CHAPTER 1

Digital and Sustainable Transformation: An Outcoming Response to the Pandemic

Salvador Estrada and Juan Reyes Álvarez

1.1 Introduction

At the end of 2019, the World was awakening from the Great Crisis. In Digital Economic, the discussion was on how to tax digital services while in climate action and sustainable development, developing the transition toward a sustainable, carbon–neutral Economy. Severe Acute Respiratory Syndrome Coronavirus 2 and its variants keep the World on a permanent fight against a health crisis leading the Economy to a permanent shock.

S. Estrada (✉)
Department of Business and Finance,
University of Guanajuato, Guanajuato, Mexico
e-mail: sestrada@ugto.mx; salvador.estrada@gmail.com

J. Reyes Álvarez
Faculty of Economics, Benemérita Universidad Autónoma
de Puebla, Puebla, Mexico
e-mail: juanreyesalvarez@hotmail.com

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The measures for contending the pandemics have included several lockdowns of economic activities extending digital activities and restraining environmental impacts. While the first has been chosen intentionally in search of normality, the other has been a secondary effect, unintended but highly revealing of the catastrophe in progress. This double reaction encloses a timely and convenient change toward accelerating an underway transformation. Improving the knowledge of this dual Digital and Sustainable Transformation is a pending task to enhance the World's resilience capacity to cope with crises.

Since there is a lack of studies showing the emergence of digital and sustainable transformation, this work aims to pursue a systematic review to foresee a research agenda and future development of this double transformation in a Post-COVID World. A thorough examination of the state-of-art is presented to accomplish this objective. A bibliometric analysis is then prepared to structure the research topics and develop insights on the becoming of the research on Digital and Sustainable Transformation. The transformation is in transitional mode impacting the economic dimension of sustainability and gaining momentum through an ethical and relational view of the innovation process and business models crafting opportunities to pursue environmental and societal impacts on sustainability. The challenge is open to harnessing a complex and systemic phenomenon with many expectations to lead word recovery from the pandemic outbreak.

1.2 Literature Review

1.2.1 The Digital Transformation as a Point of Departure

Worldwide there has been an increasing interest in digital transformation. As soon as 2015, prominent organizations and consulting firms, such as World Economic Forum and MIT or Deloitte and Accenture [1], have stressed the irruption of the phenomena. A 2017 survey showed that at least 50% of firms planned to adopt a digital transformation strategy among multinational enterprises.

As a matter of study, digital transformation has been treated as a change process. In private and public sectors and the social domain, modern communication and information technologies have been adopted as changes in the performance, structure, and culture of individuals, organizations, and ecosystems have been taking place. These changes have

not been neutral for society but threaten, replace, and complement the existing rules of the game.

The consequences on society and economics are being studied. At least three views may be mapped: an institutional focus, a business approach, and a technological perspective [2]. Digital transformation is a systemic phenomenon and, according to the first view, has been changing ground rules within organizations, ecosystems, and industries [3]. The second one warns of new and disruptive incumbent business models, value chains, organizations' advantages, and business activities, ranging from agriculture to manufacturing and tourism, among others [4]. The third venue is related to the outcomes of digital technologies adoption, provoking radical changes and driving innovation mostly when the physical World begins to be connected through the cyberspace. For example, we can mention domestic appliances, manufacturing equipment, medical devices, tourism attractions, or city utilities integrated on Internet of Things platforms [5].

Despite the potential advantages in the literature, few companies have adopted purposeful strategies to pursue significant achievements [6]. Some authors match this transformation to an Industrial Revolution or a productive paradigm named Industry 4.0 [7]. Several authors identify some outcomes of integrating digital technologies into business processes, including product efficiency, productivity increases, and the developing of new business models. These advantages go along with improved flexibility and customization. Sustainability enhancement is also foreseen as an outcome as socio-environmental functions are adopted, and triple bottom responsibility is considered in the companies [8]. Businesses must focus on energy sustainability, reducing harmful emissions, resources, waste-friendly management, and social welfare improvements [9–11].

1.2.2 The Twin Sustainable Transformation

This work must track back to eco-innovation, since digital is based on technical change, to look at the origins of the current sustainability wing in the ongoing digital transformation. Since the innovation-competitiveness paradigm originated in the 90s, eco-innovation research has been developed [12–15]. As determinants and outcomes of eco-innovation have been studied [16–20], it has been shown that the adoption of digital technologies drives this type of innovation [21].

In pursuing competitive advantages and improved experiences, the adoption of digital technologies is an allied, and extended to the ecosystem may accomplish significant gains in sustainability and quality of life, facilitating the put-on practice of Circular Economy and the improvement of safety conditions [5, 22]. As industrial plants are becoming complex digital systems, the transversal aspects of industrial management, such as sustainability and energy, shall be levered and improved as connectivity, data analysis, and automation are extensively integrated with the facilities. However, industries must note that effectively fostering implementation is not simple [23]. The use of visualization software and 3D simulation facilitates and improves human–machine interaction increasing workers' comfort and safety while anticipating mistakes and minimizing times and production costs [22]. The digital technologies let business operations servitization leading to a structural division of work where major economies move from mass to customized production, and new models of organization stem interactions of agent–machines–organization are core to production. In contrast, the ongoing digital transformation may endanger developing countries and isolate small businesses by reducing employment [24].

Furthermore, literature reviews recently conducted [2, 25], and [26] show that digital transformation is changing radically value chains and manufacturing environment, where emergent and the recurring topic is sustainability and sustainable development. The Industry 4.0 tools and applications may permit the achievement of enduring sustainability, but there is a lack of studies on the social and environmental dimensions impacts [26, 27]. Since a pre-COVID expectation was to achieve economic, social, and ecological gains due to digital transformation [28], our insight and stake are that the sustainable part of the double transformation may express on increasing resources running out and society anxiety augmenting scenario as the prevailing pandemic one we are currently facing.

1.3 Materials and Methods

The present review aims to achieve a bibliometric analysis of trends and research topics in 2018–2021. The following overview is based on a systematic literature review utilizing the academic Database Elsevier

Table 1.1 Queries for data search

Queries	*Terms in Title, Abstract, or Keywords*	*Number of hits*
1	"digital transformation" AND "sustainable transformation"	2
2	"digital transformation" AND ("sustainable transformation" OR sustainability)	239
3	"digital transformation" AND ("sustainable transformation" OR sustainability) AND innovation	75

Source Own elaboration based on Scopus queries

Scopus. We have used a network analysis technique based on the authors' keywords, and from the results obtained, we arranged a focus group discussion to identify the trends and topics.

