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The influence of firm digitalization on sustainable innovation performance and the moderating role of corporate sustainability practices: An empirical investigation

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Abstract

This paper seeks to shed light on the relationship between firm digitalization and the likelihood of launching sustainable innovations (social and environmental, social only, and environmental only), for which the extant research has provided a paucity of evidence. In detail, the role of digitalization is considered in terms of (i) the specific effect of a given digital technology (DT)—among artificial intelligence, cloud computing, robotics, smart devices, big data analytics, high speed infrastructure, and blockchain—and (ii) the effect of the concurrent adoption of multiple DTs (degree of digitalization). Furthermore, the paper assesses if and how the effect of the degree of digitalization is moderated by the implementation of sustainability practices, as the two issues are often treated independently. Research questions are proposed instead of hypotheses. Econometric analysis to answer proposed questions is based on a sample of 14,125 firms, whose information is gathered from the survey Flash Eurobarometer 486. Results reveal that each DT differently affects the likelihood of launching sustainable innovations, while the degree of digitalization is always beneficial. Moreover, it appears that firm digitalization and the adoption of sustainability practices are not complementary. All in all, this paper helps to illuminate current representations of the interplay between digitalization, sustainability practices, and sustainable innovations at the firm level, with implications for research, managerial practice, and policymaking.

KEYWORDS

corporate sustainability practices, environmental innovation, firm digitalization, social innovation, sustainable innovation

Abbreviations: AI, artificial intelligence; BDA, big data analytics; Cloud, cloud computing; DT, digital technology; HSI, high speed infrastructure; IPCC, Intergovernmental Panel on Climate Change; IoT, Internet of Things; *PSW*, post-stratification weight; *PW*, population size weights; SmartDev, smart devices; WCED, World Commission on Environment and Development.

1 | INTRODUCTION

Nowadays, many governments look for a model of economic development that overcomes today's dominant model that generates widespread threats to the environment, exacerbates inequalities, and hampers human health (e.g., Intergovernmental Panel on Climate Change [IPCC], 2014; United Nations Environment Programme [UNEP], 2022). The launch of innovations accounting for and aiming at addressing economic, environmental, and social issues (sustainable innovations, hereafter) is one of the key components of such desired model of economic development (e.g., Adams et al., 2016; Ghobakhloo et al., 2021).

In this context, firms, being important contributors to innovation, are asked to embrace a business ethics approach and introduce sustainable innovations (Boons et al., 2013; Longoni & Cagliano, 2018), hence becoming part of the solution to social/environmental problems rather than part of the problem (Del Río Castro et al., 2021; Simanis & Hart, 2011; United Nations, 1999). Consequently, there has been an increased academic interest in unveiling firm-based practices, processes, and capabilities leading to sustainable innovations (e.g., Ardito et al., 2019; Dangelico et al., 2013; Inigo et al., 2020; Reficco et al., 2018). However, although firms' adoption of digital technologies (DTs) is now a renowned source of innovation (Usai et al., 2021), and "digitalization is discussed as an enabler of environmentally [and socially] sustainable development" (Isensee et al., 2020, p. 2), no previous studies have empirically tested whether and how firms adopting advanced DTs (e.g., big data analytics [BDA], Internet of Things [IoT], robots, and cloud computing) (Organisation for Economic Co-operation and Development [OECD], 2020) are more likely to launch sustainable innovations. Indeed, the role of firms in contributing through digitalization to sustainability "seems neglected by academic production or touched only at high level" (Guandalini, 2022, p. 462). Studies dealing with the role of digitalization for sustainable development, even at higher levels of analysis, revealed a preference towards specific industries or geographies (Clapp & Ruder, 2020; Forcadell et al., 2020; Singh et al., 2021) and focused on, often perceived, sustainability-related performance different from sustainable innovation performance specifically, such as the achievement of sustainable development goals (e.g., Brenner & Hartl, 2021; Del Río Castro et al., 2021; Denicolai et al., 2021). Likewise, studies dealing with innovative outcomes of digitalization have examined the influence of firm digitalization on innovation performance in general but not sustainable innovation performance (e.g., Usai et al., 2021), focused on a single DT (e.g., artificial intelligence [AI]) (e.g., Hermann, 2022), or provided insights based on a few cases or conceptual models (e.g., Ghobakhloo et al., 2021).

Eventually, these gaps lead to a limited transferability and generalizability of previous findings, a limited possibility to unveil pros and cons of firm digitalization for sustainable innovation, and a "scarce consideration from the pure management subject towards the relationship between digital transformation and sustainability" (Guandalini, 2022, p. 463).

Therefore, the main goal of this paper is to address the above mentioned gaps by conducting a large-scale, cross-country, and cross-sectoral econometric study that aims to unveil the relationship between firm digitalization and the likelihood of launching sustainable innovations (i.e., if firm digitalization is actually related to sustainable innovations). In detail, the study looks at the stand-alone effects of specific DTs as well as at the effect of the degree of digitalization, that is, the degree to which firms adopt multiple DTs concurrently. This recalls research evidencing that DTs may be implemented individually or in combination, with diverse effects on firm performance (Büchi et al., 2020), given the multifaceted nature of the digitalization phenomenon (Lanzolla et al., 2020; OECD, 2021). Furthermore, the study assesses sustainable innovation performance by looking at whether firms launch both social and environmental innovations, social innovations only, and environmental innovations only. This choice aims to advance the extant literature on sustainable innovation, in that only a few studies (Inigo et al., 2020; Inigo & Albareda, 2019; Longoni & Cagliano, 2018) simultaneously account for both social and environmental aspects in relation to firm innovation performance. Relatedly, empirical investigations on the antecedents of social innovations are scant (Adams et al., 2016; Pel et al., 2020), further providing an incomplete view of what favors sustainable innovations at the firm level.

Of course, this study acknowledges that firm digitalization does not necessary targets sustainability goals (Beier et al., 2018, 2020; Osburg, 2017) and that digitalized firms do not necessarily follow sustainability practices since the digitalization megatrend was born and grown independently from the sustainability megatrend (e.g., Brenner & Hartl, 2021; Denicolai et al., 2021). In other words, improved sustainable innovation performance of digitalized firms may be attained regardless of a formal commitment to corporate sustainability due to the new, intrinsic value creation opportunities opened up by DTs (Broekhuizen et al., 2021; Nambisan et al., 2019). Actually, according to Markman et al. (2016), corporate sustainability and other missions or goals (e.g., digitalization) are often in contrast. Some studies provided first empirical evidence in this sense, questioning the complementarity between firm digitalization and the adoption of sustainability practices (Ardito et al., 2021; Denicolai et al., 2021). In this vein, the paper also aims to examine if and how firm degree of digitalization is complementary to the implementation of sustainability practices (recycling, saving energy and resources, setting better work conditions, etc.) (e.g., Ameer & Othman, 2012; Hong et al., 2012) in launching sustainable innovations. More formally, the moderating role of the adoption of sustainability practices on the relationship between firm degree of digitalization and the likelihood of launching sustainable innovations is examined. Filling this gap is in line with the fact that "[a]lthough the convergence of digital and sustainability imperatives has begun to gain momentum in both the private and public sector, scholars have yet to conduct rigorous, systematic research that fully explores that nexus" (Brenner & Hartl, 2021, p. 2), "as the two issues are often treated independently" (Denicolai et al., 2021, p. 3).

Given the novelty of the topic and the exploratory nature of the study, this paper examines the extant, distinct debates about digitalization and sustainability, eventually posing two research questions (RQs) instead of hypotheses (see, for instance, Fini et al., 2020): (RQ1) How does firm (degree of) digitalization influence the likelihood of

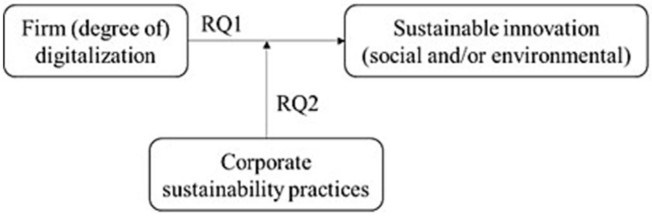


FIGURE 1 Conceptual model.

launching sustainable innovations (social and/or environmental)? (RQ2) How does the implementation of sustainability practices moderate the relationship between firm degree of digitalization and the likelihood of launching sustainable innovations (social and/or environmental)? Figure 1 represents the conceptual model.

To answer those questions, econometric analysis based on a sample of 14,125 firms operating in diverse sectors and headquartered in several countries is run. The sample firms and related information about digitalization, sustainability practices, and innovation performance were gathered from the survey Flash Eurobarometer 486 (SMEs, Start-ups, Scale-ups and Entrepreneurship) (European Commission, 2020).

Results reveal differences among DTs in affecting the likelihood that firms launch both social and environmental innovations, social innovations only, and environmental innovations only. A higher degree of digitalization always increases the likelihood of launching sustainable innovations. The conjoint impact of digitalization and sustainability practices is not significant when referred to the launch of both social and environmental innovations, while it is negatively related to the launch of environmental and social innovations only.

These results add to the extant literature by examining a novel antecedent to sustainable innovations at the firm level, that is, digitalization and its complementarity with corporate sustainability practices (Ardito et al., 2021). Also, the social and environmental performance aspects of sustainable innovations are considered simultaneously (Adams et al., 2016). Furthermore, results add to the literature on digital innovation by revealing the different impacts firm digitalization has on sustainable innovations, in terms of relevance of each DT and degree of digitalization (Büchi et al., 2020). In turn, managers and policymakers are advised that digitalization can boost sustainable innovations at the firm level, so it should be promoted. At the same time, its non-complementarity with sustainability practices is highlighted, hence calling for actions aimed at reconciling firms' commitment to digitalization and corporate sustainability, in line with the relatively recent view according to which digitalization should go hand in hand with sustainability practices.

