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Smart technologies and corporate sustainability: The mediation effect of corporate sustainability strategy

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ABSTRACT

The focus of this paper is on the relation between smart technologies and corporate sustainability. Specifically, the purpose of this paper is to empirically examine the mediating role of corporate sustainability strategy between smart technologies and corporate sustainability. By building on a survey of 280 SMEs, the results show that corporate sustainability strategy fully mediates the relation between smart technologies and environmental sustainability, and smart technologies and social sustainability. Moreover, smart technologies have a direct significant influence on economic sustainability, but the relationship is also partly mediated by corporate sustainability strategy. Smart technologies do not have a direct influence on environmental or social sustainability.

1. Introduction

Smart technologies increasingly derive utility from the functional relations they maintain, and potential benefits are indicated by the growing prospects of combining software and software parts and mixing content across infrastructures, production systems, and platforms [1–7]. Manufacturing is going smart, and firms are progressively utilizing wireless technologies and sensors to seize data at multiple phases of a product's lifecycle [8]. Smart technologies that make physical products addressable, programmable, communicable, sensible, traceable, memorable, and associable authorize novel incorporations of physical and digital proportions to generate fresh products and manufacturing [3,4]. As a continuation of rapid development of smart technologies, there is a need to examine the implications they have generated [9,10].

Regarding the development of technology, especially smart technology, many studies emphasize that the implications need to be investigated through the aspects related to environmental, social, and economical dimensions ([11,12]; Becthsis et al., 2018). However, in profit-oriented organizations, the social and environmental dimensions may be considered subsets of corporate competitive strategy [13]. As a solution, a growing number of studies suggest that companies should have corporate sustainability strategies, which intend at stabilizing the economic, social, and environmental needs of both the society and company to achieve corporate sustainability performance [14–16]. This means that corporate sustainability strategy compounds environmental and social dimensions into the process of strategic management [13]. However, there is lack of research considering the role of corporate sustainability strategy in the relation between smart technologies and corporate sustainability.

Based on the notions above, this study has the ambition to empirically examine the effect of the utilization of smart technologies on the three dimensions of corporate sustainability: environmental, social, and economical sustainability. The paper also aims to study the mediating role of corporate sustainability strategy between smart technologies and corporate sustainability. In other words, it is essential to study whether the corporate sustainability strategy can facilitate the impacts of smart technologies on corporate sustainability. The study builds on the analysis of 280 responses from a random survey of Finnish SMEs. The results show that corporate sustainability strategy completely mediates the relation between smart technologies and environmental sustainability, and smart technologies and social sustainability. Moreover, smart technologies have a direct significant influence on economic sustainability, but the relationship is also partly mediated by corporate sustainability strategy. Smart technologies do not have a direct influence on environmental or social sustainability.

The remnant of this article is organized like this: First, the current understanding of smart technologies, corporate sustainability strategy, and corporate sustainability has been explored,

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and the conceptual framework for the study established. Then, the hypotheses are discussed, followed by a section on the research methodology and results. Finally, the theoretical and managerial implications of the study and avenues for further studies are proposed.

2. Conceptual framework

2.1. Smart technologies

Today, smart technologies pervade each firm's operations and change the nature of the business. For instance, firms try to provide intelligent management systems by embedding smart technologies in machines [17]. Products and services equipped with smart technologies offer novel functions that convert their designing, manufacture, delivery, and use [4]. Additionally, smart technologies provide huge potential for building new processes, experiences, organizational forms, and relationships in which radio-frequency identification (RFID) tags, digital sensors, networks, and processors create required properties related to smart technologies [17].

Yoo [3] has used the term "digitalized artifacts" to describe the necessary and desirable properties of artifacts to be digitalized. He defined seven features of digitalized artifacts, including addressability, programmability, communicability, sensibility, traceability, associability, and memorizability. Programmability is the first characteristic of digitalized artifacts, meaning that the devices should have the capability to accept new reconfigurations or changes of their functions. The second characteristic is addressability, which refers to the devices' ability to answer messages individually. The next characteristic is sensibility, which enables devices to track and react to changes in the surroundings. Communicability is another characteristic, defined as the devices' ability to send and receive messages with other devices. Memorizability is the next characteristic, defined as the devices' ability to both record and store the information that created, sensed, or communicated. Traceability is another characteristic that enables devices to chronologically recognize, memorize, and integrate incidents and totalities over time. The final characteristic is associability that provides the capacity for devices to be recognized with other totalities, such as other artifacts, places, and people. Kallinikos et al., [6] use the term "digital artifacts," and state that interactivity, editability, distributedness, and reprogrammability/openness are among the four aspects of digital artifacts. Editability refers to continuous updating of the content, items, and data, while interactivity means enabling exploitation of information using the receptive and flexible nature of the objects embedded in digital artifacts. They defined reprogrammability/openness as the ability of the digital artifacts to be accessible and modifiable, while distributedness refers to the borderless capability of digital objects.

In another study, Yoo et al. [4] refer to reprogrammability, data homogenization, and self-referential as the fundamental properties of smart technologies. Reprogrammability means that new functions or abilities can be added to the devices after they are designed or produced, while data homogenization refers to different types of digital contents (e.g., text, audio, image, and video) being stocked up, dispatched, refined, and displayed utilizing the identic digital networks and devices. Self-referential refers to the necessity of utilizing smart technology in offerings. Further, Yoo et al. [4] referred "the incorporation of digital capabilities into objects that had a purely physical materiality beforehand" as the main characteristics of pervasive digital technology. They also explained physical materiality as the tangible artifacts that are usually hard to move in terms of time and place limitations.