Regarding the database used in this review, the source Scopus is one of the two main commercial-academic databases. This source asserts to be the largest (7.8 million records) in its class and offers broader coverage, according to several studies [29]. Also, it claims to keep on with the different research communities' interests and needs due to its Content Selection and Advisory Board formed by scientists, researchers, and librarians from the major scientific disciplines [30]. The quality of its metadata and the ease of information extraction make it suitable and reliable for bibliometric analysis [31]. The limitation is that English-language journals are overwhelmingly represented but show superiority in non-English literature and regional coverage compared to Web of Science [32] (Table 1.1).

We have done our research-based in three phases to get a literature corpus on digital and sustainable transformation. We have tried three different search algorithms. The first attempt was to assess the double transformation literature directly, but there were few results. Then, we broadened the search, including a much more common term, but the result folded more than a hundred times. Finally, we added a new term from this search to specify our intent for finding the trends through the newness, so we get a manageable set of entries.

1.4 Results

The conducted search algorithm throws 75 publications to accomplish all the proposed terms and restrictions. The VOSviewer software maps three keyword clusters digital transformation and sustainability, innovation and Industry 4.0, sustainable development, and smart city/cities). But there were common areas around the double transformation: the topics on innovation and Industry 4.0 while digitalization is more related to digital transformation, and smart cities to the sustainable transformation. In this array, the authors proposed 631 different keywords. Twelve occurred at least within five documents and 80 at least in two. The most common keywords are Digital Transformation appearing in 42 papers, sustainability with 26 occurrences, and development with 17 appearances (Fig. 1.1).

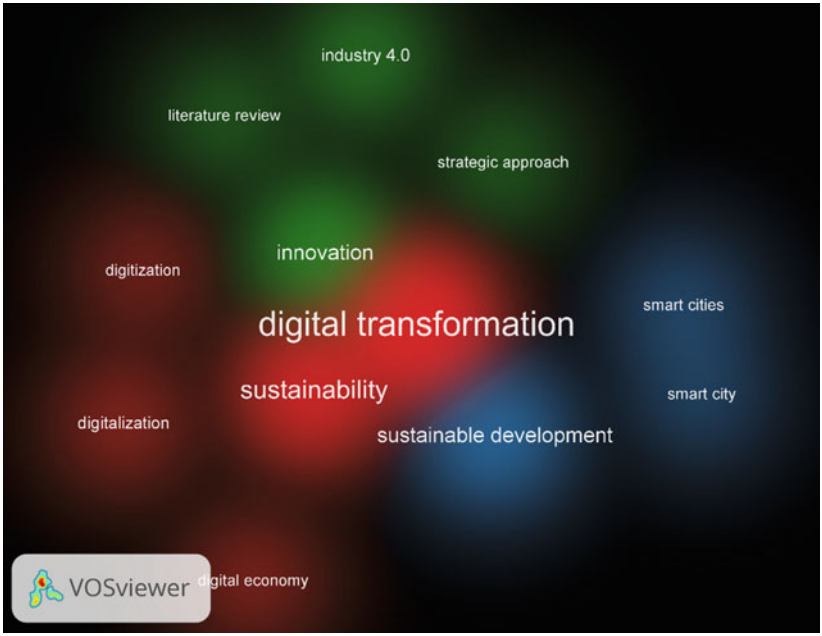

Fig. 1.1 Keyword co-occurrence map (*Source* Own elaboration based on the VOSviewer map generator)

The production is highly concentrated in Europe, particularly in the Mediterranean countries (Italy and Spain) and the German-speaking countries. Among the Anglo-Saxon countries, the United Kingdom is at the head of interested countries. In Asia, China is the leader in publications, as in Oceania, Australia has the lead. In other parts of the World, the topic seems to be nascent, as in the United States and Russia, Asian South-eastern countries, Arab countries, and Latin America.

Considering the academic institution of adscription of researchers, we have found dispersion worldwide showing a nascent topic more of the interests of the individuals or groups research located at specific universities that in many cases represents the whole country's figures. In the United States, since 2014, the Commission has provided several measures to foster a digital transformation and, later in 2020, established a digital decade while it has engaged in a neutral climate strategy to 2050. In the academic realm, our analysis highlighted the interest in Italy (groups located in Milano, Rome, and Pisa, to mention a few), Spain (mainly in Madrid and Barcelona), Germany (especially in Berlin, Baden Wurttemberg, North Rhine-Westphalia), and the United Kingdom (Newcastle upon Tyne, Manchester, and Edinburgh, among others).

The main documents, because of their number of citations, are Pappas [33], Ghobakhloo [7], Abad-Segura [34], and Savastano [6], with more than 25 publications citing each work. Nevertheless, each document provides different influences and topics to the digital and sustainable transformation field as their sharing citations referred. Several clusters appear if we use a bibliographic coupling network to measure similarity among documents. Our most cited paper, Pappas [33], is in the field's periphery. Its main ideas are to adopt big data analytics technologies and work in alliance with several actors to provide an ecosystem of change, facilitating the digital transformation of a sustainable society. This proposition is among documents highlighting the topics of precision agriculture and smart city, especially in the planning and the objective of creating value (Fig. 1.2).

Concerning Abad-Segura [34], it leads a cluster of documents practicing literature review exercises, shedding light on the interaction among management, digital transformation, and sustainability. The business research provides a kaleidoscope view of the actual application of digitization technologies among management activities ranging from finance to marketing and innovation, impacting diverse economic sectors, especially manufacturing, tourism, and higher education. There is a gap in

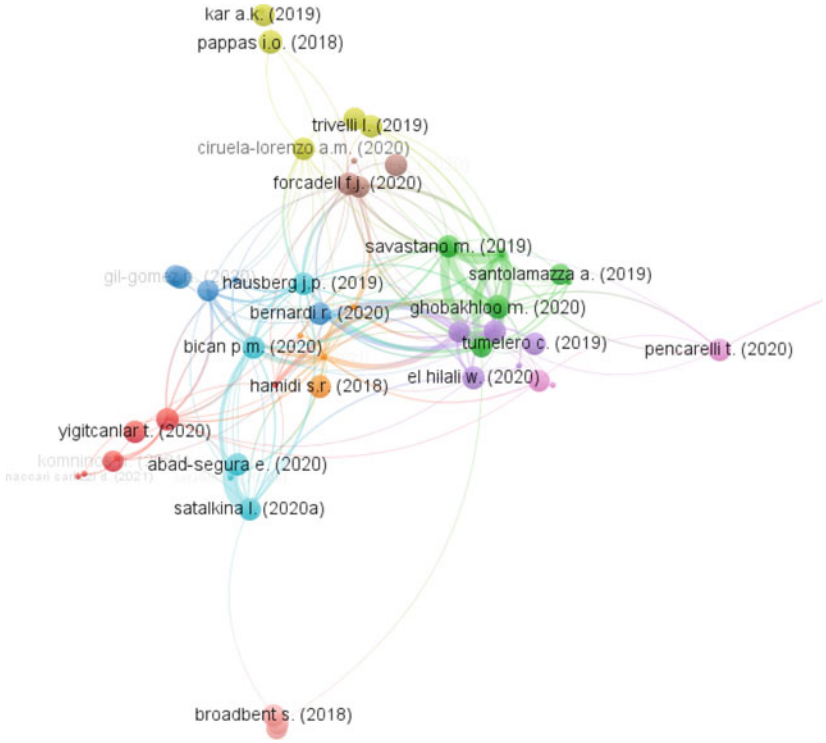

Fig. 1.2 Bibliographic coupling network (*Source* Own elaboration based on the VOSviewer map generator)

