Journal of Cleaner Production 208 (2019) 325–332

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Review

Innovations for sustainable development: Moving toward a sustainable future

Bruno S. Silvestre [a, *], Diana Mihaela Ţîrcă [b]

[a] Asper School of Business, University of Manitoba, 181 Freedman Crescent, Winnipeg, MB, MB R3T, Canada
[b] "Constantin Brancusi" University of Targu-Jiu, Faculty of Economics, Tineretului Street, No. 4, Targu-Jiu, Gorj, 210185, Romania

ARTICLE INFO

Article history:
Received 20 April 2018
Received in revised form
26 September 2018
Accepted 28 September 2018

Handling Editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Innovations
Sustainable development
Sustainable innovation
Environmental dimensions
Social dimensions
Triple bottom line

ABSTRACT

The view that innovation is a key driver for sustainability is widely accepted among scholars, industry professionals, and government representatives. This is due to the fact that sustainable development is a pressing issue that requires immediate action and changes from governments, industry, and society as whole. This article reviews the literature on innovations that can lead to transformations in individuals, organizations, supply chains, and communities toward a sustainable future. Although many of the articles explored in this review report on existing urgent environmental and social issues, their findings, recommendations, and contributions are encouraging as we make progress toward a sustainable society through innovation and change. This article reviews the diversity of innovation for Sustainable Development in the literature, proposes a typology of such a phenomenon, provides an overview of key articles based on the primary subjects they address, and identifies a series of recommendations for the future development of the field.

Contents

1. Introduction

Sustainable Development (SD) has been receiving growing attention from academics, industry representatives and policy-makers (e.g., United Nations, 2016; European Union, 2014). One of the key areas that has been addressed by the SD discourse is the role of innovations in enhancing sustainability (Silvestre and Silva Neto, 2014a). Since innovations are constantly changing the external environment and our way of life (Huisingh et al., 2013), they are key elements through which organizations, supply chains,

* Corresponding author.
E-mail address: b.silvestre@umanitoba.ca (B.S. Silvestre).

https://doi.org/10.1016/j.jclepro.2018.09.244
0959-6526/

institutions, communities, regions, and countries can implement sustainability (Silvestre, 2015a). In fact, the literature acknowledges that sustainability should be tackled based on innovation-centered approaches (Silvestre, 2015b). However, in practice, the pace of change towards a more sustainable world seems to be frustratingly slow, and there are urgent calls for further investments and initiatives from organizations, educational institutions, and governments to implement innovative multidisciplinary approaches to resolve our current and pressing sustainability challenges (Almeida et al., 2013).

The Brundland Commission's (WCED, 1987) seminal definition of SD emphasizes the interdependence among social, economic, and environmental dimensions of sustainability. Elkington (1997), using the so-called "triple bottom line," suggests that equal consideration should be given to financial, environmental, and social dimensions when making business and policy decisions. Some studies observe that the sustainability discourse has evolved from the relationship between economic and environmental parameters to also include social impacts (Seuring and Muller, 2008). Buchholz et al. (2007) similarly recognize the need to analyze the complex interactions between all three dimensions; they conclude that the evolving nature of sustainability requires an adaptive process that involves the active participation of all stakeholders. However, since studies are diverse in terms of the definition of innovation for SD, this introductory article and indeed the entire Special Volume aims to contribute to narrowing the existing gap in this knowledge area.

The paper proceeds as follows. First, we review the literature associated with the topic of sustainability, which is then used as a base to propose a typology of innovation for SD, based on the three key pillars of sustainability (financial, environmental, and social). Second, a brief overview of each of the papers published in this Special Volume is presented according to the primary area that each one of them addresses (i.e., new technologies for SD, new management practices for SD, and new policy approaches for SD). Third, the paper concludes with a discussion on how this Special Volume contributes to the literature, and identifies trends for future research within the innovation for SD discourse.