As discussed before, similar ideas have developed with different terminology [3,4,6,17]. Thus, in this study, smart technologies refer to the bundle of properties embedded into previously nondigital devices and enabling smartness for those devices.

2.2. Corporate sustainability

From the corporate perspective, sustainability research often adopts a systems perspective that concentrates on business-driven operations in natural systems [18]. It is widely accepted that firms, albeit, business-driven schemes, are coevolving with sundry schemes (involving the society and environment) [19]. This necessities investing in economic factors, but also in environmental and social aspects [20–24]. For example, Elkington's [25] triple bottom line approach considers the prolonged prosperity of a firm to be dependent on paying attention to three aspects of sustainability: social (social surroundings), environmental (natural surroundings), and economic. Environmental sustainability is based on the presumption that people live within the physical and biological boundaries that attend on the source of life and waste disposal [26–28]. Social sustainability adverts to accompanying social capital for example by means of participating to local communities [26]. This requires balancing human needs with economic and environmental wellbeing [29,30]. Economic sustainability concentrates on the financial value of things, including the costs of environmental effects [26]. Triple bottom line is the most prominent framework to understand the facets of sustainable development and that is why it was selected as a basis of this study. The three dimensions of triple bottom line were considered as the most essential from the perspective of corporate sustainability performance. Lozano [31] has proposed an extension to the triple bottom line by incorporating the dynamics of the three dimensions over time. This temporal dimension highlights the tension among environmental, social, and economic troubles, but also over long and short-term perspectives. We use the term "corporate sustainability" to describe the idea that, to induce sustainability in the long run, firms need to process all three dimensions that they are coevolving with: environmental, social, and economic [20,22].

2.3. Corporate sustainability strategy

Ranged sustainability and business strategies mirror the amplitude and nature of the possibilities affiliated with sustainable development as regards to the recreation of value for the company [32]. Baumgartner and Rauter [13] present that the prime justification for selecting a sustainability stance is to decrease the negative social and environmental effects of company operations, while enhancing the economical performance of the organization. Corporate sustainability strategies can be considered as strategies that point towards "balancing the social, environmental and economic needs of both the company and society" [14,15,33]. Baumgartner and Rauter [13] suggest that a corporate sustainability strategy connects environmental and social aspects into the process of strategic management and emphasizes the strategic standing of a corporation in terms of sustainable development. The unification of social and environmental factors into company mid-time and long-time visions claims that a prudent stability is reached between the requirements of external and internal stakeholders [13]. Building on the above, this study defines corporate sustainability strategy as the integration of sustainable development principles into business operations.

3. Hypotheses development

Our hypotheses are built on the following argumentation. Smart technologies reduce the need for resources (human, material, etc.) and increase the expectation for efficiency, so they are hypothesized to be a driving force for corporate sustainability

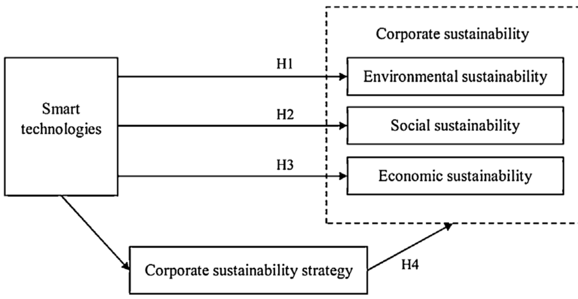

Fig. 1. Research model and hypotheses.

strategy and corporate sustainability. Corporate sustainability is examined through social, environmental and economic sustainability. The hypotheses' development is defined and discussed next (Fig. 1).

3.1. Smart technologies and environmental sustainability

Smart technologies, such as information and communication technologies, and digitalized production machines have been considered to have potential positive impacts to the environment, for example, by reducing greenhouse gas (GHG) emissions (e.g., [34,35]). In addition to the reduction of GHGs, smart technologies currently provide possibilities for intelligent and automated solutions and production optimization among different industries, such as manufacturing, power generation, and agriculture, thus improving energy efficiency. For example, different kinds of digital twins can produce real-time data and automatically adjust and optimize processes. Iacovidou et al. [36] present that RFID technologies can be used to support and increase the reutilization of building components and decrease their waste, thus supporting environmental sustainability achievements within the building sector. Smart technologies can also be used to support the achievement of sustainable development and environmental protection goals by supporting information flow throughout production processes. For example, Tao et al. [37] conclude that if data are gained in real time, manufacturing processes can be effectively controlled, and this may decrease the energy expenditure in public premises, production devices, and workpieces.

As such, smart technologies can be considered enablers that can reduce the energy consumption and emissions of industrial processes, electrical grids, and transportation systems [38]. Different studies have reported that smart technologies, such as digitalized manufacturing technologies and automatized working machines, can be an important part of the solution in dealing with current environmental challenges and issues related to climate change [38,39]. Thus, based on the evidence from previous research, the following hypothesis is presented:

H1. Smart technologies are positively related to environmental sustainability.