the knowledge on how digitalization is transforming other activities and sectors. However, it is core to sustainable growth and strongly contributes to other related phenomena like entrepreneurship, innovation, and business model development. These may be related to an encompassing process of digital transformation that may deploy through several stages, highlighting the importance of readiness and maturity models to diagnose the actual stake of enterprises and the feasibility of expanding ideas to models, content, and theories of superior complexity as business models, ecosystems, and innovation systems.

Finally, in this network, Ghobakhloo [7] and Savastano [6] are located close to the center, showing an important influence on digital and

sustainable transformation. Their cluster of related documents underlines Industry 4.0 as a capital term, playing a structuration role in the double transformation. They signal the dramatic changes in the manufacturing environment and value chains with the use of digital technologies and the potential gains in the efficiency, customization, flexibility, and sustainability of the production and operations. In brief, they strengthen the open opportunities to improve performance and note the critical strategies to empower humans in inclusive digital solutions. Digital innovation and technology developments seem essential to harness value-added to corporate sustainability strategies. This review proposes a field synthesis according to the following terms grouped in the next subsections considering the keyword co-occurrence map and the bibliographic coupling.

1.4.1 Digital Transformation

Our review reveals that in the digital transformation literature, the topic of the double transformation appears under two notions. The first provides a vision of the future and a strategic perspective on its sustainability, and the second an environmental, societal, human, or inclusive view of sustainable development. We can derive the second interpretation of these views as a process and outcome interplay. The quest for sustainability is explained in business resilience, marketing, production and operation of products and services, and response to consumer awareness.

For Wang [35], due to the COVID-19 pandemic, the notion of recovery is consubstantial to global sustainable development, and this only can be obtained by nurturing a green and digital transformation. So, investing and planning industrial development must attain this double purpose. In their interpretation, this transformation consists of the digital technologies' usage seeking green and inclusive growth. Meanwhile, for Pappas [33], achieving digital transformation must lead to the development of sustainable development. They signal the business compromise to search for shared value and adopt a corporate social responsibility.

Another point of view is to ubicate the digital and sustainable transformation into a higher level of analysis from a macro and systemic perspective. Li et al. [36], studying the Digital Economy, argue that sustainability is an unintended effect of coupling the Digital Economy with a real-life Economy. An example may be the challenges around the sustainable production of energy, the demand for sustainable housing, the

growth of ride-sharing services, or the efforts from grass-root innovations to attain the United Nations' 2030 Agenda for Sustainable Development.

For Pappas [33], the dual transformation can occur as Big Data and Business Analytics ecosystems evolve. Stakeholder needs can drive this dynamic, further stakeholder aggregation, a process of enhancing developed capabilities, and societal sustainability being envisioned as the overarching goal. Literature can suggest a more concise idea in Satalkina's [37] arguments on the impact of digitization on innovation systems, extending beyond the mere rethinking of business models to restructuring competition and forms of networking arrangements. Thus, increased interaction and aggregation are paramount to trigger the double transformation. In line with Pappas [33], Caldarelli [38] points to capabilities as key to implementing sustainable blockchain-based supply chains, addressing knowledge management capabilities as crucial in the reliability and transparency of information due to the source of origin of the information, not stored on the blockchain, but in its environment collected through physical assets.

A micro vision emerges in managing data, resources, and demand, i.e., operations and production management [25], where efficiency, savings, and sustainability are expected to be achieved simultaneously in the activities of use, exchange, organization, and recycling.

The third approach is to search for a causal relationship between digital transformation and sustainable transformation. For example, following Ghobakhloo [7], the Industry 4.0 implementation offers opportunities to achieve sustainability, but economic sustainability seems to be reachable as an immediate outcome, reflecting on the impacts on productivity and business model innovation. Meanwhile, socio-environmental sustainability outcomes remain lagging as Industry 4.0 sustainability functions, like social welfare improvement, harmful emissions reduction, or energy efficiency, are considered secondary to delivery.

Another point of departure is proposed by Wang [35], where the relationship can be seen as a double game. Digital transformation acts as an enabler of sustainable transformation, but also digital transformation performs as a challenge to sustainable development because of the share of ICTs on global energy consumption.

Zehir and Özgül [28] suggest double causation with two-way directionality. In one way, Industry 4.0, its paradigms, and related technologies have several outcomes in performance that are translated into economic, social, and environmental gains. On the other, the severe

damages inflicted on the environment by productive activities (i.e., natural resources increasingly become to be exhausted, the life-cycle has been shortened by fierce competition, and mental illness is growing because of the social stress charge and anxiety) has been forcing the development of Industry 4.0.

Another position, complementary to Wang [35] but more deployed, is to look at digital technologies as enablers of sustainable transformation. This process entailed understanding how organizations must change to embrace digital technologies and reach societal changes [33]. So, these technologies may be headed by Big Data Analytics to convoy value for developing sustainable societies.

Another approach to this venue is Yigitcanlar et al. [39]. These Australian authors assert that Artificial Intelligence related technologies (Big Data, Automation, and Robotics) used in urban planning and development may lead to the digital transformation and sustainability of cities, so according to Naccari Carlizzi and Quattrone [40], public administration requires to invest purposefully on innovation and digital management to facilitate and prepare these technologies usage.

Within the Malaysian experience, Hamidi et al. [41] seek to measure SMEs' maturity level to embrace Industry 4.0. Under the expectation of gaining opportunities to sustain current competitiveness, they developed the idea that becoming proficient in digital technologies opens opportunities for pursuing sustainable industrial value creation through sustainability's economic, social, and environmental dimensions.