2 | LITERATURE REVIEW

Two megatrends of renowned importance in business could be recognized, as the digitalization imperative and the sustainability imperative (George et al., 2021). While these megatrends have evolved and often studied independently (Denicolai et al., 2021), there exist a heightened interest to comprehend the relationships between (firm) digitalization and sustainability. However, clear evidence on the direct contribution of digitalization (at the firm level) and its complementarity with corporate sustainability practices to sustainable innovation performance is poor (Brenner & Hartl, 2021; Gouvea et al., 2018). In the following, we review key insights on the two megatrends and on their relationships, with particular reference to sustainable innovation. Afterward (see Section 3), drawing on the conflicting views about the effects of firm digitalization on sustainable innovation and about the complementarity between firm digitalization and corporate sustainability, RQs to be answered by the study will emerge.

2.1 | Digitalization megatrend

The first mentioned megatrend relates to the rapid digitalization of firms. The origin of such megatrend dates back to 2011, with the advent of the Industry 4.0 revolution (Ardito et al., 2018). Since 2011, firms have been prominently involved in a digitalization process (Lanzolla et al., 2021), also encouraged by many governments (European Parliament, 2016; OECD, 2021). Specifically, digitalization entails firms to use advanced DTs to alter value proposition, value creation, and value capture components of their business models (Broekhuizen et al., 2021). DTs include, among others, AI, cloud computing, robotics, smart sensor devices (e.g., IoT), BDA, high speed infrastructure (HSI), and blockchain. Each DT presents some specificities that enable firms to alter their business models (Nambisan et al., 2019). For instance, AI and robotics serve to automate and/or augment firm processes and higher order cognitive processes (Johnson et al., 2022). Cloud computing makes available, on demand and remotely, computer system resources (mainly storage and computing power) (Voorsluys et al., 2011). Smart sensor devices promise to connect billions of devices and acquire a large amount of data. BDA allows analyzing a large amount of diversified and unstructured data (Tsai et al., 2015). HSI refers to a faster and more reliable broadband technology (Hasbi, 2020). Blockchain is a decentralized, distributed ledger consisting of growing lists of blocks linked together via cryptographic hashes that cannot be altered retroactively (Zheng et al., 2018). Firms may adopt a given DT alone or multiple DTs in combination, with different potential impacts on firms' business models and firm performance, including innovation performance (Büchi et al., 2020; Usai et al., 2021).

2.2 | Sustainability megatrend and sustainable innovation

The second megatrend recognizes that sustainable development and the opportunities to innovate for sustainability received wide attention back to the late 1980s (World Commission on Environment and Development [WCED], 1987); notwithstanding, sustainability challenges endure unanswered, showing a glaring sustainability gap (Köhler et al., 2019; Seele, 2016). Consequently, firms are willingly or, under pressure of their stakeholders, committing to social and environmental goals, in addition to the economic one (Delmas et al., 2019; IPCC, 2014; United Nations, 1999). Stated differently, firms have been urged to accept that value is not unidimensional, and so to contribute to the development of a new economic model by launching sustainable innovations (Ricci et al., 2020). Indeed, sustainable innovations integrate the three dimensions of value identified in the concept of sustainable development (social, environmental, and economic) and are hence positioned to be a win–win situation (Porter & Kramer, 2019). Relatedly, as also underlined in the Sustainable Innovation Forum at COP26,[1] firms are key innovating organizations and are so deemed to play a key role in the launch of sustainable innovations, thus addressing the "need for societal actors to take on expanded roles in the production of environmental and social value" (George et al., 2021, p. 999). Historically, firms have relied on the adoption of sustainability practices as a mean to consider stakeholders' pressure towards sustainability issues, acquire social/environmental knowledge, and, hence, be in a better position to align economic, social, and environmental aspects into their innovation strategies (Cheng, 2020; Perrini & Tencati, 2006; Schaltegger et al., 2019).

2.3 | The nexus amid digitalization and sustainability megatrends

The convergence of the digitalization and sustainability megatrends is a relatively recent phenomenon that is beginning to gain traction (e.g., Aksin-Sivrikaya & Bhattacharya, 2017; Denicolai et al., 2021; George et al., 2021; Ghobakhloo et al., 2021). For instance, the European Commission is calling for a more sustainability- and socially oriented use of DTs through the development of proper skills[2] and is referring to the notions of twin transition[3] and Industry 5.0.[4] Industrial reports advocate that digitalization offers numerous potential benefits for sustainability (e.g., McKinsey & Co., 2022; PwC, 2018). In this vein, increasing attention is devoted by research to understand whether digitalization can be directed towards sustainability principles and lead to sustainable innovations. Some studies reveal that DTs can be seen as resources that can have positive implications for the achievement of sustainable development goals (Del Río Castro et al., 2021), sustainable manufacturing (Despeisse et al., 2022), circular economy (Agrawal et al., 2022), and socioecological sustainability (Stock et al., 2018) through their creative deployment. However, other studies reveal that the potential of DTs to stimulate social and environmental value creation is controversial (e.g., Akande et al., 2019; Beier et al., 2020; Unwin & Unwin, 2017). Consequently, a nascent academic interest is on whether digitalization has positive and negative potential to launch sustainable innovations, with still little evidence about its contribution at the firm level (Brenner & Hartl, 2021; Osburg, 2017). This means that there is not a conclusive answer to the question of whether firm (degree of) digitalization positively affects sustainable innovation performance. Accordingly, scholars are doubtful about "what contribution the management scholars are providing in support of companies and business regulatory bodies" in this sense (Guandalini, 2022, p. 456).

Furthermore, Ghobakhloo et al. (2021, p. 4238) acknowledge that "the technological push under Industry 4.0 [i.e., digitalization] does not necessarily prioritize environmental [and social] sustainability" (Ghobakhloo et al., 2021, p. 4238) and argue that digitalization may "inadvertently" lead to sustainable outcomes, such as energy efficiency, cleaner production, improved working conditions, or job creation. Indeed, the adoption of DTs and the adoption of sustainability practices as a source of (sustainable) innovation have been viewed so far as two independent firm strategic approaches. In particular, while a positive influence of sustainability practices on sustainable innovation has been proved and is quite straightforward (Bos-Brouwers, 2010; García-Granero et al., 2020), the nexus amid digitalization and sustainability practices (i.e., their complementarity), especially at the firm level, represents a nascent field enduring complexities and uncertainties (Brenner & Hartl, 2021; Del Río Castro et al., 2021; Isensee et al., 2020), alongside a lack of large-scale analysis. Ardito et al. (2021) first attempted to explore this nexus, revealing that firms simultaneously implementing DTs and environmental practices have worse product and process innovation performance. A similar result has been found by Denicolai et al. (2021), albeit considering internationalization as the performance outcome. In sum, according to previous studies, one could contend that the "practices enabled by the digital logic [may] support the interrelation of the environmental, social, and commercial logics but also entail tensions" (Gregori & Holzmann, 2020, p. 6). As such, it is worth assessing whether the influence of digitalization on the likelihood that firms launch sustainable innovations is contingent upon a firm's adoption of sustainability practices.

3 | RQs DEVELOPMENT

As discussed, each DT presents some specificities and can be deployed by firms alone or in combination with other DTS to integrate economic, social, and environmental value creation, eventually affecting their sustainable innovation performance. However, conflicting views exist about the effects of the adoption of DTs firm digitalization on sustainable innovations. Furthermore, our understanding on the contingent effects of corporate sustainability on the relationship between firm digitalization and sustainable innovation performance is poor.

3.1 | Conflicting views on the effects of firm digitalization on sustainable innovation performance

Accessing data through smart sensor devices like IoT and smartphones is key to remain competitive. Accordingly, there is a battle for

[1] https://events.climateaction.org/sustainable-innovation-forum/.
[2] https://www.etf.europa.eu/en/news-and-events/news/shifting-skills-green-and-digital-transition.
[3] https://joint-research-centre.ec.europa.eu/jrc-news/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en.
[4] https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en.