3.2. Smart technologies and social sustainability

It is suggested that the growing prospects of combining software and software parts and mixing content across infrastructures, production systems, and platforms increasingly derive utility from the functional relations they maintain [1–4,6]. Social sustainability is one of the most important perspectives when considering the benefits and impacts of these smart technologies [11,40]. Chen et al. [11] studied the incorporation of production technology and product modeling that straightly transforms digital patterns to physical affairs without the demand for tooling, suggesting social sustainability outcomes such as: equivalent opportunities to all parties in societies and markets, user-oriented goods and services, enhanced customer value, possible advantages for worker/human health, and influence on an industry's working situation. Further, Bechtsis et al. [40] studied intelligent, self-governing vehicles in digital supply chains, suggesting that, considering the social sustainability, employee accessibility and safety, together with safety and health of the conveyors, is dominant. Furthermore, they highlighted the ongoing recreation of proficient jobs, the sustained enhancement of ergonomics for the workforce, the recognition of possibilities for sensors' applicability to upgrade work safety, and the enactment of objects for tracking and estimating possible dangers.

Summarizing this, smart technologies seem to have implications for social sustainability in terms of increasing safety [40] and employment [11]. Thus, the evidence from prior studies supports the formation of the following hypothesis:

H2. Smart technologies are positively related to social sustainability.

3.3. Smart technologies and economic sustainability

Bekaroo et al. [34] present that, so far, scholars have shown that main drivers for sustainability using smart technologies usually include an economic expectation to improve efficiency. Issues related to climate change and growing environmental worries are changing the form of operations and organizations in the energy sector [41]. Further, the power-saving features of current smart technologies can help reduce cooling burdens by decreasing the quantity of heat produced to deliver a more effective economic benefit [34]. Technological development and new types of smart technologies can offer inferior cost structures and opportunities for reaching the goals of different sustainability aspects (Costa-Campi, 2018). In addition to the possibilities of economic sustainability in the energy sector, current and emerging smart technologies also provide possibilities for economic sustainability among many other industries. Automated and digitalized energy-efficient smart technologies and different resource-saving technologies and processes can reduce costs and, thus, improve the productivity of organizations among different industries [42]. Smart technologies assist in optimizing production processes and the entire life cycle of products. Thus, smart technologies provide greater benefits for the state of the workforce, the site and organization of lots, and the state of manufacturing machinery [43]. Further, self-organizing production, predictive and cooperative maintenance, efficient transport planning, as well as accurate classification of retirement and disposal decisions, can increase economic returns from smart technologies [37,43].

Based on the above, by digitalizing traditional manufacturing environments, smart technologies can be used to increase productivity, speed, quality, and the safety of operations aiming to increase economic sustainability (e.g., [44]). Thus, based on the evidence from previous research, the following hypothesis is presented:

H3. Smart technologies are positively related to economic sustainability.

3.4. Corporate sustainability strategy as a mediator

Demands for cleaner production have increased because of issues related to environmental, social, and economic sustainability. Referring to Caputo et al. [45], to achieve sustainability, research on both structural and dynamic dimensions must be conducted. The structural dimensions refer to the existence of resources and feasible strategic pathways, while the second dimension is the way of managing those resources and the pathway according to sustainable strategy. In their research, they also refer to the being of a solid relationship between sustainability and smartness. They mentioned that, to clarify the presence of this relationship, there is a need for the precise definition of emerging and evolving this relationship over time. Despite the fact that cleaner production strategy provides huge potential for environmental, social, and economic benefits, many difficulties and barriers (e.g., absence of sufficient awareness about cleaner technologies, shortage of enough tools and information, and weak communication schemes) [46,47] need to be overcome.

As one of the main characteristics of smart technologies is being present at any time, they are always threatened by certain risks, such as being lost, hardware crash, or other accident. Consequently, sustainability of smart technology can be mentioned as one of the ideal approaches to reducing the number of the above-mentioned risks [48]. Additionally, the way that knowledge is collected, distributed, and exploited with technologies can be considered as the most important issues in achieving sustainability [39]. According to Stuermer et al. [48], full exploitation of sustainability needs sustainability of smart technologies. Thus, smart technologies can be considered the means to sustainability.

Based on Caputo et al. [45], smart technologies support the definition by clarifying more efficient, effective, and sustainable pathways. Besides, they address the interlinkage between smartness and sustainability, leading to new insights. Thus, in light of sustainability science, the effective approach toward smartness will be achieved based on building a collaborative approach among the actors involved. Similarly, Maher et al. [49] refer to the way digital tools can help tackle sustainability issues by making progress in ways of thinking, communicating, and collaborating. In their research, they refer to the need for a synergy map to develop sustainability. In this synergy map, they refer to finding the linkage between key issues of sustainability, identifying devices to tackle these issues, the relationship between these devices, and they underline the potential for adding digital artifacts to these devices. In this regard, Romanelli's [50] reference to building sustainable value using technology depends heavily on cooperation and collaboration within the ecosystem and named governments, businesses, and communities as the key actors and enablers of value. Furthermore, he refers to the impact of utilizing technology in knowledge creation to sustain development in the long term. Thus, constituting a corporate sustainability strategy that integrates sustainability with business operations plays an important role between smart technologies and the achievement of sustainability.

To sum up, smart technologies can be considered the bundle of properties that are embedded into previously nondigital devices and enable smartness for those devices. To provide benefits from smart technologies, there is a need for corporate sustainability strategy, which will fuel corporate sustainability in three dimensions (environmental, social, economic). Therefore, smart technologies enable corporate sustainability strategy, which fuels corporate sustainability in all three dimensions (social, environmental, and economic) (cf. [51]). Therefore, based on the beyond-mentioned evidence, the last hypotheses formed is as follows:

H4. Corporate sustainability strategy mediates the positive relation between smart technologies and corporate sustainability.

H4a. Corporate sustainability strategy mediates the positive relation between smart technologies and environmental sustainability.

H4b. Corporate sustainability strategy mediates the positive relation between smart technologies and social sustainability.