El Hilali [42] shed light on the drivers of the double transformation of Moroccan SMEs, customers, data, and innovation. They prove they are significant for digital transformation and, simultaneously, to the commitment to sustainability. They also support the idea that innovation, particularly radical changes in business models, plays a digital and sustainable transformation role. They underline that customer experience and client-centricity strategy, data analytics, and shifting innovation business models guide the digital transformation journey toward sustainability.

1.4.2 Innovation

The innovation category shows three factors related to the double transformation: the business model innovation, the business process innovation, and sustainable innovation. New business models are an outcome of a digital transformation—the use of data, digital technologies, and

entrepreneurial mindset–of products, processes, and business. But to foster sustainable processes and practices, the management must put cognitive abilities to anticipate, visualize, and exploit opportunities on the triple bottom line dimensions of sustainable development and value creation [6, 43]. The digitalization of activities provides the opportunities to align and save resources, connect different players and machines, coordinate stakeholders in the value chain, enhance productivity, and improve product quality and organizational performance. But according to Karimi [43], the digital business model, the digital entrepreneurship, or Reis-Marques [44], the digitally enabled innovation requires a deeper understanding of where the value is and how value is created and delivered to foster sustainability and development. So, there seems to be a sequential interrelation between digitalization, innovation, and sustainability.

In resuming the second strain about business process innovation, the literature searches on the role of the "digital" in achieving the twin transformation [45]. In one part, the authors state that it is capital for sustainable development and the Circular Economy. It shall be part of any innovation in the future, and digital innovation leads to new sustainable business models. In exploring how business processes digitalize and how the digital enables innovation, they signal as fundamental drivers of this transformation, the technology, the strategy, the culture, the business model, the readiness, the entrepreneurial spirit (opportunity seeking and foresight cognitive ability) as the environmental restrains, that address the reconfiguration of the value chain and the manufacturing processes [6, 44–46]. These considerations may have positive impacts, such as saving or reducing the use of resources, deepening customer interaction and inclusion, and avoiding waste, or negative ones, like a higher energy demand, labor replacement, or customers' mistrust.

From this strain, Agasisti [46] developed a case to show how the COVID-19 outbreak prompted digital innovation and how this supports sustainability. On the other hand, Broadbent [47] proposed that innovation creates a space for a digital culture of sustainability. The most popular areas for applying Artificial Intelligence in urban development and planning are digital transformation, innovation, and sustainability [39]. In the view of Forcadell [48], the digitalization of banking services changes the business model by narrowing its boundaries due to costs, transactions, and uncertainty reduction and widening its scope through improving services design and developing new services in new markets that leads to

inclusion and environmental care. In the tourism industry, digital technology usage and infrastructure have changed game supply and demand rules. These changes had reconfigured the value chain, enhancing client information and integrating destination services, putting pressure on environmental care, the quality of life, and corporate responsibility, but also on the possibilities to innovate from the diverse stakeholders intervening in the smart destination competitiveness [5, 49].

Similarly, smart cities literature refers to the innovative use of digital technologies to reach a more inclusive and sustainable ecosystem [50]. Reis-Marques and Popovic [44] consider strategy's main role in digitally enabled innovation. In this venue, Di Vaio's [51] work set up knowledge management systems as an enabler of digital innovation that may lead to value creation on sustainability. In the same venue, Mihardjo [52] signals that the core variables to drive a business model innovation toward sustainable development are customer experience orientation, organizational agility, and organizational efficiency.

In addition, another strand of the literature points to the resistance to adopting IT innovations in the healthcare sector. The problem arises in the tension between the management and the institutions [53]. So, organizations must cope with paradoxes in implementing the digital transformation and the digital innovation adoption process. According to Smith and Beretta's [54] case study of a large firm, these may be of an organizational or knowledge nature. A willingness to change and commitment is essential to change management practices and participate in learning experimentation with stakeholders [55].

El Hilali [42] points out that changes in business model innovation are essential to reach digital and sustainable transformation. De Bernardi [56] shows examples of the food sector. Li et al. [36] work on a case to show how implementing a digital twin platform network may lead to an innovative sustainable business model in the home appliance sector. In the same sense, Gil-Gomez [57] argues that CRM is a way to reach sustainable business models. Similarly, Caldarelli [38] develops a case on how blockchain adoption leads to sustainable business models in the Italian Agri-food sector.

Savastano's [6] paper surveys the digital manufacturing ecosystem and reveals that innovation processes enable digital transformation. These may occur in logistics, continuous improvement, standardization needs, lifecycle management, customer-driven activities, safety assessment, or the

business model. These authors consider additive manufacturing technologies [6] as a radical innovation enabling cost reduction, shortening lead time, reconfiguring the supply chain, improving product customization, and facilitating sustainable remanufacturing practices and recycling. In the digital manufacturing ecosystem literature review, Savastano [6] highlights innovation processes as emergent technologies and innovation and technology management and process innovation as a rising research area.

The last category, sustainable innovation, refers to the purpose and impact of innovation on the triple bottom line dimension [6]. The digital innovations push organizational changes and business model reconfigurations, paving the way for sustainable gains related to faster market responses and client and user involvement. But research must review the readiness of the business models and their sustainability impacts in terms of economic and environmental effects because not all digital innovation may be manifested in a sustainable positive way [45]. Addressing innovation toward client requirements may require novel design methodologies, as proposed by Lee [58]. For another part, there is evidence that eco-innovation may represent the environmental line and that this type of innovation, related to a product or organization, positively influences the socio-economic performance of manufacturing [21]. The tourism literature believes that value creation and delivery by digital technologies and innovation must be attached to sustainability to maintain competitiveness and smartness for destinations [5, 59]. A complementary point of view is Salminen [60], who sustains that responsible business leadership drives digital innovation to respond to the Circular Economy. This ethical and socio-relational model seeks to preserve and restore resources, optimize efficiency, offer life-cycle services, foster sustainable solutions co-create, and may profit from digital technologies' potential. Living labs may be valuable in implementing these solutions, keeping innovation, digital and participation, and engaging in the Circular Economy paradigm [61].

1.4.3 Sustainability

In this branch of literature, sustainability is treated as the environmental, social, and economic complex of the triple bottom line [7, 21, 25, 62], the effort to persevere with the digital transformation of ecosystems, business models and innovation processes [63, 64], and the way to keep creating or increasing profitability [41].

Tumelero's [21] paper on eco-innovation shows that the triple bottom line environmental issue represented by this type of innovation impacted the social and economic results and raised the topic of how Industry 4.0 and the Internet of Things may trigger the efficiency of this kind of innovation. The current trends and design principles of Industry 4.0 show that this transformation is converging toward sustainability, but the economic dimensions of the triple bottom line have been much reachable. However, its environmental integrity and human impact performance take more time to achieve. There may be some unforeseen and unintended consequences, so some public policies are desired to prevent the harmful effects on Earth's ecosystems and the quality of life [7].