data among firms in nearly all business sectors (Osburg, 2017). When it comes to social and environmental aspects, instead, things are not so straightforward. On one side, firms gathering (real-time) data about cars, drivers, patients, citizens, home appliances, and manufacturing machines, among others, may launch systems that can avoid car accidents, improve medical services for people, and monitor environmental burden (e.g., Dimitrov, 2016; Song et al., 2017), hence constituting innovations with social and/or environmental values. The possibility to gather data across products' life-cycles and from geographically dispersed value chains can enhance the development of sustainability management systems (Kunkel & Matthess, 2020). Also, such data may sustain the creation of closed material loops and interaction among firms that give rise to more environmentally friendly new products (Agrawal et al., 2022). The analysis of gathered data, for example, through BDA and AI, may further add social and/or environmental functions like automatic forecasting of risky events, detection citizens' misconduct, and identification of firms with which form more sustainable supply chains (Zomaya & Sakr, 2017). On the other side, staying anonymous becomes nearly impossible. People and their electronic devices get tracked or leave traces, and people lose control over their data (and privacy), as they do not know whether data owners keep confidentiality or exploit data opportunistically by targeting advertisements, selling data, and so on (Forcadell et al., 2020; Loi et al., 2022). Likewise, AI applications, for example, can be discriminatory in various respects (see Hermann, 2022). This may question the ethical principles and social relevance of innovations originating from data-gathering and data-analyzing solutions. Moreover, a frequently cited work by Frey and Osborne (2017) reveals that about 47% of the current jobs in the United States may be automated due to the reliance on advanced robots. Or course, robots can lead to efficiency gains when adopted in firm processes, so constituting an environmentally friendly process innovation (Liu et al., 2007). An example refers to the use of "Recycle Bots," which results in a strong decrease of recycling-related energy consumption (Kreiger et al., 2014). However, such efficiency gains are in contrast with social values (i.e., negative impact on employment allowing for staff reduction) and, in turn, jeopardize the potential gains of digitalization (Hoepner et al., 2016). Blockchain is another relevant DT. Systems based on blockchain are not limited to financial transactions but virtually all, such as government record-keeping, tracking the flow of goods and services along (sustainable) supply chains, voting, and verifying the identity of citizens (Khan et al., 2021; Mubarik et al., 2021). The key advantage is that blockchain "could be ethically utilized to serve the best interests of the stakeholders in the ecosystem" (Tan & Salo, 2021, p. 23). Indeed, blockchains are well renowned as incorruptible digital ledgers (Koh et al., 2020). Thus, innovations based on this technology may have positive social and environmental repercussions. Notwithstanding, the carbon footprint of this DT is also not negligible, as evidenced by several initiatives aimed at compensating for such issue (Howson, 2019). In addition, compensation efforts are prevalently directed towards some local communities (i.e., are centralized locally), while climate impacts of blockchain are global given its decentralized nature (Howson, 2019). Thus, blockchain-based innovations may create structural social inequalities.

Following the foregoing discussion, whether firms adopting one of these DTs more likely launch sustainable innovations is not easy to predict.

Digitalization is not only about adopting one DT for a given purpose but can involve the adoption and integration of several different DTs (Lanzolla et al., 2020; OECD, 2021). The adoption of multiple DTs may make firms in a better position to launch sustainable innovations by leveraging the potential environmental and/or social benefits of each DT as sources of value creation (Büchi et al., 2020). Still, the integration of multiple DTs can come with a price, and this price may grow as the variety of DTs implemented by firms increases, hence making firms victims of the digital age (Sommer, 2015; Trittin-Ulbrich et al., 2021). For instance, DTs are inherently different from each other and most of the digitalization costs are due to the "inability to actually screen and select the available technologies that may sustain such transition" (Ardito et al., 2018, p. 324). Accordingly, digitalizing firms require diverse experts that firms do not often have (e.g., Tamakhina et al., 2020). This leads to a higher degree of uncertainty about the applicability of multiple DTs for their operations and, in turn, about their potential environmental and/or social benefits. The top management may get muddled when tasked to choose among many digital solutions and integrate them into a coherent whole due to the lack of digital skills and attention allocation issues (Kane et al., 2019; Ocasio, 1997). Furthermore, it must be acknowledged that a higher degree of digitalization in firms will be responsible for increasing demand for critical materials amount of electricity and non-recyclable and/or untracked e-waste (Baldé et al., 2017; Lange et al., 2020), hence hindering social and environmental value creation potential of firms.

In line with this reasoning, one could question the view that increased digitalization provides increasing opportunities for launching sustainable innovations. Therefore, we pose the following RQ:

RQ1. How does firm (degree of) digitalization influence the likelihood of launching sustainable innovations (social and/or environmental)?

3.2 | The moderating role of corporate sustainability practices

Firms adopting sustainability practices have required to develop and commit internal resources, competences, and culture to cope with social and/or environmental issues such as by reducing consumption of natural resources, switching to sustainable resources, and improving working conditions of employees (e.g., Ameer & Othman, 2012; Hong et al., 2012). Moreover, sustainability practices have made firms consider stakeholders' (government, customers, and suppliers) needs and concerns towards sustainability (Perrini & Tencati, 2006; Schaltegger et al., 2019). This allows better aligning economic, social, and environmental aspects into innovation strategies and acquiring new social/environmental knowledge to include in innovation processes (Cheng, 2020). Thereby, the implementation of sustainability practices likely places firms in a better position to launch innovations considering and aiming at addressing social and/or environmental concerns (Bos-Brouwers, 2010; García-Granero et al., 2020).

In turn, one could contend that firms implementing sustainability practices may guide digitalization towards unleashing the social and/or environmental value creation potential underlying DTs to innovate. Indeed, firms may be (come) more aware and account for the social and/or environmental benefits/risks each DT and their integration may provide. However, the advantages above mentioned manifest only if digitalization is entrenched with sustainability practices, which is often not the case. Indeed, at least so far, digitalization has been mainly conceptualized as a (digital) technology-driven transformation of firms' production facilities and operations,[5] with no (direct) intent to address social/environmental concerns (Beier et al., 2020). Eventually, firms that adopt sustainability practices may not necessarily improve their likelihood of launching sustainable innovations by leveraging on their DTs since digitalization and corporate sustainability are seen as distinct approaches for different purposes, based on diverse visions and strategic orientations (Beier et al., 2018; Osburg, 2017).

Even assuming that firms attempt to make digitalization and sustainability practices related to each other, it should be acknowledged that the transformational nature of corporate sustainability requires distinct changes in organizational structures, performance indicators, and company resources than those required for digitalization, thus fostering the emergence of different levels of complex dynamic capabilities (Castiaux, 2012; Inigo & Albareda, 2019). That is, corporate sustainability logics are differently understood in relation to digital logics (Brenner & Hartl, 2021). Thus, "internal misunderstandings and tensions hampering the effective implementation of processes including the two different philosophies will likely emerge" (Ardito et al., 2021, p. 47), eventually hindering sustainable innovation performance. A "major tension between the social and environmental values and the digital logic originates from the collision of digital and physical aspects of the business model" (Gregori & Holzmann, 2020, p. 6); the digital logic relates to a potential infinite scalability, which is instead constrained by natural boundaries that are governed by environmental and social logics. An example in this sense refers to online gardening applications that potentially enable anyone to join the platforms to cultivate a piece of land remotely (potential positive social and environmental impact) but are constrained by the availability of lands and by the fact that vegetables and fruits must by eventually delivered to distant end consumer (negative environmental impact) (Gregori & Holzmann, 2020).

Furthermore, the attention allocation problem should be recognized. Attention is limited, so executives need to "concentrate their energy, effort and mindfulness on a limited [non-competing] number of issues" to achieve superior (innovation) performance (Ocasio, 1997, p. 203). In this context, sustainability practices will unlikely nurture digitalization, thus failing to provide the expected advantages in terms of sustainable innovation performance. In addition, firm resources are scarce, so that corporate sustainability and digitalization may compete for same (scarce) organizational resources. Particularly, since the knowledge, relational, and human resources required to digitalize and implement sustainability practices are inherently distinct and address different goals, executives will likely fail to manage resource commitments towards both digitalization and sustainability practices (De Roeck & Delobbe, 2012; Stevens et al., 2015). This issue is exacerbated as the number of DTs to adopt grows, hence leading to a "double" attention allocation problem: One pertains to the integration of digitalization and sustainability practices, and one pertains to the integration of multiple DTs (as also exposed in the previous section). Accordingly, Aksin-Sivrikaya and Bhattacharya (2017) recognize that actions (e.g., the development of appropriate governance models) are needed reduce digitalization versus sustainability frictions and favor their integration. Following to the foregoing discussion, we pose the following RQ:

RQ2. How does the implementation of sustainability practices moderate the relationship between firm degree of digitalization and the likelihood of launching sustainable innovations (social and/or environmental)?

4 | DATA AND METHODS

Data were gathered from the novel Flash Eurobarometer 486 (SMEs, Start-ups, Scale-ups and Entrepreneurship). It was carried out by Kantar at the request of the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (European Commission, 2020). The survey was conducted in the EU27 and an additional 12 non-EU countries and territories[6] between February 19 and May 5, 2020, and involved enterprises employing one or more persons in multiple sectors, hence underlining the wide coverage and the recency of the data. Additionally, Flash Eurobarometer surveys,[7] like the 486 one, have been designed and launched by the European Commission since the late 1980s. Thus, they have been subject to extensive pilot tests and have been proposed to firms frequently in recent years; moreover, responses are collected through telephone interviews, which reduced misunderstanding about questions. In turn, issues of interpretability, reliability, and validity are limited. Consequently, Flash Eurobarometer surveys have been adopted by several scholars (e.g., Hoogendoorn et al., 2019; Parboteeah et al., 2015; Triguero et al., 2013). The choice to rely on such type of survey is also consistent with several previous studies that used, for example, the

[5]This is evidenced by the fact that many digital transformation projects failed because of their lack of vision and the idea that technologies like IoT, big data, and artificial intelligence would have led automatically to improved performance.

[6]The typical sample size is 500–1000 respondents per country, and interviews are usually conducted by phone in the respective national language. A multi-stage random sample was drawn from the population of the respective nationalities.

[7]The Flash Eurobarometer includes series on special topics (Common Currency, EU Enlargement, Information Society, Entrepreneurship, Innovation) as well as special target group polls, particularly company managers with enterprise related topics.

Eurostat's Community Innovation Survey (e.g., Blindenbach-Driessen & van den Ende, 2014; Laursen & Salter, 2006).