H4c. Corporate sustainability strategy mediates the positive relation between smart technologies and economic sustainability.

4. Methodology

4.1. Sample and data collection

The sample of the research includes Finnish firms with 20–250 employees. According to the database, the population comprised approximately 20,000 firms. A population of 6816 firms was randomly selected. Among the 6816 SMEs, 986 had invalid contact information; thus, the survey was conducted with 5830 firms. Therefore, the sample represents approximately 30% of the entire population of Finnish firms that met the criteria. The decision of working with a sample of firms with more than 20 employees is based on the idea that microfirms usually do not have the opportunity to concentrate on sustainability, as they have fewer financial resources and knowledge.

To collect data, a structured questionnaire was created, and a direct link was sent to the respondents by e-mail. The questionnaire was aimed at the top managers of the firms, as they have a general vision of the topics of this study. In the end, 280 valid questionnaires were obtained. Approximately 70% of the responses came from small companies, and approximately 30% came from medium-size companies. Further, 81.8% of the companies were established more than 15 years ago. About 57.1% of the respondents were from service-oriented firms, whereas 42.1% were from manufacturing firms.

Non-response bias was assessed by testing for differences between early respondents and late respondents on study items (independent, mediation, and dependent variables). Early respondents responded within a reasonable period after receiving the first e-mail. Late respondents were those who responded after several reminders. Late respondents most precisely reminded non-respondents (Armstrong and Overton, 1977). Both tests on the means of the constructs, as well as on the means of each of the items, revealed no statistically significant differences (at significance level 5%). Thereby, non-response bias did not cause any problems.

Several practices were used to diminish a common method bias (Podsakoff et al., 2003). First, every questionnaire item was informed by previous studies, and scales were informed by expert views to decrease item obscurity. Second, a letter of invitation ensured confidentiality to decrease social desirability bias. In addition, Harman's single factor test was used to explore for common method bias (Podsakoff et al., 2003). The exploratory factor analysis of all items displayed more than single factor with eigenvalues higher than 1.0, proposing that common method bias does not exist.

4.2. Measures

This study utilized a managerial assessment of the utilization of smart technologies, as well as the state of sustainability strategy, and corporate sustainability in the respondents' firms. Thus, the respondents provided evaluations of the constructs in their firms. The response to the question required adequate knowledge concerning their firm's operations. Managers were selected as respondents because they were expected to have this knowledge. The items measuring theoretical constructs were informed by literature review, but where existing items were not identified, the researchers relied on the extant literature to specify the content of each construct. Since the target firms are SMEs, the items were selected based on relevance in the SME context. Detailed description of measurement items are presented in the Appendix.

Smart technologies. This independent variable is a multidimensional construct, and we used a six-item measure that has been previously used (in [3]) to assess smart technologies. The respondents were requested to express the degree to which they agreed with the consequent statements: “In our company, all the devices are programmable,” “In our company, all the devices are able to be uniquely identified,” “In our company, all the devices are aware of the respond to changes in their environment,” “In our company, all the devices can send and receive messages,” “In our company, all the devices can record and store all information,” and “In our company, all the devices can be identified with other devices, places, or people.” The respondents were asked to choose a number from 1 to 7 (from (1) strongly disagree to (7) strongly agree). Cronbach’s alpha of the construct is 0.945, which exceeded the recommended threshold of 0.7 [52].

Sustainability strategy. The mediating variable, sustainability strategy, was measured by the following: “what is your company̓s ability to integrate sustainable development principles into business operations over the last three years”. The respondents were asked to choose a number from 1 to 4 (1=weak, 2=satisfactory, 3=good, 4=excellent).

Corporate sustainability. Three widely accepted dimensions measured the dependent variable: environmental sustainability, social sustainability, and economic sustainability. The respondents were asked to assess the following over the last three years: environmental sustainability, social sustainability, and economic sustainability. The items were as follows: “what is the state of your company̓s environmental sustainability (ability to take into account and reduce the environmental impact of the activity) over the last three years”, “what is the state of your company̓s social sustainability (ability to promote health, safety, and well-being) over the last three years”, and “what is the state of your company̓s economic sustainability (ability to ensure the long-term economic balance of the company) over the last three years”. The respondents were asked to choose a number from 1 to 4 (1=weak, 2=satisfactory, 3=good, 4=excellent).

Single-item measures have started to suffer puzzles with their validity and reliability (Sarstedt and Wilczynski, 2009; Diamantopoulos et al., 2012). However, they are acceptable with some limitations: if the empirical setting contains concrete singular objects (Bergkvist and Rossiter, 2007, 2009), if the objects are homogenous (Loo, 2002), and if the objects are unequivocal to the respondent (Sackett and Larson, 1990). These terms are met in this study.

The control variables—company size, age, and industry—were included, as they are considered the determinants of sustainability. Company size was estimated as the amount of employees in the company. Company age was computed as the amount of years since its foundation. Industry was controlled by using a dummy variable according to the value of “1″ if the firm operated in a manufacturing sector.

5. Results

The validity and reliability of the variables were investigated past to hypothesis testing, and this examination was presented in the methodology section. Table 1 presents the correlations for the smart technologies, sustainability strategy, and corporate sustainability. The Table 1 demonstrates significant correlations along with the variables throughout. These results express a relationship between the study variables. To test the possibility of multicollinearity, the variance inflation factors were computed. They were below the cutoff value of 10 and, therefore, multicollinearity did not cause problems.