A clue to preserving digital transformation has to do with developing capabilities. In the base of maturity models, there is the idea that organizations may pass through several stages that represent the mastering of a series of capabilities or a performance achievement. Its first building block may be human resources, as the work of Ghobakhloo [7] suggests. The following stages may enable flexibility, productivity, and resource-friendly production. This performance may be related to strategies focusing on client experience and centricity, data analytics capabilities, and shifting innovation to business models [42].

Pencarelli [5] and Mihardjo et al. [52], in very different settings, tourism sector, and multidimensional model, propose a transitional model where digital technologies adoption is not enough to reach sustainability and underline customer and organizational agility as key issues to attend. Agasisti et al. [46] assert this view and complementary adds a strategic orientation and cultural openness based on an Italian higher education case.

Forcadell [48] states that digitalization triggers fierce competition and new technological players in the bank sector, but these processes present disadvantages. The uncertainty generated by new services and providers associated with technical changes, the clients' renewed concerns about their privacy and security, and the mistrust of non-person-to-person interactions besides fear of opportunistic usage of personal information. These can be superseded by the reputation gained through digitization and corporate sustainability. Through reputation, firms may enhance trustworthiness, provide a credence factor to clients, and facilitate people's endorsement through word-of-mouth and third-party assessment.

1.4.4 Industry 4.0 (I4.0)

This section focuses on remarking the research trends and results according to selected texts on I4.0. At least two common elements are observed. In principle, they assert that I4.0 will optimize the production and distribution processes, which leads to less use of material and human resources and a decrease in time. These savings involve cost reduction and increased productivity. So I4.0 has important effects on the economic sphere of sustainability. On the other hand, this strain of literature assumes that I4.0 will positively impact the other areas constituents of the three-bottom line.

Regarding this approach, some papers focus on a documentary review (some interviews with experts are included) to observe research trends. Savastano et al. [6] aim to analyze 156 documents on the digital manufacturing ecosystem. The authors identified five clusters of technologies within the digital manufacturing ecosystem, in parenthesis the proportional importance: additive manufacturing (46%) and digital tools (29%), followed far below by ICT (13%) and innovation processes (10%); in the end, the tools of design (2%). On the other hand, the research identified 22 research domains (research areas); the main four are innovation and technology management (16%), value chain management (15%), process innovation (9.6%), and economics of production (9.6%). It stands out that sustainable development appears in eighth place as a theme of the reviewed literature (4.5%). The document emphasizes that although there is a growing research interest, the issue of sustainability (in its different domains) is little studied.

On the other hand, the paper by Felsberger and Reiner [25] carried out a documentary review of 89 documents. It proposed a classification of four themes: smart factory technologies (57%), conceptual and theoretical elements about I4.0 (45%), data-driven technologies and process optimization (39%), and technologies for the production floor (16%). Regarding the issue of sustainability, 47 papers out of 89 address this issue in at least one of its three pillars. The document finds that 23 have the economic and environmental as their main axis, 12 refer to the economic and social, and finally, only seven to the socio-environmental, showing important evidence of the role of the economic pillar. In addition, the article points out the transversal position of the economic pillar over the other two. For example, cost reduction in floor technologies allows progress toward environmental or social sustainability, reflected in the job

generation. The focus group analysis with experts makes it possible to point out trends from developing I4.0 and new business models, such as cost reduction, increased productivity, energy efficiency, CO2 reduction, or improvement in plant knowledge management (including the three pillars). In short, based on the literature review and the focus group, they can conclude that sustainability has been proven, is running, and will be deepened in the future.

In that direction, Ghobakhloo [7] focused on analyzing the impact of I4.0 on economic, social, and environmental sustainability. Based on both literature review (96 articles) and expert interviews, the work had two objectives, to identify the sustainability functions (16 in total) of I4.0 and, to recognize the sequence of determinations that enable the improvement of social welfare (through the pillars of sustainability). He states the three most studied functions in the literature reviewed were (1) energy and resource sustainability, (2) increased productivity and productive efficiency, and (3) risk management and safety. Based on graph theory, the author proposed how the functions interact, concluding that the human resource development function is the key step in giving rise to the rest of the tasks within sustainability. The following functions are digitizing global value chains, production modularity, manufacturing flexibility, and risk management. Elements linked first-hand to the economic dimension are assumed to be environmentally sustainable, as in Felsberger and Reiner's [25] research. Ghobakhloo [7] pointed out some sustainability functions as drivers, as the steppingstones toward a transition to environmental and societal sustainability dimensions, but still needed to converge toward the business model innovation that may need to prove fitness. Once these functions are triggered and act as linkage functions, the I4.0 may prompt sustainability's environmental and societal components.

Another branch of literature has linked I4.0 with specific sectors and applications. Trivelli et al. [65] aim to investigate how I4.0 and precision agriculture are connected. Precision agriculture has its axes in digitalization, efficient use of resources, productivity, monitoring, and decision-making within the agro-industrial activity. This research obtains two specific products, a dictionary of precision technologies and a graphic representation of these technologies grouped into five clusters. The research concludes that precision agriculture and I4.0 overlap. The analysis assumes that precision agriculture is sustainable, although few articles in their review analyze this issue. Another study that focuses on applying

I4.0 within or linked to a sector is Santolamazza et al. [23], which identifies opportunities for managing an industrial plant's energy systems to be transformed through I4.0. They carried out a literature review to identify the key aspects of energy management. In addition, the research identified that the technologies developed around I4.0 could favor aspects of energy management (because they already have applications in that direction). The work assumes that economic and environmental sustainability results from better energy management and that I4.0 allow it; however, it does not delve into the key technologies that could directly impact.

Ávila Gutiérrez et al. [66] propose a framework for manufacturing that is smart and *affective*, and inclusive. They present a model that uses sensors inside a steel factory to capture the difference between workplace demand and workers' capabilities to reduce demand and expand capacity. The research studies workers with autism spectrum disorder from a methodology that crosses technological elements, adaptation to work, *affectivity*, and improvement of productive activity. This work allows observing the potential of I4.0 in the pillar of social sustainability (improvement of working conditions).

Another focus developed in the literature on I4.0 is proposing a diagnosis of digitization in SMEs. Hamidi et al. [41] explore the level of maturity within the I4.0 of SMEs in Malaysia. The work is based on six dimensions; jobs, strategy, smart factory, smart operations, smart products, and data-driven services. According to the study, small businesses rank low levels in them, and given global competitiveness, it is necessary to remedy those shortcomings.