In particular, the considered survey focuses on the barriers and challenges that firms face when growing and transitioning to more sustainable and digitally based innovative business models. Therefore, the survey allowed obtaining relevant information to answer the proposed RQs, alongside other firm-level data (firm size, firm age, operating sector and country, etc.). Specifically, information about RQs includes, first, the types of innovation launched, as social and environmental innovations. Second, the DTs adopted among (a) AI, for example, machine learning or technologies identifying objects or persons; (b) cloud computing (Cloud), that is, storing and processing files or data on remote servers hosted on the internet; (c) robotics, that is, robots used to automate processes, for example, in construction or design; (d) smart devices (SmartDev), for example, smart sensors and smart thermostats; (e) BDA, for example, data mining and predictive analysis; (f) HIS; and (g) blockchain. Third, the sustainability practices implemented among (a) recycling or reusing materials, (b) reducing consumption of or impact on natural resources (e.g., saving water or switching to sustainable resources), (c) saving energy or switching to sustainable energy sources, (d) developing sustainable products or services, (e) improving working conditions of its employees, (f) promoting and improving diversity and equality in the workplace, (g) evaluating the impact of your enterprise on society, and (h) engaging employees in the governance of the enterprise.

The survey collected 16,365 responses. However, not all observations could be employed due to missing data on key variables. Moreover, the study excluded non-profit organizations as non-business entities that follow different logics than for-profit companies. Eventually, 14,125 observations constitute the final sample. Appendix A presents descriptive statistics about the sample firms.

4.1 | Variables

The study adopts three dependent variables (DVs). The first is a binary variable taking the value of one if a firm has launched both social and environmental innovations (*SocEnvInno*). The second is a binary value taking the value of one if a firm has launched social innovations only (*SocInno*). The third is a binary value taking the value of one if a firm has launched environmental innovations only (*EnvInno*). Thus, the first DV captures whether a firm has been able to innovate including both environmental and social aspects in value creation, while the others capture whether a firm has included only one of those sustainability principles. The timeframe considered to capture this information by the survey is 1 year prior to the survey. The use of a binary variable to capture firms' innovativeness is line with the extant innovation literature, as demonstrated by its adoption in previous studies (e.g., Ardito et al., 2021; Leiponen & Helfat, 2011).

To assess the effect of a given DT on the likelihood of launching sustainable innovations, seven dummy variables were used. Each binary variable is associated with the adoption of a given DT among the ones mentioned in the data description (*d_AI*, *d_Cloud*, *d_Robots*, *d_SmartDev*, *d_BDA*, *d_HSI*, and *d_Blockchain*). Specifically, they take the value of one if the respective DT is adopted by a firm, zero otherwise. These dummy variables are not mutually exclusive since a firm may adopt multiple DTs. To assess the relationship between the degree of digitalization (*Digitalization*) and the likelihood of launching sustainable innovations, the seven binary variables described above were summed up (Ardito et al., 2021) (Cronbach alpha, including the option for no DTs adopted, is equal to .71). A similar approach has been used to measure, for instance, knowledge search breadth in terms of reliance on multiple knowledge sources (e.g., Laursen & Salter, 2006; Leiponen & Helfat, 2011).

The moderating variable (*SustPractices*) is operationalized following the same rationale of *Digitalization*. That is, eight binary variables were created, one per each sustainability practice that a firm has implemented. Then, the binary variables were summed up (Cronbach alpha, including the option no digital sustainability practices adopted, is equal to .81).

Several control variables were included to improve the reliability of the model. These include (i) firm age (*Age*) (Gopalakrishnan & Bierly, 2006), log transformed; (ii) firm size in terms of both number of employees (*Employees*) and turnover (*Turnover*) (Damanpour, 2010; Gopalakrishnan & Bierly, 2006), log transformed; (iii) a dummy variable equal to one if the firm is in an industrial area (*Industrial*) (Fan et al., 2021); (iv) a dummy variable equal to one if the firm is a mutual corporation (*Mutual*) (Wadhwani, 2011); (v) a dummy variable equal to one if the firm is mainly family-owned (*Family*) (Calabrò et al., 2019); (vi) a dummy variable equal to one if the firm has patents (*Patents*) (Acs et al., 2002); (vii) a dummy variable equal to one if the firm is part of a global value chain (*GlobalVC*) (Reddy et al., 2021); (viii) a dummy variable equal to one if the firm is part of an industrial cluster (*Cluster*) (Grimpe & Sofka, 2009); (ix) the number of innovation barriers faced by the firm (*Barriers*) (Madrid-Guijarro et al., 2009); (x) post-stratification weight (*PSW*) and population size weights (*PW*) to account for potential sample bias (Riillo, 2017); (xi) a set of dummy variables controlling for the industry sector (*d_Sector*); and (xii) a set of dummy variables controlling for the headquarter country (*d_Country*).

4.2 | Model specification

DVs can assume either value of zero or one. In this instance, probit or logit regressions are the most appropriate econometric techniques (Hoetker, 2007). While the two approaches often lead to coherent results, the choice among them was made by considering respective values of Akaike's information criteria and Bayesian information criteria. The approach with the lowest values should be preferred (Wooldridge, 2012), which is the logit regression in this case.

TABLE 1 Descriptive statistics and pairwise correlations.

	1	2	3	4	5	6	7	8	9	10	11	12
1. SocEnvInno	1											
2. SocInno	.48*	1										
3. EnvInno	.57*	−.13*	1									
4. d_AI	.13*	.04*	.06*	1								
5. d_Cloud	.15*	.06*	.06*	.16*	1							
6. d_Robots	.14*	.02*	.08*	.23*	.12*	1						
7. d_SMartDev	.21*	.02*	.12*	.19*	.23*	.21*	1					
8. d_BDA	.17*	.05*	.06*	.25*	.22*	.15*	.22*	1				
9. d_HSI	.17*	.06*	.06*	.16*	.29*	.11*	.22*	.22*	1			
10. d_Blockchain	.10*	.05*	.01*	.18*	.13*	.11*	.13*	.19*	.14*	1		
11. Digitalization	.28*	.08*	.12*	.49*	.64*	.44*	.62*	.57*	.63*	.36*	1	
12. SustPractices	.37*	.11*	.18*	.17*	.30*	.18*	.28*	.21*	.30*	.12*	.43*	1
13. Age	.04*	−.03*	.05*	.01*	.02*	.06*	.05*	.00	.05*	.00	.06*	.11*
14. Employees	.14*	.00	.10*	.13*	.15*	.24*	.22*	.22*	.14*	.09*	.31*	.21*
15. Turnover	−.04*	−.02*	−.03*	−.03*	−.09*	−.02*	−.03*	−.03*	−.04*	−.01*	−.07*	−.12*
16. Industrial	.08*	.02*	.05*	.02*	.07*	.07*	.06*	.03*	.05*	.02*	.09*	.13*
17. Mutual	.04*	.02*	.01	.02*	.03*	.02*	.04*	.04*	.04*	.00	.06*	.09*
18. Family	.10*	.01	.06*	.02*	.07*	.02*	.07*	.02*	.08*	.00	.09*	.20*
19. Patents	.15*	.04*	.06*	.12*	.11*	.17*	.12*	.10*	.10*	.08*	.21*	.20*
20. GloalVC	.14*	.02*	.08*	.11*	.15*	.14*	.12*	.14*	.12*	.06*	.22*	.21*
21. Cluster	.14*	.03*	.07*	.08*	.13*	.09*	.12*	.10*	.11*	.06*	.19*	.25*
22. Barriers	.21*	.09*	.08*	.05*	.11*	.06*	.11*	.08*	.11*	.05*	.16*	.30*
23. PSW	−.08*	−.00	−.06*	−.05*	−.06*	−.17*	−.13*	−.10*	−.05*	−.04*	−.16*	−.12*
24. PS	.01	.05*	−.04*	−.00	.00	−.06*	−.01	−.00	.04*	.01	.00	.07*
Mean	0.322	0.101	0.138	0.079	0.487	0.088	0.282	0.146	0.342	0.033	1.46	3.90
SD	0.467	0.301	0.344	0.269	0.499	0.284	0.450	0.353	0.474	0.180	1.43	2.48
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	1	1	1	1	1	1	1	1	1	1	7	8

	13	14	15	16	17	18	19	20	21	22	23	24
13. Age	1											
14. Employees	.27*	1										
15. Turnover	.01*	.05*	1									
16. Industrial	.07*	.12*	−.04*	1								
17. Mutual	.06*	.05*	−.02*	.02*	1							
18. Family	.13*	.03*	−.05*	.11*	.05*	1						
19. Patents	.05*	.16*	−.01	.09*	.02*	.08*	1					
20. GloalVC	.04*	.17*	−.05*	.11*	.04*	.07*	.18*	1				
21. Cluster	.10*	.10*	−.07*	.09*	.04*	.13*	.16*	.21*	1			
22. Barriers	−.00	.04*	−.10*	.06*	.04*	.08*	.12*	.10*	.12*	1		
23. PSW	−.22*	−.58*	−.02*	−.12*	−.02*	−.04*	−.13*	−.13*	−.06*	−.03*	1	
24. PS	−.04*	−.17*	−.05*	−.01	.02*	.04*	.01*	−.02*	.04*	.08*	.38*	1
Mean	2.93	2.30	21.5	0.132	0.036	0.214	0.069	0.096	0.147	1.48	1.01	1453
SD	0.791	1.60	10.2	0.338	0.187	0.410	0.254	0.295	0.354	1.40	0.644	2817
Min	0	0	4.91	0	0	0	0	0	0	0	0.01	0.793
Max	5.14	8.85	34.5	1	1	1	1	1	1	7	3.12	27,209.41

$^{*}p < .05$.