Table 2 shows the results of the regression analysis for the relationship between smart technologies and corporate sustainability. The significance of the F-value determines whether the model in question supports the hypothesis. Moreover, the coefficient of determination, noted as R^2, measures the power of the regression model. According to Hair et al. [52], there is interplay between the sample size and number of independent variables in detecting a significant minimum value of R^2. Based on the sample size ($N = 280$) and number of independent variables ($IV = 1$) in this study, the R^2 values of 3% and greater have been detected. Model 1 includes the effect of smart technologies on the environmental dimension of corporate sustainability. The model is significant, but only industry explains the variance in environmental sustainability. Thus, environmental sustainability is considered better in service-oriented firms than in manufacturing-oriented firms. Model 2 includes the effect of smart technologies on the social dimension of corporate sustainability. Model 2 is not significant. Model 3 is significant, and the results indicate a positive relation between the smart technologies and economic dimension of corporate sustainability. The results show that smart technologies positively and significantly influence only one dimension of corporate sustainability, economic sustainability, supporting Hypothesis H3. However, contrary to our expectations, no significant results were found regarding the link between smart technologies and two dimensions of corporate sustainability: environmental and social. Thus, our findings provide no support for H1 or H2. Finally, model 4 includes the effect of smart technologies on the mediating variable, sustainability strategy. As Table 2 shows, model 4 is significant, and smart technologies explain the variance in sustainability strategy. The model also shows that firm age is positively related to sustainability strategy. To sum up, the results from the analyses show that smart technologies are directly connected with the economic dimension of corporate sustainability, but not the environmental and social dimensions of corporate sustainability.

Hypothesis 4 proposed that corporate sustainability strategy mediates the relationship between smart technologies and corporate sustainability. This mediation was tested by using the Baron and Kenny (1986) procedure. This procedure includes three steps. First, a regression analysis between the independent variable and dependent variables is conducted. Second, the effect of independent variable on the mediator is determined. These analyses are presented in Table 2 when testing for H1-H3. Finally, a regression analysis is conducted with all the variables, and these results are presented in Table 3. Based on Zhao et al. (2010), the model has full mediation if there is a significant mediated effect but no significant direct connection between the independent

Table 1
Mean values, standard deviations, and correlations among the variables.

	Mean	Std. Dev.	1	2	3	4	5
1 Smart technologies	3,7574	1,64131	1000				
2 Sustainability strategy	2,52	,734	,083	1000			
3 Environmental sustainability	2,70	,691	,012	,680***	1000		
4 Social sustainability	2,90	,641	,095	,426***	,433***	1000	
5 Economical sustainability	2,86	,793	,152*	,167**	,149*	,230***	1000

Sign. *** $\leq$ 0.001, ** 0.001 < p $\leq$ 0.01, * 0.01 < p $\leq$ 0.05.

Table 2
Regression results for direct effects.

Models	β	SE	St. β	t	R	R^2	Adj. R^2	SE	F
Dependent: Environmental sustainability									
1. (Constant)	3,056	,180		16,965	,194	,038	,023	,682	2,611*
No of employees	-,001	,001	-,050	-,817					
Firm age	,000	,002	,017	,268					
Industry	-,269	,087	-,193	−3,113**					
Smart technologies	,024	,026	,056	,891					
Dependent: Social sustainability									
2. (Constant)	2,832	,170		16,688	,128	,016	,002	,642	1,118
No of employees	,001	,001	,050	,808					
Firm age	,000	,002	-,005	-,086					
Type of operation	-,087	,082	-,067	−1,066					
Smart technologies	,047	,025	,120	1,892+					
Dependent: Economic sustainability									
3. (Constant)	2,536	,208		12,204	,173	,030	,015	,786	2,062+
No of employees	-,001	,001	-,065	−1,052					
Firm age	,000	,002	,014	,231					
Type of operation	,061	,100	,038	,612					
Smart technologies	,068	,030	,142	2,243*					
Dependent: Sustainability strategy									
4. (Constant)	2,333	,190		12,249	,185	,034	,020	,721	2,372+
No of employees	-,002	,001	-,114	−1,863					
Firm age	,004	,002	,123	1,991*					
Type of operation	-,028	,092	-,019	-,307					
Smart technologies	,051	,028	,116	1,839+					

Sign. ** $0.001 < p \leq 0.01$, * $0.01 < p \leq 0.05$, + $0.05 < p \leq 0.1$.

variable and dependent variables. If there is a direct connection between the independent variable and dependent variables but also a significant mediated effect, the mediation is partial.

Following this procedure, it was observed that smart technologies are not related to environmental sustainability (model 1) and social sustainability (model 2) but are related to economic sustainability (model 3). Second, the effect of smart technologies on sustainability strategy was examined. The results indicate that this relationship is positive and significant (model 4). Finally, the joint effects were examined. The coefficients show that the inclusion of the sustainability strategy variable in model 5 makes the relationship between smart technologies and environmental sustainability non-significant and the relationship between sustainability strategy and environmental sustainability significant. Therefore, sustainability strategy plays a full mediator role in the relationship between smart technologies and environmental sustainability, thus supporting H4a. The same procedure was followed to evaluate H4b-4c. The coefficients show that the inclusion of the sustainability strategy variable in model 6 makes the relationship between smart technologies and social sustainability non-significant and the relationship between sustainability strategy and social sustainability significant. Therefore, sustainability strategy plays a full mediator role in the relationship between smart technologies and social sustainability, thus supporting H4b. The results also show that, when including sustainability strategy and smart technologies together in model 7, the effect of smart technologies on economic sustainability continues to be significant, but sustainability strategy is also significant. This indicates partial support for H4c.

