse logistics, collectors' incentives, and return rates. Similarly, the second hypothesis that is not supported, H_{2f}, links to *the adoption of safety risk procedures*. Although it gives a significant coefficient $\beta = 0.426$ (*p*-value < 0.01), it is not statistically different from the original coefficient (*z*-test gives a *z*-value $= 1.222$). This result suggests that the adoption of safety risks procedures is independent of the adoption of digital technologies and should always be ensured. In fact, firms should have in place protocols and procedures to identify, assess, analyze, communicate, correct, and mitigate the risks associated with the entire organization.

Proposition 2. *When firms target CSR, a portfolio composed of digital technologies including Artificial Intelligence, IoT sensors, Big data, and Intelligent Transportation Systems can achieve higher levels of responsible digitalization when adopting green process innovations, green packaging, recycling materials, and energy-efficient solutions*.

5 | CONCLUSIONS

In this paper, we develop a theoretical framework to enrich the literature of a new concept, namely, responsible digitalization. To our knowledge, this is the first paper that deals with this concept from both a theoretical point of view and an empirical point of view. In fact, responsible digitalization has been coined by De Giovanni (2021) and analyzed using a game theory approach; here, the concept finds application in a specific research setting linked to the game structure using Artificial Intelligence, emissions, and profits as main ingredients. Instead, this paper brings the concept of responsible digitalization to another level, in which the batch of digital technologies investigated is much wider, the set environmental practices is very broad, and the focus is on CSR. Therefore, this research aims at creating knowledge around the concept of responsible digitalization by taking both a theoretical approach and an empirical approach.

From a theoretical approach point of view, the study contributes to the analysis of CSR as a second-order factor in which the TBL pillars given by economic, environmental, and social components are first studied separately and independently and then put all together to investigate the CSR. The development of a second-order factor is necessary in the domain of CSR since it is well documented that the TBL can often be in a trade-off. For example, the development of green chemicals to get rid of industrial waste turns out to be considerably effective from an environmental perspective while bringing important challenges from an economic point of view due to the technology immaturity and its expensive implementation. Hence, rather than struggling to find (ineffective or partial) measures to directly observe CSR, we develop a theoretical framework to study CSR as a second-order factor that carries out a comprehensive meaning as being composed of the TBL. Hence, firms, supply chains, governments, and policy makers can use the approach suggested in this research to comprehensively study CSR.

Afterwards, we enrich the theoretical framework by searching for digital technologies aiming at the CSR and leading to responsible digitalization. This search is justified by the challenging trade-offs emerging from the digital transformation. For example, the use of Big Data requires a heavy consumption of energy; therefore, along with the well-document benefits, there are unwanted consequences leading to worse environmental performance. Similarly, the adoption of Intelligent Transportation Systems induces several opportunities in terms of risk reduction, efficiency, and effectiveness; however, it decreases the job opportunities for logistics operators, consequently harming the social sphere. Therefore, firms, supply chains, governments, and policy makers should take into consideration the possible impacts that digital technologies can have on CSR before diving into their implementation. This would lead them to target responsible digitalization.

Finally, we suggest a theoretical framework that considers, along with investments in digitalization, also investments in green practices. If, as earlier mentioned, the digital technologies can have some side effects on CSR, the adoption of green practices can mitigate such effect and lead to responsible digitalization. In such a case, being conscious of the implications of digital technologies, the adoption of green practices can support the transition to a more responsible digitalization process. Therefore, firms, supply chains, governments, and policy makers should be aware of the challenges that digital transformation can entail and make use of green practices to mitigate possible unwanted effects.

In addition to providing a theoretical framework, we also seek to test it using an empirical approach. Therefore, we pursue an empirical analysis composed of four steps: First, we measure the TBL pillars to search for their isolated effects; second, we use the TBL to measure the CSR, which becomes a second-order factor; third, we explore the link between digital technologies and CSR to identify the type of existing relationships leading to responsible digitalization; finally, we check whether the adoption of some green practices can boost the opportunities for firms to set responsible digitalization goals.

Our findings suggest that CSR is a multidimensional component made of economic performance, environmental attitudes, and social intentions. Then, a portfolio of digital technologies composed of Artificial Intelligence, Big Data Analytics, Intelligent Transport Systems, and IoT allows firms to achieve responsible digitalization. Among the constellation of models we have investigated, we identify a linear relationship existing among the digital technologies and CSR, which leads to responsible digitalization. Finally, we observe that green packaging, recycling material, energy efficient solutions, and green process innovation are effective green practices to improve the transition toward responsible digitalization.

Our work has several limitations that can be seen as opportunities to explore future research in the same domain. First of all, we developed a theoretical framework and then we tested it using a sample composed of 157 firms. Indeed, other samples can be used in the future to check the validity of these findings, which can be either based on a single sector or on a single country. Furthermore, we have focused our interests on a few digital technologies, while the panorama of technologies available is rich with opportunity. Hence, future research can develop alternative portfolios of digital technologies and check the attitude toward performing responsible digitalization. Similarly, we have taken a certain number of items to measure CSR, reaching 60% of the explained variance. This implies that other items should be considered to explain higher variance. Future research can investigate these directions to improve the body of knowledge in this domain. We focused on environmental-based moderators. However, other types of moderators can be used in the future, like coordination, innovation, supply chain collaboration, quality management, and incentives for sustainable initiatives. It would be interesting to analyze the concept of responsible digitalization in a dynamic manner; the application of dynamic models and approaches will determine how responsible digitalization evolves over time and how one can improve its path. This is a current investigation that the authors are pursuing.

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