1.4.5 Digitalization

Literature on digitalization has as a starting point that it is a process that optimizes resources, production, and services, which helps economic efficiency. In addition, it agrees that this process allows the opening of business opportunities for companies.

On the other part, some of the papers grouped in this strain focus on resolving problems that can occur through digitalization. In this regard, Alves et al. [67] analyze the effects of innovation within home medical services. The authors find that while the number of patients under treatment and prescription remains stable during the period studied, the

number of medications decreases drastically after implementing the digital process. That means improving hospital processes, specifically in logistics, but also real-time monitoring of patients. It is worth noting that the authors suggested that this brings with it an advance in sustainability. Another study that focuses on applying digital technologies is that of Ciruela et al. [68], which analyzes how different digital technologies would improve the activities of agro-cooperatives. The research takes up a diagnostic analysis to assess the position of two cooperatives and observe the strategies they have taken that place them at a level of digitization—the greater the depth of digitization, the greater the impact within the value chain. The article then presupposes that digitization would allow them to take advantage and acquire sustainability (on the environmental and social dimensions).

The study by Bican and Brem [45] seeks to identify whether digitalization will impact sustainability. The authors recognize no clarity on what digitalization means at the academic level regarding digitization. Furthermore, a case study of a German corporation showed that employees do not have a common vision of these concepts. The study also proposes a simple model of what digital transformation would involve within the corporate. Changes within the company in the digital direction will be implemented if they are part of the business model. In addition, the study, based on the interviews and the literature review, found that the impact of digitalization on sustainability is not linear. Some actions could favor it (online meetings reduce resource consumption) and others not (the case of the energy demand of cryptocurrencies). In this venue, Evangelatos [69] detects that technology is not neutral nor is it without a trade-off, as some of the reviewed literature assumes.

Another part of the literature highlights the increase in risks in some parts of the Economy because of digitization. Forcadell et al. [48] state that digitization has made it possible to optimize various processes and products. Above all, it makes it possible to reduce transaction costs (costs generated by going to the market and negotiating). However, it has increased risks in financial services, which has led to a negative perception of these organizations. The authors propose building a reputation by creating signals to partners and clients to compensate. Such a reputation is based on corporate sustainability and digitization itself.

1.4.6 Smart Cities

In the literature on the smart city referred to the digital and sustainable transformation, an expression that appears frequently is stakeholder, a term that encompasses a business vision in which the town is pigeonholed. Each actor within the city is a stakeholder. In the background are the citizens or governments. If it is assumed that whoever decides within the cities will first be someone who invests and expects a return, there is no longer a place for the citizen, only for the merchant, to obtain returns. Another element that stands out is that some of the texts on this topic confirm the possibilities technology delivers for the city in terms of benefits in the economic, political, and general sustainability spheres. The importance of this literature stream lies in the fact that the design elements of smart cities could be equal to the enablers of digital transformation and the building blocks of the digital ecosystem.

Komninos et al. [63] analyze thirteen cases of European cities that the European Commission recognizes in its Blueprint for Cities and Regions as Launch Pads for Digital Transformation. Assuming that digital transformation is the basis of a smart city, they detected some common elements: (1) leadership by institutions to successfully carry out the transformation, (2) human resources with a talent for digital development and entrepreneurship that accelerate the formation of a digital ecosystem, (3) access to the management of a large amount of data and address the challenges that a city faces, and (4) investment in key infrastructures. The authors emphasize the need to create platforms (with public investment) or common infrastructures to establish a collaborative ecosystem for new processes and products needed for the city, markets, and public services.

As seen in this section and the previous ones, a strong investment is required for the digital transformation and conversion to smart cities. Much of the literature assumes public investments in products and services infrastructure. However, the financing it must resort to must be innovative, as pointed out by Canas da Costa and Popović [70]. The required investments include the communication part as a transversal element and the requirements for it to be sustainable, such as energy considered clean. In general, investment in infrastructure has two characteristics, long-term and high volume, requiring planning. The work takes as a reference the financial alternatives to which some projects have resorted, such as the well-known case of green bonds, insurance for natural disasters that allow recovering the loss of natural infrastructure

due to some climatological catastrophe, or the payment for the capture of surplus value by exploitation in the use of wild land.

Complementary to the work of Komninos et al. [63], is Hämäläinen [71]. She states that the design of a smart city requires incorporating four aspects: (1) Strategy for integrating digital technology into a sustainable city, (2) Digital technologies such as infrastructure or platforms for services and products that the city requires, and high computing capacity to handle a large amount of data that needs to be used in the city, and at high speed, experimentation with technology for cities, and security, among others, (3) A governance that includes organizations of different kinds (companies, governments, non-profit organizations, citizens, all of them called stakeholders), and (4) The stakeholders that are regularly seen from the quadruple helix, which integrates citizens. For his part, Nugraha [72], through a review of the literature on smart cities, suggests that a relationship between people, the business process, and emerging technology can be observed by implementing a smart city. Furthermore, he assumes that smart cities help improve quality of life, economic growth, and sustainability.

Other research focuses on identifying the challenges for smart cities, as the case of Kar et al. [64] states that the central challenge for digital transformation is not only to transform cities into smart ones but also nations. Both urban and rural territories must have changed in the direction of digitization in which all stakeholders benefit. This position rests on the fact that social needs can be recognized at the national level and thus be the starting point. A smart nation not to continue opening the gap between rural and urban spaces in digitalization needs national governance. Complementary to Pereira [73], the new governance models required collaborative control, information exchange, evidence-based decisions, resource management transparency, and citizen participation. The authors raise the need for new governance, considering that the smart city's central objective is to create a public value that ranges from sustainability, creativity, efficiency, innovation, or citizen participation.

A challenge for developing countries is the lack of funds to transform the requirements demanded by smart cities, as stated by Alcaide-Muñoz and Rodríguez-Bolivar [74]. They started from the idea that the governments of these countries have focused on providing social support instead of involving citizens in the technological environment. This idea is

contrary to the promotion of developed countries, which requires innovation and creativity or sustainability. Finally, according to the literature review, Lucelly and Marín [50] pose a series of challenges for developing smart cities in countries. Among the challenges highlighted by the authors is the low investment in R&D, as in the Colombian case, or those related to mobility, education, and qualification of human resources, not only in the technological part but also in participation that allows them to integrate.

1.5 Discussion

This paper's main stake is to devise a future for a more sustainable development hand-on-hand with the Digital Transformation evolution. First, our work states that digital and sustainable transformations are emerging in the literature. Our results show a strong coincidence with other reviewing studies. Sustainability and industry 4.0 as its related technologies (Big Data and Artificial Intelligence, and Business models) are listed among the most recurring topic in the literature reviews, and research trends are uprising around SMEs, Blockchain, Machine Learning, and Sustainable Development [2].