To sum up, the results suggest that corporate sustainability strategy fully mediates the relationship between smart

Table 3
Regression results for mediation effects.

Models	β	SE	St. β	t	R	R^2	Adj. R^2	SE	F
Dependent: Environmental sustainability									
5. (Constant)	1,475	,157		9,381	,729	,532	,523	,476	60,628***
No of employees	,001	,001	,032	,736					
Firm age	-,002	,001	-,072	−1,647					
Industry	-,250	,060	-,180	−4,140***					
Smart technologies	-,011	,019	-,027	-,607					
Sustainability strategy	,678	,040	,715	16,786***					
Dependent: Social sustainability									
6. (Constant)	1,938	,192		10,111	,445	,198	,183	,581	13,198***
No of employees	,002	,001	,100	1,767+					
Firm age	-,002	,001	-,059	−1,034					
Type of operation	-,076	,074	-,059	−1,032					
Smart technologies	,027	,023	,070	1,210					
Sustainability strategy	,383	,049	,434	7,780***					
Dependent: Economic sustainability									
7. (Constant)	2,160	,257		8,398	,226	,051	,033	,779	2,862*
No of employees	-,001	,001	-,047	-,771					
Firm age	,000	,002	-,004	-,072					
Type of operation	,066	,099	,041	,670					
Smart technologies	,060	,030	,124	1,973*					
Sustainability strategy	,161	,066	,148	2,431*					

Sign. *** ≤ 0.001, * $0.01 < p \leq 0.05$.

Table 4
Summary of hypothesis test results.

Hypothesis	Models	Hypothesis support
H1: Smart technologies are positively related to environmental sustainability	1	Not supported
H2: Smart technologies are positively related to social sustainability	2	Not supported
H3: Smart technologies are positively related to economic sustainability	3	Supported
H4a: Corporate sustainability strategy mediates the positive relation between smart technologies and environmental sustainability	1, 4, 5	Supported
H4b: Corporate sustainability strategy mediates the positive relation between smart technologies and social sustainability	2, 4, 6	Supported
H4c: Corporate sustainability strategy mediates the positive relation between smart technologies and economic sustainability	3, 4, 7	Supported

technologies and corporate sustainability, but only in the case of environmental sustainability and social sustainability. In the case of economic sustainability, the mediation effect is partial. Summary of hypotheses testing is presented in Table 4.

6. Discussion and conclusions

6.1. Theoretical implications

The purpose of this study was to explore the mediating role of corporate sustainability strategy between smart technologies and corporate sustainability. Smart technologies have been suggested to play a crucial role in the sustainable development of firms (e.g., [36,37,43]). Our findings add to the evidence supporting sustainability strategy as an important factor in smart technologies research. The main contributions to theory are as follows.

First, the study contributes to the literature on smart technologies [3,4,6,8,17] and their role as a driver of corporate sustainability [37,40]. As predicted, smart technologies had a direct effect on economic sustainability. Thus, the study supports the views of previous research indicating that smart technologies can reduce costs ([42]; Costa-Campi, 2018) and increase economic returns by using self-organizing production, assisting predictive and cooperative maintenance, intensifying transport planning, as well as classifying retirement and disposal decisions accurately [37,43]. This finding suggests that the smart technologies have a crucial role to play in attaining economic sustainability.

Contrary to previous research (cf. [10,11,36]), the study did not find support for the direct linkage between smart technologies and environmental and social sustainability. Previous research has indicated that smart technologies may contribute to environmental and social sustainability, for example, by decreasing energy consumption [37], and improving the safety and employment situation [11,40]. Our results show that the environmental and social returns from smart technologies are not self-evident, and smart technologies alone are not sufficient to generate environmental and social sustainability.

Second, the study adds to the evidence regarding the role of sustainability strategy in obtaining corporate sustainability [14,15,33,45,49]. Our results also indicate that corporate sustainability strategy fully mediates the effect of smart technologies on environmental sustainability. This suggests that smart technologies act on corporate sustainability by encouraging a firm to integrate sustainable development principles into business operations. In turn, corporate sustainability strategy enables the firm to increase its environmental sustainability. Similarly, the results show that the effect of smart technologies on social sustainability was fully mediated by corporate sustainability strategy. The finding suggests that implementing smart technologies increases the integration of sustainable development principles into business operations which, as above, drives increased social sustainability. Our results support the results of Caputo et al. [45] who highlight the managing corporate resources and pathway according to sustainable strategy.

6.2. Managerial implications

We entrust that this study offers novel insights for firms looking for to enhance the utilization of smart technologies in increasing corporate sustainability. The implications of these findings for managerial practice are as follows. Smart technologies can generate financial returns, but they alone are not sufficient to generate environmental and social sustainability. Instead, the influence of smart technologies on corporate sustainability is influenced by the extent of the integration of sustainable development principles into business operations. Implementing smart technologies is not in itself sufficient; rather, it is the process of integrating sustainable development principles into daily business operations that creates the returns of smart technologies in terms of corporate sustainability. Firms often prefer to implement smart technologies without integrating them into sustainable development goals. Evidence from this study suggests that smart technologies serve to improve corporate sustainability primarily because they stimulate the integration of sustainable development principles into business operations. Thus, managers need to recognize the importance of this strategy for integrating the use of smart technologies and firm-level sustainable development and ensure that the resources required to support such activities are adequate and available.