TABLE 2a Results, with robust s.e. in parentheses.

	Model 1a DV: SocEnvInno	Model 2a DV: SocInno	Model 3a DV: EnvInno	Model 1b DV: SocEnvInno	Model 2b DV: SocInno	Model 3b DV: EnvInno
d_AI				0.229***	0.087	0.139
				(0.077)	(0.101)	(0.094)
d_Cloud				0.038	0.124+	−0.036
				(0.046)	(0.067)	(0.058)
d_Robots				0.225**	−0.001	0.06
				(0.074)	(0.107)	(0.087)
d_SMartDev				0.391***	−0.139+	0.379***
				(0.047)	(0.072)	(0.060)
d_BDA				0.269***	0.066	0.016
				(0.059)	(0.082)	(0.075)
d_HSI				0.123**	0.123+	0.02
				(0.047)	(0.067)	(0.060)
d_Blockchain				0.354**	0.344**	−0.197
				(0.109)	(0.132)	(0.138)
SustPractices	0.299***	0.104***	0.190***	0.263***	0.095***	0.172***
	(0.01)	(0.014)	(0.013)	(0.011)	(0.015)	(0.014)
Age	−0.056*	−0.149***	0.061+	−0.033	−0.141***	0.065+
	(0.027)	(0.039)	(0.035)	(0.028)	(0.04)	(0.035)
Employees	0.107***	−0.036	0.116***	0.056**	−0.047+	0.095***
	(0.017)	(0.024)	(0.021)	(0.018)	(0.025)	(0.022)
Turnover	0.001	0.000	−0.004	0.001	0	−0.003
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Industrial	0.089	0.033+	0.126	0.1	0.035	0.132+
	(0.059)	(0.085)	(0.073)	(0.06)	(0.085)	(0.073)
Mutual	0.061	0.151	−0.203	0.044	0.155	−0.214
	(0.1)	(0.138)	(0.132)	(0.101)	(0.138)	(0.133)
Barriers	0.161***	0.115***	0.064***	0.155***	0.114***	0.06**
	(0.015)	(0.020)	(0.018)	(0.015)	(0.02)	(0.018)
Family	0.096+	−0.139+	0.156+	0.095+	−0.133+	0.149*
	(0.049)	(0.073)	(0.061)	(0.05)	(0.073)	(0.062)
Patents	0.380***	0.111	0.098	0.297***	0.085	0.06
	(0.078)	(0.107)	(0.092)	(0.08)	(0.108)	(0.094)
GlobalVC	0.249***	−0.079*	0.164	0.178*	−0.104	0.139+
	(0.068)	(0.098)	(0.080)	(0.069)	(0.099)	(0.081)
Cluster	0.232***	0.169*	0.086	0.191**	0.157+	0.065
	(0.059)	(0.083)	(0.073)	(0.06)	(0.084)	(0.074)
PSW	−0.002	−0.176*	0.07	0.001	−0.178*	0.074
	(0.051)	(0.073)	(0.066)	(0.052)	(0.073)	(0.066)
PS	0.000+	0.000**	0.000	0.000+	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
d_Sector	Yes	Yes	Yes	Yes	Yes	Yes
d_Country	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi(2)	2163.38***	549.97***	845.61***	2289.48***	576.52***	918.00***
Log-pseudolikelihood	−7513.47	−4354.26	−5221.89	−7410.22	−4343.20	−5195.49

+$p < .10$, *$p < .05$, **$p < .01$, and ***$p < .001$.

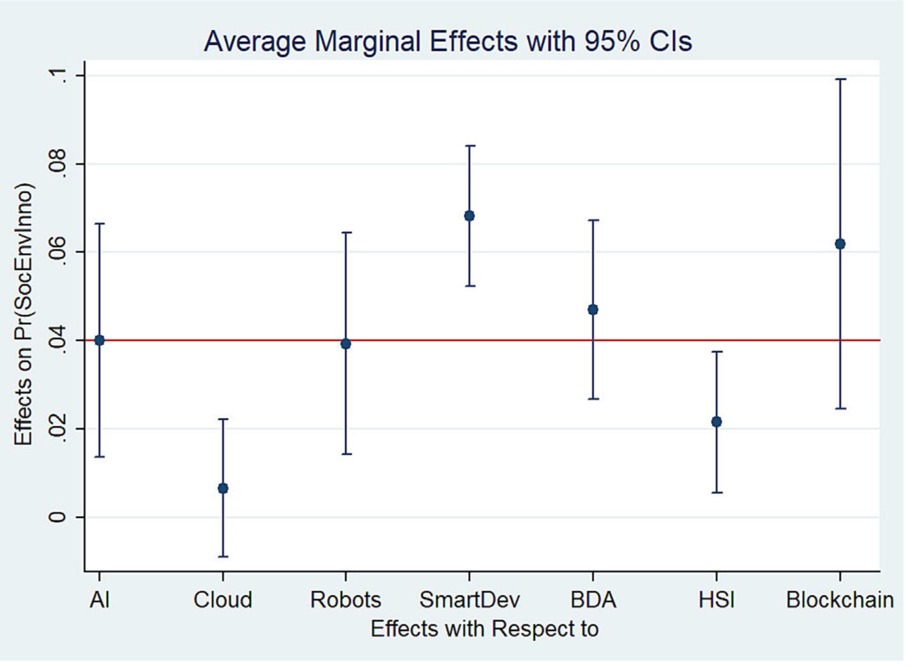


FIGURE 2 Marginal effects of each DT dummy.

5 | RESULTS

Table 1 shows descriptive statistics and pairwise correlations. All correlation values are sensibly below the .70, thus suggesting multicollinearity is not a relevant issue.

Table 2a presents the results for what concerns the single effect the considered DTs for each DV. Models 1a–3a include control variables only. They reveal that *SustPractices* (as expected) and *Barriers* are positively associated with all DVs. Firm age negatively affects the likelihood of launching both social and environmental innovations as well as social innovations only. The number of employees, instead, positively affects the likelihood of launching both social and environmental innovations as well as environmental innovations only. Patenting, being involved in a global value chain, and being part of an industrial cluster positively affect the likelihood of launching both social and environmental innovations.

Models 1b–3b include dummy variables capturing the adoption of each DT. According to Model 1b, except for Cloud ($\beta = .038$, $p > .10$), AI ($\beta = .229$, $p < .001$), Robots ($\beta = .225$, $p < .01$), SmartDev ($\beta = .391$, $p < .001$), BDA ($\beta = .269$, $p < .001$), HIS ($\beta = .123$, $p < .01$), and Blockchain ($\beta = .354$, $p < .01$) have a positive, significant effect on *SocEnvInno*. To gain further insights into this result, I calculated and plotted average marginal effects of each dummy (Figure 2), which allow highlighting the most impactful DTs. Per Figure 2, the relevance of DTs is ranked as follows (descending order): SmartDev, Blockchain, BDA, AI, Robots, and HIS. The average marginal effect of Cloud is not significant. According to Model 2b, Blockchain appears to be the only DT that significantly affects *SocInno* ($\beta = .334$, $p < .01$). According to Model 3b, SmartDev appears to be the only DT that significantly affects *EnvInno* ($\beta = .379$, $p < .001$) according to Model 3b.

Table 2b presents the results for what concerns the effect the degree of digitalization, as well as the moderating effect of *SustPractices*. Models 1c–3c add *Digitalization* to Models 1a–3a discussed above. For the sake of brevity, only significant results are reported.[8] Thus, as compared to Model 3c, Models 1c and 2c do not include the squared term of *Digitalization* since it is not significant. According to Models 1c and 2c, *Digitalization* is positively related to *SocEnvInno* ($\beta = .213$, $p < .001$) and *SocInno* ($\beta = .063$, $p < .001$). By contrast, it seems to have an inverted U-shaped effect on *EnvInno* according to Model 3c, as its linear term is positive and significant ($\beta = .287$, $p < .001$), while its squared term is negative and significant ($\beta = -.042$, $p < .001$). However, I plotted the predicted effect of *Digitalization* against *EnvInno* (Figure 3), and it appears that the tipping point does not manifest within the data range. Therefore, I eventually contend that *Digitalization* is also positively related to *EnvInno*.

Models 1d–3d include the interaction term *Digitalization* × *SustPractices*. It is not significant when the DV is *SocEnvInno* ($\beta = -.007$, $p > .10$), while it has a negative, significant effect on *SocInno* ($\beta = -.035$, $p < .001$) and *EnvInno* ($\beta = -.022$, $p < .01$), hence suggesting a negative moderating effect of *SustPractices* in the last two cases. Figures 4 and 5 depict the effect of *Digitalization* against *SocInno* and *EnvInno*, respectively, at different levels of *SustPractices* (i.e., one standard deviation below the mean, mean level, and one standard deviation above the mean), further suggesting a negative moderating effect of *SustPractices*.

6 | DISCUSSION AND CONCLUSION

This paper seeks to illuminate current representations of the interplay between digitalization, sustainability practices, and firms' sustainable innovations at the firm level. Based on a novel sample of more than

[8]Complete set of analysis is available upon request.

TABLE 2b Results, with robust s.e. in parentheses.