2. Innovation for sustainable development

The process of innovation development and adoption is perceived to have at least three fundamental characteristics: complexity, dynamism, and uncertainty. The innovation process is *complex* because it typically deals with a large number of interconnected factors that impact, or are impacted by, the other factors (Hall et al., 2012a). When complexity is high, it is difficult to identify the characteristics of the entire system, as the nature and connections of the interacting factors can easily be missed or misunderstood (Anderson, 1999). The innovation process is *dynamic* because these interacting factors change and evolve over time, and this can lead to changing contexts that may make an innovation unviable, or may produce unintended outcomes within a short period of time (Utterback, 1994). As a result of these two characteristics, the innovation process is also *uncertain* (Freeman, 1982). That is, the complexity and dynamism of the innovation process make it a very uncertain initiative in terms of its motivations, goals, and outcomes.

Innovation uncertainty is a very well explored topic in the literature. For example, the TCOS framework (Hall and Martin, 2005) helps managers and scholars to understand how organizations, supply chains, and communities can better address uncertainties associated with innovations. The TCOS framework proposes that there are four types of innovation uncertainty that must be carefully addressed: a) technological feasibility (i.e., existence or not, and possibility to develop the required technology); b) commercial viability (existence or not, and possibility to create a market for the innovation); c) organizational appropriability (i.e., the potential to appropriate the benefits of the innovation and how difficult it is for competitors to imitate the innovation); and d) societal acceptability (i.e., the potential to have the innovation accepted by society given its societal side-effects, including environmental, social, cultural, and political implications).

Innovation for sustainable development (SD) is a newer phenomenon, but its development and implementation are equally complex, dynamic, and uncertain as other types of innovations (Seyfang and Smith, 2007). The literature converges to the fact that enhanced sustainability performance cannot be achieved without innovations (Silvestre, 2015a). This is because achieving enhanced sustainability performance requires adaptation and change in processes, products, management approaches, and policy orientations. Therefore, change is a fundamental element for organizations, supply chains, and communities as they evolve on their sustainability trajectory. Sustainable innovations that are continuously adopted improve specific organizations and the entire supply chain's sustainability trajectory, allowing them to achieve superior sustainability performance.

Sustainability trajectories are the paths organizations, supply chains, and communities take to become more sustainable through innovations (Silvestre, 2015a). Whether an innovation is incremental or radical, whether it focuses on processes or products, and whether it is new to the organization, or to the industry, or to the world (Schumpeter, 1934), it is always bounded by what economists call path dependence. Path dependence refers to the series of contextual and historical elements that together influence decision makers to go in one direction or another (Martin and Sunley, 2006). That is, innovation decisions that need to be made will be bounded by the decisions that have been made in the past. Aghion et al. (2014) argue that when developing and adopting innovation for SD, path dependence often emerges due to existing powerful network effects and high switching costs. For example, innovations developed and adopted by a firm may very well be selected because of the existing complementarities with other assets inside the firm or in its supply network. Innovations that are not historically binding with the previous path may diminish the existing positive network effect externalities and may generate high switching costs.

An important benefit of conceptualizing different innovations for SD in terms of the key challenges they address is the potential it provides to examine the complexity of these phenomena and their implications for society. Research on innovation for SD is complex and rich, reflecting the different perspectives and interests that emerge in different communities (Franceschini et al., 2016). Drawing from the literature, this paper suggests that the most pressing issues of sustainability pertain to environmental challenges and social challenges (Hilgartner and Bosk, 1988; Epstein and Buhovac, 2014). To that end, we now introduce these two key challenges and the resulting typology of innovations for SD.

2.1. Environmental challenges

A frequent issue discussed in the recent years, which prevents us as a society from pursuing a sustainable development trajectory, is related to the environmental challenges the world is currently facing. These challenges include, for example, air and water pollution (Greenstone and Hanna, 2014), waste disposal and management (Calcott and Walls, 2000), ozone layer depletion (Canan et al., 2015), and as a result, and perhaps most importantly, climate change (Huang et al., 2016).