6.3. Limitations and further research directions

First, this study is cross-sectional, which limits the ability to study issues that evolve over time. Thus, our findings may be validated with additional longitudinal research. Second, geographical area of the research should be taken into account when generalizing the results. The data is also based on the self-reports of managers within the firms and, therefore, potentially subject to biases. A better assessment of the relationships between smart technologies, corporate sustainability strategy, and corporate sustainability outcomes could be gathered if additional perspectives were sought. Finally, there may be other contingency factors that affect the relationships in the model. Due to practical restrictions, the number of control variables in the survey was limited. Future research could take closer look into the context that smart technologies generate corporate sustainability.

Appendix A. Measurement items

Construct	Items
Smart technologies [3]	*Indicate the degree to which you would agree with the following statements between [1–7] (1 = Strongly disagree ; 7 = Strongly agree)* All the devices are programmable. All the devices are able to be uniquely identified. All the devices are aware of and respond to changes in their environment. All the devices can send and receive messages. All the devices can record and store all information. All the devices can identify with other devices, places, or people

(*Continued*)

Construct	Items
Sustainability strategy	*The response scale to the following items ranged 1 – 4 (1= weak, 2 = satisfactory, 3= good; 4= excellent)* What is your company's ability to integrate sustainable development principles into business operations over the last three years?
Corporate sustainability	What is the state of your company's environmental sustainability (ability to take into account and reduce the environmental impact of the activity) over the last three years? What is the state of your company's social sustainability (ability to promote health, safety, and well-being) over the last three years? What is the state of your company's economic sustainability (ability to ensure the long-term economic balance of the company) over the last three years?