	Model 1c DV: SocEnvInno	Model 2c DV: SocInno	Model 3c DV: EnvInno	Model 1d DV: SocEnvInno	Model 2d DV: SocInno	Model 3d DV: EnvInno
Digitalization × SustPractices				0.007	−0.035***	−0.022**
				(0.007)	(0.008)	(0.008)
Digitalization	0.213***	0.063**	0.287***	0.175***	0.248***	0.362***
	(0.016)	(0.023)	(0.050)	(0.038)	(0.048)	(0.057)
Digitalization^2			−0.042***			−0.032**
			(0.010)			(0.010)
SustPractices	0.264***	0.093***	0.170***	0.253***	0.145***	0.204***
	(0.011)	(0.015)	(0.014)	(0.014)	(0.020)	(0.019)
Age	−0.033	−0.142***	0.072*	−0.033	−0.138**	0.074*
	(0.028)	(0.04)	(0.035)	(0.028)	(0.040)	(0.035)
Employees	0.059**	−0.051*	0.097***	0.059**	−0.048+	0.098***
	(0.017)	(0.025)	(0.022)	(0.018)	(0.025)	(0.022)
Turnover	0.002	0.000	−0.003	0.002	0.000	−0.003
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Industrial	0.096	0.034	0.120	0.097	0.032	0.119
	(0.060)	(0.085)	(0.073)	(0.060)	(0.084)	(0.073)
Mutual	0.052	0.147	−0.211	0.050	0.160	−0.203
	(0.101)	(0.138)	(0.132)	(0.101)	(0.138)	(0.132)
Barriers	0.155***	0.113***	0.056**	0.156***	0.108***	0.055**
	(0.015)	(0.020)	(0.018)	(0.015)	(0.02)	(0.018)
Family	0.096+	−0.138+	0.144*	0.096+	−0.142+	0.143*
	(0.050)	(0.073)	(0.061)	(0.050)	(0.072)	(0.061)
Patents	0.299***	0.086	0.0810	0.294***	0.112	0.094
	(0.079)	(0.107)	(0.093)	(0.080)	(0.107)	(0.093)
GlobalVC	0.176+	−0.103	0.144+	0.173*	−0.082	0.151+
	(0.069)	(0.099)	(0.081)	(0.069)	(0.098)	(0.080)
Cluster	0.196**	0.156+	0.071	0.196**	0.161+	0.073
	(0.060)	(0.084)	(0.073)	(0.060)	(0.083)	(0.073)
PSW	0.002	−0.174*	0.081	0.001	−0.170*	0.082
	(0.051)	(0.073)	(0.066)	(0.051)	(0.073)	(0.066)
PS	0.000+	0.000+	0.000	0.000+	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
d_Sector	Yes	Yes	Yes	Yes	Yes	Yes
d_Country	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi(2)	2277.61***	563.38***	889.51***	2286.02***	566.23***	872.81***
Log-pseudolikelihood	−7427.01	−4350.47	−5202.50	−7426.39	−4342.15	−5199.28

+*p* < .10, **p* < .05, ***p* < .01, and ****p* < .001.

14,000 firms worldwide, results reveal that almost all DTs, ceteris paribus, positively influences the likelihood of launching environmental and social innovations concurrently. The only exception is Cloud, probably because it supports internal activities and/or enable the use of other DTs (e.g., the storage of data gathered through devices and the analysis of data through AI, remotely), without a direct impact on subsequent (sustainable) innovations. Moreover, DTs aimed at acquiring data (i.e., smart sensor devices) and at assuring safer transactions (i.e., Blockchain) appear to be the most relevant followed by those allowing extracting value from (big) data (Figure 2). This can be explained by the fact that data, as well as their safer transactions, represent the basic resources upon which firms can rely on to understand and act on social and environmental issues. Quite surprisingly, firms launching either social or environmental innovations benefit only from Blockchain and smart sensor devices, respectively. One could argue that blockchain is specifically directed to social issues. Likewise, it

FIGURE 3 Predicted effect of Digitalization against EnvInno.

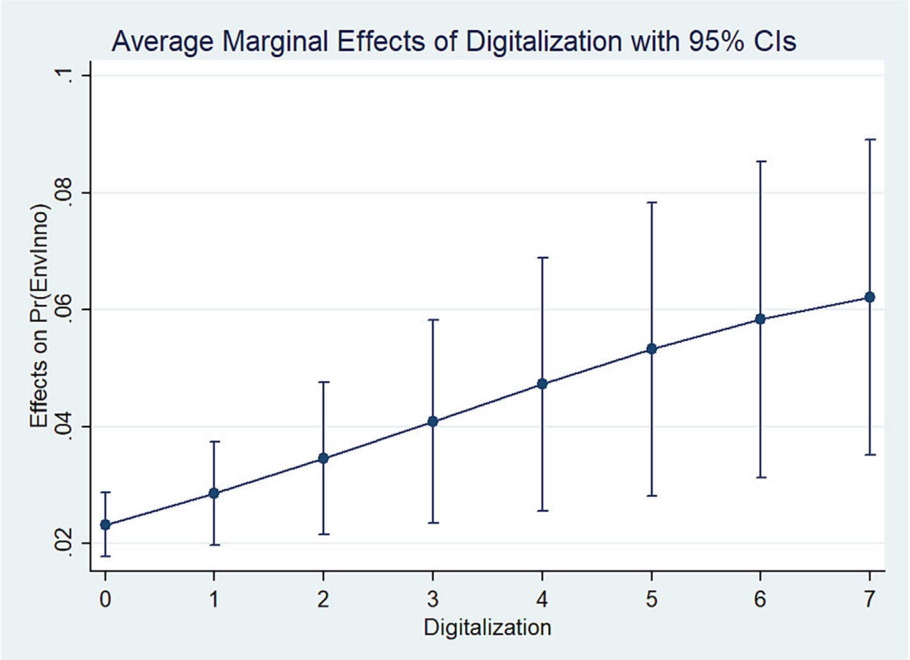
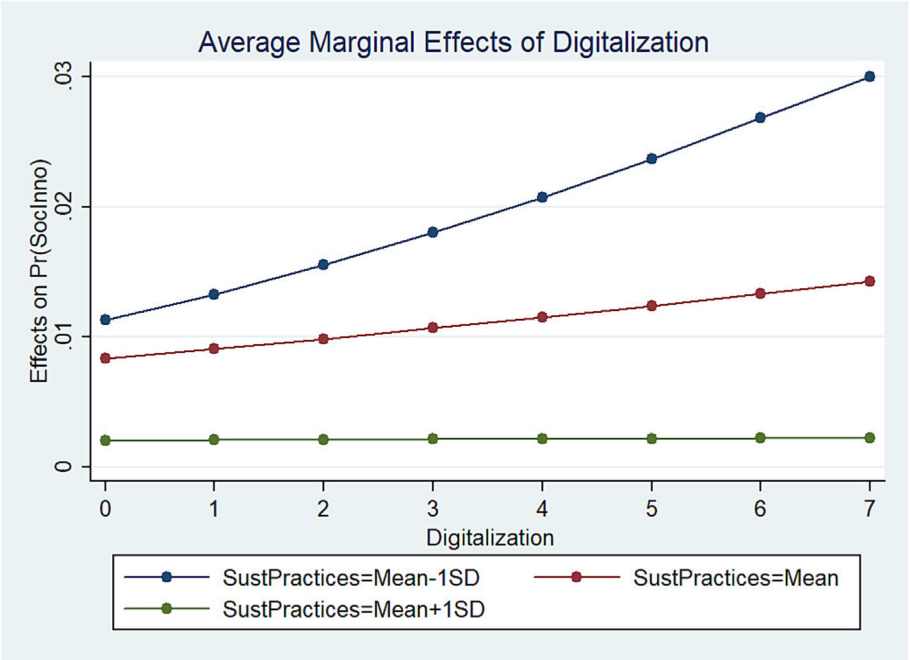


FIGURE 4 Predicted effect of Digitalization against SocInno at different levels of SustPractices.



seems that the launch of environmental innovations is mainly driven by the possibility to gather data through smart devices. Explanations, at least partial, for the non-significance of the other DTs may lie in the fact that they need to be integrated into a comprehensive whole to gain the benefits for sustainable innovations, as revealed by the positive relationship between firm degree of digitalization and the different DVs. Finally, the econometric analysis provides further insights into the non-complementarity of digitalization and sustainability practices, which might relate to the inability to reconcile their logics and/or balance resource commitment towards their adoption. These results may lead to relevant theoretical, managerial, and policy implications.