Regarding the co-word analysis structure, our findings on commonalities to explain digital and sustainable transformation are backed up by Wang's [35] review on how cyberspace enables green and digital transformation. This twin transformation is guided by industry 4.0 applications based on Artificial Intelligence, Cloud, Big Data, and Internet of Things technologies. Cavalieri et al. [75] find complementary results to understand the relation between eco-innovation and digital transformation in a Circular Economy framework.

According to the literature reviewed, sustainability is a companion to digital transformation, but it cannot be granted nor treated as an externality from the digital technologies' diffusion process. Several mechanisms operate systemically at the macro, meso, and micro levels to achieve the whole dimensions of sustainability.

For example, the COVID-19 pandemic has triggered a more sustainable awareness of digital transformation. Recent literature sustains the case exposed by Agasisti [46] in our review. Nonetheless, some authors do show that the booster occurs in the digitization of urban environments [76], work environments [77], or the steel supply chain industry [78]. However, the evidence is not strong enough on sustainability endeavors.

A clue may be in incorporating other variables as moderators, such as innovation, whereas business process innovation, customer engagement, and organizational resilience, among other factors, have proven incidence on the Iranian business to become more sustainable while adopting digital technologies [79].

Our work confirms that technology and its applications are backing up the digital and sustainable transformation. What about institutions and business changes? The digital transformation is not a neutral process [69], and to obtain economical, environmental, and social benefits, values, norms, and behaviors are at stake. Our review showed that reputation might avoid customers' mistrust of data usage in the banking sector and the uncertainty associated with new products or services [48]. Meanwhile, responsible business leadership is essential to include sustainability issues in the development of the new business model [60]. To corroborate, in the same sense, this kind of ethical concern shall be put in place for the development of AI technologies, as recently researched by Weber-Lewerenz [80].

How this double transformation occurs at the business level? They can be seen as growing paths, appearing in a converging way, may be simultaneously or sequentially, depending on the structural dimensions of firms [62], and are foreseen to be much more intertwined in the future in the New Normal. In our previous review on production and operations management, digital and sustainability occurred simultaneously in using, exchanging, organizing, or recycling data or materials and produced economic and sustainable results [25]. Nevertheless, other authors underline that process innovation must occur to embrace digital transformation and address sustainability [6, 33, 35] or even that mastering the digital transformation is required (or of a certain technology, i.e., data analytics capabilities harnessing) to pursue sustainable value creation [41, 42]. Other researchers went further and proposed a sequential interrelation among digitization, innovation, and sustainability [6, 43, 44], whereas digitalization ignites a businessmodel innovation, and through this model change, a sustainable business model is born. But this change may be possible only if management considers customer orientation, organizational agility, and efficiency and engage in organizational learning [52, 55]. The value obtained may fall short of an environmental or societal impact or even drive negative effects, so a purposeful guide must be addressed as a responsible business leadership that assures an ethical attitude and stakeholder inclusiveness.

Recent examples of works sustaining simultaneous or sequential modes of interaction are Lichtenthaler [81] and Ghobakhloo et al. [27]. The first author coined *digitainability* to propose a framework that simultaneously includes digitalization and sustainability in the innovation strategy and avoids negative outcomes or unintended consequences. For another part, Ghobakhloo and colleagues [27], based on an extant literature review and experts' opinions, develop sustainable innovation functions for I4.0 identifying sequences to deploy eco-innovation departing from a horizontal and vertical integration to an enhancement of the knowledge base and advanced competencies, and from developing organizational capabilities (green absorptive capacity, sustainable partnership, and sustainable innovation orientation) toward eco-friendly innovation on process and products. A complementary approach to the interdependencies of the sustainability dimensions is the work of Veile et al. [82]. They craft a model of interactions among the triple bottom line components in the digital transformation context.

The literature review showed that several cases are depicted to provide a view of how the digital transformation has occurred throughout the whole Economy and how it is related to sustainability [5, 6, 38, 39, 46, 49, 53, 56, 59, 65, 68]. The structural and size conditions are important to explain the pace and depth of outcomes of the diffusion and express sustainability as survival, aspiration, by-product, performance, or strategic results. There is still much room to envisage different changes in several industries. As the construction [83], fashion [84], lodging [85], food processing [86], agri-business [87], pharmaceutical [88], including responsible innovation approach in the digitization of a dairy farm [89]. Recently, Dalmarco et al. [90] have shown that territories are a driver to creating and delivering sustainable value along several digital-based business models spread all over Europe. Li et al. [36] argue that the I4.0-sustainability bond occurs naturally due to linking digital with real-life. However, even this process can decelerate the complexities and paradoxes of high energy consumption if sustainable designs are considered, leveraging a smart sustainability transformation [91].

The digital transformation does not linearly determine a sustainability process (economic or environmental). As can be seen, digital technology also brings challenges and new problems. Digital technology is not neutral or without a trade-off, as some reviewed literature on I4.0 states. However, it is assumed largely as a product of efficiency.

A careful strategy is required to innovate based on the digital transformation in response to reaching the whole scope of sustainability [5, 6, 21, 45, 58–60]. In this line is the work of Padua [92], who proposes a mindset to include social concerns in any sustainable innovation based on I4.0 technologies, and Ghezzi [93], who drafted a tool to enable competitive empathy with rivals to get a common ground and shared value. For business, it is not only good-will address social and environmental sustainability, but some capabilities also are required to drive the business model. In the case of capabilities, both streams of literature, digital transformation and innovation, agree that behind the transformation, there is a process of building and deploying capabilities [33, 38, 41–43]. Even though the intermediate innovation phase, the literature points out the capabilities' promotion. One of these appears reiterative in the review, with several different names. It has to do with identifying and assessing business opportunities, so it is called "opportunity seeking" or "foresight cognitive ability" [43] or, in a more recent model, "prognosis search" [94]. Other capabilities are restricted to the technological dominion. They may be more directed toward the managing of digital transformation technologies (Big Data and Analytics capabilities, platform capabilities, knowledge management, and blockchain) [5, 38, 42, 84]. Finally, the third class of capabilities is related to the organization; current literature highlights: absorptive capacity, partnership development, ambidexterity, resilience, agility, customer engagement, and leadership [27, 79, 95–97]. In the case of SMEs, to keep growing and going digital, technological capabilities are a strong moderator, especially those related to innovation and marketing [98, 99].