References

[1] R.N. Langlois, The vanishing hand: the changing dynamics of industrial capitalism, Ind. Corp. Change 12 (2) (2003) 351–385.
[2] R. Merrifield, J. Calhoun, D. Stevens, The next revolution in productivity, Harv. Bus. Rev. 86 (6) (2008) 72–80.
[3] Y. Yoo, Computing in everyday life: a call for research on experiential computing, Mis Q. 34 (2) (2010) 213–231.
[4] Y. Yoo, O. Henfridsson, K. Lyytinen, Research commentary—the new organizing logic of digital innovation: an agenda for information systems research, Inf. Syst. Res. 21 (4) (2010) 724–735.
[5] M.G. Guillemette, G. Paré, Toward a new theory of the contribution of the IT function in organizations, Mis Q. 36 (2) (2012) 529–551.
[6] J. Kallinikos, A. Aaltonen, A. Marton, The ambivalent ontology of digital artifacts, Mis Q. 37 (2) (2013) 357–370.
[7] D. Cerri, S. Terzi, Proposal of a toolset for the improvement of industrial systems' lifecycle sustainability through the utilization of ICT technologies, Comput. Ind. 81 (2016) 47–54.
[8] A. Kusiak, Smart manufacturing must embrace big data, Nature News 544 (7648) (2017) 23.
[9] E. Ziemba, Synthetic Indexes for a Sustainable Information Society: Measuring ICT Adoption and Sustainability in Polish Enterprises. In Information Technology for Management. Ongoing Research and Development, Springer, Cham, 2017, pp. 151–169.
[10] E. Ziemba, The contribution of ICT adoption to the sustainable information society, J. Comput. Inf. Syst. 59 (2) (2019) 116–126.
[11] D. Chen, S. Heyer, S. Ibbotson, K. Salonitis, J.G. Steingrímsson, S. Thiede, Direct digital manufacturing: definition, evolution, and sustainability implications, J. Clean. Prod. 107 (2015) 615–625.
[12] L.M. Hilty, B. Aebischer, Ict for sustainability: an emerging research field, ICT Innovations for Sustainability, Springer, Cham, 2015, pp. 3–36.
[13] R.J. Baumgartner, R. Rauter, Strategic perspectives of corporate sustainability management to develop a sustainable organization, J. Clean. Prod. 140 (2017) 81–92.
[14] M.J. Epstein, M.J. Roy, Sustainability in action: identifying and measuring the key performance drivers, Long Range Plann. 34 (5) (2001) 585–604.
[15] S. Engert, R.J. Baumgartner, Corporate sustainability strategy–bridging the gap between formulation and implementation, J. Clean. Prod. 113 (2016) 822–834.
[16] C. Wijethilake, Proactive sustainability strategy and corporate sustainability performance: the mediating effect of sustainability control systems, J. Environ. Manage. 196 (2017) 569–582.
[17] Y. Yoo, R.J. Boland Jr, K. Lyytinen, A. Majchrzak, Organizing for innovation in the digitized world, Organ. Sci. 23 (5) (2012) 1398–1408.
[18] P. Bansal, H.C. Song, Similar but not the same: differentiating corporate sustainability from corporate responsibility, Acad. Manag. Ann. 11 (1) (2017) 105–149.
[19] A. Rego, M.P. e Cunha, D. Polónia, Corporate sustainability: a view from the top, J. Bus. Ethics 143 (1) (2017) 133–157.
[20] M. Amini, C.C. Bienstock, Corporate sustainability: an integrative definition and framework to evaluate corporate practice and guide academic research, J. Clean. Prod. 76 (2014) 12–19.
[21] C. Leyh, M. Rossetto, M. Demez, Sustainability management and its software support in selected Italian enterprises, Comput. Ind. 65 (3) (2014) 386–392.
[22] R. Strand, Strategic leadership of corporate sustainability, J. Bus. Ethics 123 (4) (2014) 687–706.
[23] V. Mani, R. Agarwal, A. Gunasekaran, T. Papadopoulos, R. Dubey, S.J. Childe, Social sustainability in the supply chain: construct development and measurement validation, Ecol. Indic. 71 (2016) 270–279.
[24] M. Saunila, T. Rantala, J. Ukko, J. Havukainen, Why invest in green technologies? Sustainability engagement among small businesses, Technol. Anal. Strateg. Manag. (2018) 1–14.
[25] J. Elkington, Partnerships from cannibals with forks: the triple bottom line of 21st-century business, Environ. Qual. Manag. 8 (1) (1998) 37–51.
[26] R. Goodland, H. Daly, Environmental sustainability: universal and non-negotiable, Ecol. Appl. 6 (4) (1996) 1002–1017.
[27] J. Morelli, Environmental sustainability: a definition for environmental professionals, J. Environ. Sustain. 1 (1) (2011) 1–27.
[28] M. Nasiri, T. Rantala, M. Saunila, J. Ukko, H. Rantanen, Transition towards sustainable solutions: product, service, technology, and business model, Sustainability 10 (2) (2018) 358.
[29] S. Choi, A. Ng, Environmental and economic dimensions of sustainability and price effects on consumer responses, J. Bus. Ethics 104 (2) (2011) 269–282.
[30] E.A. Khan, M.N.A. Dewan, M.H. Chowdhury, Reflective or formative measurement model of sustainability factor: a three industry comparison, Corporate Ownership Control J. 12 (2) (2016) 84–94.
[31] R. Lozano, Envisioning sustainability three-dimensionally, J. Clean. Prod. 16 (17) (2008) 1838–1846.
[32] A. Lloret, Modeling corporate sustainability strategy, J. Bus. Res. 69 (2) (2016) 418–425.
[33] R.J. Baumgartner, Managing corporate sustainability and CSR: a conceptual framework combining values, strategies and instruments contributing to sustainable development, Corp. Soc. Responsib. Environ. Manage. 21 (5) (2014) 258–271.
[34] G. Bekaroo, C. Bokhoree, C. Pattinson, Impacts of ICT on the natural ecosystem: A grassroot analysis for promoting socio-environmental sustainability, Renew. Sustain. Energy Rev. 57 (2016) 1580–1595.
[35] M. Uddin, A.A. Rahman, Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics, Renew. Sustain.Energy Rev. 16 (4) (2012) 4078–4094.
[36] E. Iacovidou, P. Purnell, M.K. Lim, The use of smart technologies in enabling construction components reuse: A viable method or a problem creating solution? J. Environ. Manage. 216 (2018) 214–223.
[37] F. Tao, Y. Wang, Y. Zuo, H. Yang, M. Zhang, Internet of Things in product life-cycle energy management, J. Ind. Inf. Integr. 1 (2016) 26–39.
[38] D.A. Higón, R. Gholami, F. Shirazi, ICT and environmental sustainability: a global perspective, Telemat. Inform. 34 (2017) 85–95.
[39] S. Elliot, Transdisciplinary perspectives on environmental sustainability: a resource base and framework for IT-enabled business transformation, Mis Q. 35 (1) (2011) 197–236.
[40] D. Bechtsis, N. Tsolakis, D. Vlachos, J.S. Srai, Intelligent Autonomous Vehicles in digital supply chains: a framework for integrating innovations towards sustainable value networks, J. Clean. Prod. 181 (2018) 60–71.
[41] M. Costa-Campi, T. Jamasb, E. Trujillo-Baute, Economic analysis of recent energy challenges: technologies, markets, and policies, Energy Policy 118 (2018) 584–587.
[42] M. Jänicke, "Green growth": from a growing eco-industry to economic sustainability, Energy Policy 48 (2012) 13–21.
[43] D. Bandyopadhyay, J. Sen, Internet of things: applications and challenges in technology and standardization, Wirel. Pers. Commun. 58 (1) (2011) 49–69.
[44] A. Gunasekaran, N. Subramanian, Y. Yusuf, Strategies and practices for inclusive manufacturing: twenty-first-century sustainable manufacturing competitiveness, Int. J. Comput. Integr. Manuf. 31 (6) (2018) 490–493.
[45] F. Caputo, B. Buhnova, L. Walletzký, Investigating the role of smartness for sustainability: insights from the Smart Grid domain, Sustain. Sci. (2018) 1–11.
[46] J.L. Murillo-Luna, C. Garces-Ayerbe, P. Rivera-Torres, Barriers to the adoption of proactive environmental strategies, J. Clean. Prod. 19 (13) (2011) 1417–1425.
[47] B. Donnellan, C. Sheridan, E. Curry, A capability maturity framework for sustainable information and communication technology, IT Prof. 13 (1) (2011) 33–40.
[48] M. Stuermer, G. Abu-Tayeh, T. Myrach, Digital sustainability: basic conditions for sustainable digital artifacts and their ecosystems, Sustain. Sci. 12 (2) (2017) 247–262.
[49] R. Maher, M. Maher, C.A. McAlpine, S. Mann, L. Seabrook, Overcoming barriers to sustainability by combining conceptual, visual, and networking systems, Sustain. Sci. 13 (5) (2018) 1357–1373.
[50] M. Romanelli, Towards sustainable ecosystems, Syst. Res. Behav. Sci. 35 (4) (2018) 417–426.
[51] D.A. Silva, I. Delai, M.A. Castro, A.R. Ometto, Quality tools applied to cleaner production programs: a first approach towards a new methodology, J. Clean. Prod. 47 (2013) 174–187.
[52] J.F. Hair, R.E. Anderson, R.L. Tatham, W.C. Black, Multivariate Data Analysis. 2010, Upper Saddle River, Pearson Prentice Hall, 2010.