6.1 | Theoretical implications

From a theoretical perspective, this paper adds to the evolving multidisciplinary discussion about the extent to which digitalization and sustainability megatrends are related at the firm level, given that academics, managers, and policymakers increasingly seek to reconcile their distinct developmental paths. Also, this research answers the calls to study business ethics and sustainability in relation to social, environmental, and economic aspects. More formally, the theoretical contributions of the study lie at the intersection of the literatures on sustainable innovation (e.g., Longoni & Cagliano, 2018), digitalization

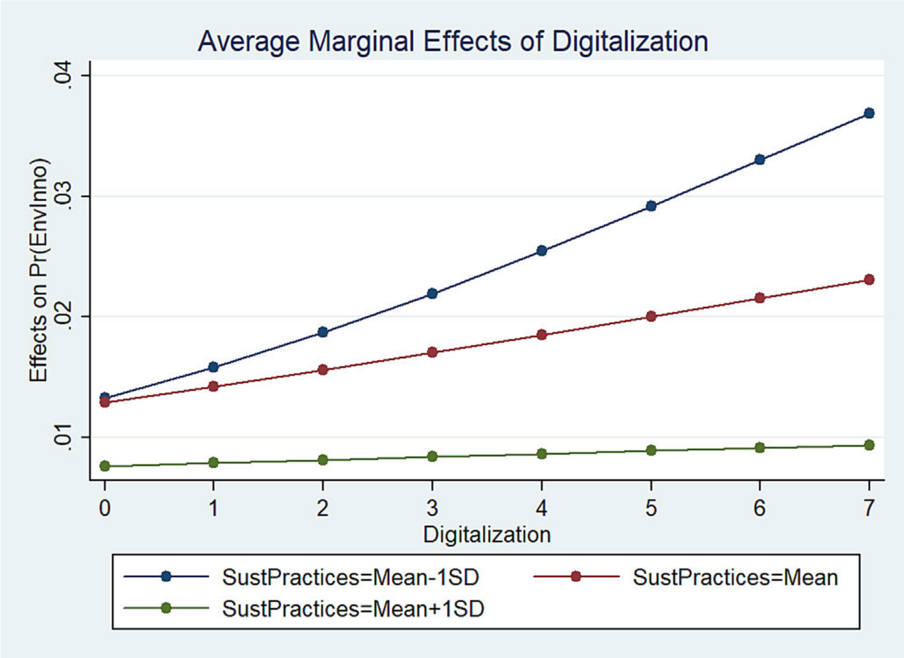


FIGURE 5 Predicted effect of Digitalization against EnvInno at different levels of SustPractices.

(e.g., Lanzolla et al., 2021), and corporate sustainability (e.g., Ameer & Othman, 2012).

More in detail, first, this paper contributes to examine a new antecedent of sustainable innovation at the firm level, that is, digitalization. Indeed, previous studies assessing the effect of digitalization on sustainable development have focused on outcomes different from innovation and/or at more aggregated levels of analysis (e.g., Del Río Castro et al., 2021). In other words, to the best of our knowledge, no studies have linked digitalization to sustainable innovation performance, at least at the firm level and embracing a large-scale, worldwide dataset. Thereby, this study may be considered the first attempt in this sense. Particularly, role of digitalization is assessed in terms of relevance of each DT, also providing a cross-comparison between DTs, and degree of digitalization.

Second, drawing on the emerging need to understand whether and how firms are able to make the efforts towards a digital and sustainable transformation complementary (Ricci et al., 2020), the moderating role of sustainability practices has been considered. This paper corroborates and complements findings by Ardito et al. (2021) and Denicolai et al. (2021), which provided the first empirical evidence on a non-complementarity effect between firm digitalization and sustainability practices, albeit in relation to a different type of performance, that is, sustainable innovation performance.

Third, it is worth mentioning that the notion of sustainable innovation in this paper includes social and/or environmental innovations as performance outcomes. While studies dealing with environmental innovations are more common, those on social innovation are rare (Adams et al., 2016), especially quantitative ones. Thus, a specific contribution to the literature on sustainable innovation pertains to the (largely unresolved) issue of what promotes social innovations, as well as to an improved understanding of the distinctions between factors favoring social innovations versus environmental innovations.

In sum, this study helps provide a more comprehensive picture of digitalization and sustainability, specifically emphasizing how firms in particular frame their relationship. Indeed, "very little is known about how different actors frame the relationship between digitalization and ecological, economic, and social sustainability" (Brenner & Hartl, 2021, p. 2).

6.2 | Managerial and policy implications

Managers and policymakers are advised that digitalization can boost sustainable innovations at the firm level, so it should be promoted (also) for this purpose. In detail, it appears that, ceteris paribus, not all DTs equally contribute to sustainable innovations, especially if either the social or environmental aspects is integrated into innovation strategies. This paper may thus provide guidance to managers in selecting the most relevant DTs for targeting sustainable innovations. Still, integrating multiple DTs, if feasible for a company, seems to be the best option to pursue. At the same time, its non-complementarity with sustainability practices is highlighted, hence advising managers that current digitalization and sustainability practices are still distant and/or managed in ways that do not make them paired. Therefore, firms may look at current practices carefully and seek to understand where/when issues emerge.

From their side, policymakers should further promote a full digital transformation of businesses, hence encouraging and easing the integration of multiple DTs, since it may lead to a positive externality like the launch of sustainable innovations of any kind. At least, the implementation of some of the most relevant DTs underlined in this paper or the most appropriate DTs according to potential sustainable innovation activities firms may want to develop may be financed through appropriate call for projects or tax credits.

Concurrently, policymakers should call for actions and/or projects aimed at reconciling firms' commitment to digitalization and corporate sustainability.

6.3 | Limitations and future research directions

This research has some limitations that may open new lines of inquiry. First, despite the academic relevance of surveys like Flash Eurobarometer and the richness of their information (e.g., no other worldwide surveys assessing the adoption of DTs have been carried put), they are not fully designed for research purposes. Thus, replication–extension studies may rely on novel surveys made for ad hoc research objectives. Second, binary DVs may limit the explanatory power of the study. Indeed, information such as sales from sustainable innovations and/or the relative importance of such innovations over non-sustainable ones may have gained better insights on the role of digitalization. Likewise, binary variables accounting for the adoption of DTs do not allow assessing, for instance, the relative commitment and financial costs underlying the adoption of each DT. Thereby, future research may go beyond the use of binary variables. Third, other contingent factors may be considered from those relevant for both digital transformation and sustainable innovations, such as external knowledge souring, training/hiring of more qualified staff, and partnering with other organizations. Finally, this paper intended to and provides (relevant) preliminary evidence on the multidisciplinary and complex relationship between digitalization and sustainability megatrends. That is, this paper does not want to be conclusive; actually, its results want to lead to more detailed and theory-driven analysis embracing "when," "how," and "why" questions, hence stimulating to open the black box about the influence of firm digitalization on sustainable innovations. Some questions to be answered are: How should firms manage the integration of multiple DTs to improve sustainable innovation performance? How do firms manage and organize sustainable innovation activities based on the adoption of DTs? Why is one DT more relevant than another for sustainable innovations? Why have DTs been adopted by firms in the first place? Concerning the moderating effect, the sign (and significance) found in the analysis implies that the tensions emerging from the concurrent adoption of DTs and sustainability practices in terms of availability of resources, attention allocation issues, and collision of digital and physical aspects of the business are prevalent over the potential benefits of corporate sustainability to guide firm digitalization towards social/environmental value creation. With this is mind, one may further wonder: How may firms relax the tensions between digitalization and corporate sustainability? When/why these tensions occur? Which of the mentioned tensions is stronger than the others?

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CONFLICT OF INTEREST STATEMENT

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX A: DESCRIPTIVE STATISTICS

The 8.35% of the sample firms has launched both environmental and social innovations, the 13.81% of the sample firms has launched environmental innovations only, and the 10.11% of the sample firms has launched social innovations only. This information underlines that firms do not necessarily launch environmental and social innovations at the same time, hence suggesting they are not correlated. Table A1a shows that the 31.32% of the sample firms has not adopted any DT and that the tendency to adopt many DTs (five to seven) is quite low, also compared to the tendency to adopt many sustainability practices (Table A1b).

The sample is composed of firms mainly pertaining to four industry sectors, as manufacturing, construction, wholesale and retail trade, and professional, scientific, and technical activities (see Table A2). Table A2 further shows the share of firms launching both environmental and social innovations, environmental innovations only, and social innovations only. Environmental innovations are more common, except in the sectors of education and human health and social work activities. Moreover, the rate of adoption of each DT per industry sector is presented. According to Table A2, some DTs have been more widely implemented (i.e., cloud computing, smart devices, and high speed infrastructure) across all sectors. The adoption of technologies as artificial intelligence and big data analytics are more instead sector-dependent. The remaining DTs are less adopted in general. Finally, Table A3 presents information about innovation performance and digitalization per country. Environmental innovations are more common almost in all countries. The table mainly confirms the technologies more widely implemented. Cross-country differences among the adoption of DTs can be recognized, especially distinguishing more developed and innovative countries (e.g., Sweden, Norway, and the Netherlands) from those developing and/or less innovative (e.g., Russia, Poland, and Romania).

TABLE A1a Tendency to adopt multiple DTs by firms.

Number of digital technologies	Number of firms	Share of firms
0	4424	31.32%
1	3932	27.84%
2	2744	19.43%
3	1642	11.62%
4	842	5.96%
5	359	2.54%
6	148	1.05%
7	34	0.24%
Tot	14,125	100%

TABLE A1b Tendency to adopt multiple sustainability practices by firms.

Number of sustainability practices	Number of firms	Share of firms
0	1107	7.84%
1	2153	15.24%
2	1694	11.99%
3	1581	11.19%
4	1502	10.63%
5	1614	11.43%
6	1703	12.06%
7	1583	11.21%
8	1188	8.41%
Tot	14,125	100%

TABLE A2 Cross-sectoral analysis.