Concerning the evolution of the sustainable transformation through smart cities, our results are aligned with Naccari-Carlizi and Quatronne [40] and Yigitcanlar et al. [39] proposals on the digital agenda and digital applications adoption to develop urban planning and control metropolitan cities. This investment in technological infrastructure may help government and citizenship go digital, facilitate exchanges, and open opportunities to a platform-based business. Applying this infrastructure to the management of public utilities boost not only the smartness but also the sustainability of cities reflected in enhanced management of energy or water, waste collection, disposal, and recycling as the mobility with eco-friendly public transport and improvement in the control of vehicles, their emissions and heat diffusion. A new path may be open to reflect on how digital innovation change public and private relationship in

terms of governance of public services and natural resources management, with real-time information, policy design and accountability, participative planning, and leadership empowering people, as is the case of water management [100].

1.6 Conclusions

Digital transformation is geared toward greater sustainability. It is undoubtedly an uprising topic as it is embodied in the current literature. The sustainable transformation appears as an aspiration to create value and merits planning. Likewise, digital transformation entails sustainability as there is a potential impact on economic sustainability performance, especially in manufacturing (production and operations), while environmental and societal constituencies can be impacted through corporate responsibility. Finally, there is a narrative on managing digital transformation and sustainability through entrepreneurship, innovation, and business model development based on functional and sectoral digitalization applications and mastery of diverse organizational capabilities.

According to our review, the major subtopics are: (1) How to assure in the whole dimensions of sustainability results and outcomes? How do we avoid negative effects? What are the main moderators of the relationship? What is the role of innovation in the relationship?

The adoption of I4.0 does not grant environmental and social sustainability. To reach these sustainable benefits is necessary that they are purposefully sought. They require investment and planning and correct responsible leadership, stakeholder participation, and the development of organizational capabilities. Effective management is necessary to engage in innovation. And to accomplish sustainable transformation, a sustainability commitment is required.

In the study of the sustainability achievement in digital transformation literature, there are several hints to feel optimistic about post-pandemic relief. The future growth of the Economy, staking on digitalization, passes through several processes. The expansion of the Digital Economy brings unintended sustainability effects and enhances the capabilities of digital ecosystems as stakeholders interact in new and diverse arrangements advocating to create social shared value. If purposeful investments and planning are put in place to reach a smart and sustainable city, knowledge management will release a capabilities challenge due to increased

reliable and transparent information generated through digital technologies. Business endurance is enabled through digital technology usage and mastering. Business model and process innovations are developed through market and data analytics capabilities, and digital achievements are intended to catch up with economic sustainability. Finally, nations, industries, cities, and businesses may seek environmental and social sustainability through increased awareness, commitment, and responsibility.

The future research agenda for a digital and sustainable transformation must open a special place for innovation. The mechanisms on how digitalization enables innovation and innovation facilitate sustainability is relevant for designing and managing sustainable businesses. Is this a sequential mechanism? What are the drivers behind this process? Some of them were identified in our review, so what may be the role of technology, strategy, culture, readiness, entrepreneurship, and environmental restrains in achieving the double transformation. To change business models and address them to sustainable development, avoiding negative effects, it seems that some organizational capabilities must be developed and deployed, just to mention a few, such as knowledge management, customer orientation, or agility. Another branch of literature states that innovation processes are enablers of digital transformation, so more reflection and empirical work are required to demonstrate their role as enablers and mediators of sustainable transformation. Certainly, there are obstacles and resistance to adopting these change processes; some belong to an organization others may have a knowledge nature, so a cross-fertilization exchange with knowledge management and organizational learning research stands out as a valuable road toward a deeper understanding. Additionally, more examples from different sectors are required to understand how organizations persevere in this dual transformation.

The pandemic's disruptive effects open a pervasive diffusion of digital technologies across the Economy. The New Normal may open the way to a digital transformation based on a transitional model to address sustainability. The business organization is urged to keep a customer orientation and agility mode of decision-making and implementation. However, a pause may be needed for a strategic assessment to support efforts on the digital transformation to achieve triple bottom line sustainability. The innovation pursued efforts on processes, and the business model shall be nurtured by digital technologies, as the eco-innovation case, but seek performance gains in the whole sustainability dimensions. Corporate

sustainability is critical to embedding business responsibility leadership and organizational sustainability culture. In this context, the readiness and maturity models must prove useful. Human resources are the steppingstone toward developing technological and organizational capabilities pivotal to advancing in the dual transformation.

Regarding the literature on I4.0, one element that stands out is a positive vision, failing to highlight economic, social, or environmental limitations, not even thinking of a technological trade-off approach. I4.0 could be a paradise on and off the factory floor. However, this academic promotion does not reveal the problems even in the economic field, such as the current low overall return on investment, ergo, the drop in ICT investment. To deepen our understanding of the structural role of I4.0 on the double transformation requires increasing the attention on sustainability dimensions, priority impacts, and how this sustains sequential models, developing cases and discussing applications in more sectors, and providing a new generation of diagnosis models that incorporate findings on the sustainability impacts sequential mechanisms.

Digitalization has covered manufacturing directly and areas such as services for both production and final consumption. Like the research on I4.0, digitization literature assumes that digitization allows economic and environmental efficiency. In this line, digital tools could enhance their strengths and solve their weaknesses. All this if values of self-help, self-responsibility, democracy, equality, and solidarity are present in their design. If a social-value-driven design is considered, sustainable business models embodying the whole sustainability dimensions may be favored by digitalization.

This contribution must put a warning note because of the digital-sustainable non-linearity behavior. Since digital technologies are not neutral, the impacts on sustainability are unpredictable. A complex system view of the array of digital and sustainable is required. Future research must consider that self-organization adaptive responses of business models and cities occur whenever confronted with disruptive events, and many variables interact to change or innovate in the business models, such as cultural trait as openness but also diverse capabilities, i.e., being of different nature such as infrastructural, technological, and organizational. An approximation to the literature on complexity is desired for planning and modeling the changes and the several variables interacting with a business model design.

Smart cities are sustainable cities; there is no doubt about that vision. However, some papers showed that we must make a pause, and before technologies, smart citizens are required. On the other hand, we must consider that in the face of challenges, it is necessary to focus on strategies to design and create this type of city, which, among many other problems, will require large investments for its implementation. In addition, various solutions have come into play for greening cities that should complement the digitization effort. In cities, digital technologies open opportunities for greening and bring lessons on how stakeholders articulate and aggregate demands, participate and generate social share value like an ecosystem. According to a stylized way to aggregate actors and differentiate them, this type of governance is depicted as a Quintuple Helix and can exemplify how to create and deploy digital and sustainable ecosystems in a Post-COVID World.

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