Sector	Firms per sector		Share of firms launching sustainable innovations per sector			Share of adopting a given DT per sector						
	Number	Share	Social and environmental	Environmental only	Social only	AI	Cloud	Robots	SmartDev	BDA	HSI	Blockchain
NACE Section B Mining and Quarrying	84	0.59%	10.71%	25.00%	8.33%	8.33%	47.62%	9.52%	46.43%	16.67%	23.81%	4.76%
NACE Section C Manufacturing	2843	20.13%	9.15%	17.13%	9.81%	8.65%	46.64%	19.77%	34.29%	14.21%	32.01%	3.90%
NACE Section D Electricity, Gas, Steam and Air Conditioning Supply	82	0.58%	12.20%	25.61%	8.54%	9.76%	51.22%	13.41%	45.12%	21.95%	46.34%	3.66%
NACE Section E Water Supply, Sewerage, Waste Management and Remediation Activities	133	0.94%	12.78%	15.79%	6.77%	3.76%	46.62%	8.27%	33.08%	18.05%	19.55%	2.26%
NACE Section F Construction	1414	10.01%	6.01%	12.73%	6.93%	4.46%	42.64%	4.67%	25.39%	6.44%	26.31%	1.63%
NACE Section G Wholesale and Retail Trade	4057	28.72%	8.97%	12.25%	10.97%	5.94%	44.61%	6.58%	25.63%	14.62%	33.62%	3.18%
NACE Section H Transporting and Storage	807	5.71%	5.70%	16.60%	6.69%	5.45%	40.77%	2.23%	27.76%	11.90%	29.00%	2.85%
NACE Section I Accommodation and Food Service Activities	788	5.58%	9.64%	17.13%	8.76%	5.08%	37.31%	3.43%	24.87%	10.41%	29.57%	1.65%
NACE Section J Information and Communication	560	3.96%	6.07%	10.18%	15.89%	25.89%	75.71%	8.75%	35.54%	33.57%	56.43%	8.75%
NACE Section K Financial and Insurance Activities	316	2.24%	11.71%	14.56%	7.59%	11.71%	68.04%	11.08%	30.06%	25.95%	53.16%	6.01%
NACE Section L Real Estate Activities	318	2.25%	10.06%	17.30%	6.60%	8.18%	56.29%	3.46%	30.82%	15.41%	41.51%	3.14%
NACE Section M Professional, Scientific and Technical Activities	1371	9.71%	5.84%	11.74%	9.26%	11.82%	62.22%	8.02%	22.98%	16.34%	40.04%	3.72%

TABLE A2 (Continued)

Sector	Firms per sector		Share of firms launching sustainable innovations per sector			Share of adopting a given DT per sector						
	Number	Share	Social and environmental	Environmental only	Social only	AI	Cloud	Robots	SmartDev	BDA	HSI	Blockchain
NACE Section N Administrative and Support Service Activities	619	4.38%	7.92%	9.37%	10.02%	7.43%	55.41%	5.49%	24.88%	15.35%	36.67%	3.23%
NACE Section P Education	194	1.37%	12.89%	9.79%	19.59%	6.19%	53.09%	7.73%	26.29%	16.49%	36.60%	2.06%
NACE Section Q Human Health and Social Work Activities	358	2.53%	8.94%	8.94%	22.35%	5.59%	51.12%	6.15%	29.89%	17.32%	32.96%	3.35%
NACE Section R Arts, Entertainment and Recreation	181	1.28%	12.71%	14.36%	10.50%	8.84%	46.96%	4.42%	30.39%	10.50%	32.04%	0.55%
Total	14,125	100.00%										

TABLE A3 Cross-country analysis.

Country	Firms per country		Share of firms launching sustainable innovations per country			Share of adopting a given DT per country						
	Number	Share	Social and environmental	Environmental only	Social only	AI	Cloud	Robots	SmartDev	BDA	HSI	Blockchain
FR	443	3.14%	9.48%	16.70%	14.00%	9.03%	48.76%	10.84%	19.19%	10.16%	55.53%	3.61%
BE	405	2.87%	8.64%	22.72%	6.67%	9.88%	60.25%	11.11%	31.60%	15.31%	29.63%	2.96%
NL	435	3.08%	12.64%	15.86%	12.18%	12.64%	71.49%	13.33%	40.69%	24.14%	58.16%	8.05%
DE	426	3.02%	7.75%	23.00%	5.87%	8.69%	51.88%	10.09%	32.86%	9.62%	44.84%	2.58%
IT	413	2.92%	1.94%	7.51%	4.12%	3.39%	22.52%	2.42%	9.44%	4.12%	11.14%	0.97%
LU	178	1.26%	20.79%	14.04%	15.17%	19.10%	56.18%	7.87%	29.78%	20.79%	65.17%	8.43%
DK	447	3.16%	10.74%	19.46%	8.50%	10.29%	62.42%	14.77%	23.49%	22.37%	34.00%	2.24%
IE	384	2.72%	14.84%	15.10%	13.54%	9.38%	61.98%	7.03%	44.53%	17.19%	47.40%	5.73%
GB	371	2.63%	9.70%	14.56%	12.13%	7.55%	58.76%	5.12%	32.61%	14.29%	34.50%	2.43%
GR	459	3.25%	4.14%	8.28%	7.41%	5.01%	45.32%	4.36%	23.31%	19.39%	47.06%	5.45%
ES	459	3.25%	15.90%	17.21%	14.60%	11.76%	59.91%	15.03%	31.37%	15.47%	51.85%	5.66%
PT	437	3.09%	14.65%	16.48%	16.48%	8.47%	52.63%	9.15%	24.49%	11.44%	41.19%	4.35%
FI	464	3.28%	9.05%	17.46%	9.91%	12.93%	62.72%	14.87%	30.82%	19.18%	30.17%	2.59%
SE	443	3.14%	10.16%	18.06%	9.03%	11.29%	75.62%	14.00%	31.83%	18.96%	39.95%	2.71%

(Continues)

TABLE A3 (Continued)

	Firms per country		Share of firms launching sustainable innovations per country			Share of adopting a given DT per country						
Country	Number	Share	Social and environmental	Environmental only	Social only	AI	Cloud	Robots	SmartDev	BDA	HSI	Blockchain
AT	438	3.10%	9.82%	18.49%	7.08%	10.50%	47.95%	11.42%	30.14%	16.67%	38.58%	5.02%
CY	181	1.28%	2.76%	9.94%	11.60%	6.63%	44.75%	6.63%	23.20%	20.99%	59.12%	2.76%
CZ	376	2.66%	8.78%	19.95%	12.50%	6.65%	45.21%	8.51%	29.79%	15.43%	30.59%	1.60%
EE	428	3.03%	2.57%	11.21%	5.37%	2.57%	44.86%	7.94%	22.20%	8.41%	44.39%	1.40%
HU	436	3.09%	2.29%	12.16%	3.21%	1.38%	36.01%	5.50%	33.49%	3.90%	18.35%	0.69%
LV	467	3.31%	8.57%	19.70%	10.49%	5.35%	52.46%	9.21%	25.91%	16.92%	32.33%	4.07%
LT	455	3.22%	0.44%	4.62%	6.15%	1.32%	30.11%	3.74%	17.58%	5.93%	4.40%	0.66%
MT	155	1.10%	10.32%	13.55%	14.19%	6.45%	45.16%	7.10%	31.61%	12.90%	30.97%	3.87%
PL	436	3.09%	10.55%	16.74%	8.94%	6.65%	31.42%	9.86%	27.29%	16.28%	10.32%	2.06%
SK	379	2.68%	7.65%	14.51%	8.97%	6.07%	29.82%	7.92%	22.69%	10.55%	22.16%	1.58%
SI	461	3.26%	4.56%	12.15%	10.85%	6.51%	56.18%	9.98%	36.44%	11.50%	16.05%	2.82%
BG	388	2.75%	9.79%	16.49%	9.28%	4.12%	40.98%	8.25%	24.74%	14.43%	20.36%	2.32%
RO	440	3.12%	3.41%	6.14%	8.64%	5.45%	18.86%	7.50%	17.50%	10.23%	22.95%	3.64%
TR	267	1.89%	16.85%	10.49%	16.85%	12.36%	45.69%	12.73%	52.81%	17.60%	41.95%	9.36%
HR	473	3.35%	2.11%	6.98%	8.67%	4.02%	43.97%	4.02%	21.56%	11.84%	21.99%	3.81%
MK	196	1.39%	2.04%	8.67%	2.55%	3.57%	39.80%	5.61%	24.49%	13.27%	7.65%	1.53%
RS	188	1.33%	2.13%	7.45%	3.72%	1.60%	22.87%	6.38%	19.68%	7.45%	13.83%	1.06%
NO	250	1.77%	11.20%	15.20%	10.80%	15.20%	78.40%	10.00%	31.60%	17.20%	62.00%	2.00%
IS	163	1.15%	23.93%	14.11%	17.18%	11.04%	77.91%	13.50%	41.72%	24.54%	84.05%	3.07%
JP	242	1.71%	2.48%	13.22%	5.79%	3.72%	33.06%	4.96%	12.81%	3.72%	24.38%	4.55%
US	445	3.15%	6.97%	6.97%	13.03%	10.56%	58.88%	8.09%	36.85%	16.18%	44.27%	4.04%
BR	293	2.07%	22.18%	9.56%	25.94%	17.06%	72.01%	7.51%	34.47%	37.20%	50.51%	4.44%
BA	191	1.35%	1.57%	3.14%	7.85%	4.19%	26.18%	4.19%	24.08%	13.09%	10.99%	0.00%
RS-KM	179	1.27%	0.56%	17.32%	12.29%	11.73%	14.53%	10.61%	8.94%	21.23%	15.08%	2.79%
CA	434	3.07%	9.22%	10.83%	12.21%	11.06%	49.77%	8.53%	39.40%	16.59%	43.09%	4.38%
Total	14,125	100.00%										