Prior research on environmental challenges has examined how environmental changes impact our way of life. For instance, Zachariadis (2016) argues that climate change itself is responsible

for a wide range of consequences, such as sea-level rise, ocean acidification, droughts, glaciers loss, and increased frequency of extreme weather events such as heat waves, floods, storms, and hurricanes. Besides these severe consequences, Wheeler and Von Braun (2013) also argue that climate change impacts crop productivity and brings consequences for food availability, which could potentially interrupt food supply chains and our progress toward a world without hunger. From such prior research, it is generally recognized that environmental challenges are often associated with the way we live and consume, which impact the other two dimensions of sustainability (i.e., the natural environment dimension is impacted by and impacts both the economic and social dimensions).

To address these environmental challenges, scholars, industry, and civil society have been discussing and proposing approaches and mechanisms that could mitigate or remove the impact of the activities of organizations, supply chains, and communities on the natural environment. Research and practice converge to the fact that to achieve superior environmental performance organizations, supply chains, and communities must align all their internal processes (including their decision making processes) to focus on the impact of their activities on the natural environment (Joyce and Paquin, 2016). This is what the literature refers to as green operations (Nunes and Bennett, 2010) and green supply chains (Srivastava, 2007; Wong et al., 2012). Adopting such a perspective in a coherent and comprehensive way facilitates the emergence of green business models (Nair and Paulose, 2014), where the focus of the organization, supply chain, or community is to reduce or eliminate the impact of their activities on the natural environment.

However, green operations, green supply chains, and green business models cannot be considered in isolation from innovation. Changes and innovations are central elements that will allow companies to enhance their environmental performance and consequently evolve on their sustainability trajectory (Silvestre, 2015a). For this to happen, the availability of the innovation (i.e., technology, product, processes, business practices, or policy approach) is not enough (Silvestre and Silva Neto, 2014b). The willingness to adopt such an innovation and to truly incorporate it into business processes (i.e., to change) are also mandatory for the success of the initiative. These paths to green approaches require changes in the mindset of top management and staff within those organizations.

2.2. Social challenges

Another pressing issue which prevents us from achieving a satisfactory sustainable development trajectory is the social challenge that the world is currently facing. This challenge includes, for example, poverty (Bush, 2010), social exclusion (Hall et al., 2012b), corruption (Silvestre et al., 2018), human rights (Giuliani, 2016), and war and disordered immigration (Ousey and Kubrin, 2018).

Prior research on social challenges has examined how this dimension impacts our lives as a society. For instance, McAra and McVie (2016) show that violence is strongly associated with poverty at the household and neighborhood levels. Khan et al. (2010) also argue that poverty is one of the reasons that women are forced into prostitution, while Shively (2004) reinforces the idea that the poor are both agents of forest degradation and victims of forest loss. From such prior research it is generally understood that social challenges also impact on, and are impacted by, the other two dimensions of sustainability (i.e., economic and environmental), implying that these three dimensions are strongly interconnected.

Scholars, industry, and civil society have been discussing and proposing strategies to address these social challenges. Similar to the environmental discussion, research and practice on social challenges converge to the fact that to achieve superior social performance it is necessary to align all internal processes (including decision making processes) to focus on the impact of their activities on society (Matos and Silvestre, 2013). This is what the literature most often refers to as corporate social responsibility or CSR (Schrempf-Stirling et al., 2016; Dahlsrud, 2008). Adopting such a perspective in a coherent and comprehensive way can allow the emergence of social business models (Yunus et al., 2010) where the focus of the organization, supply chain, or community is concentrated on reducing or eliminating the impact of their activities on society.

Although social initiatives in operations and supply chains may have different motivations and may engage different stakeholder groups (Morais and Silvestre, 2018), they also cannot be considered in isolation from innovation (van der Have and Rubalcaba, 2016). Changes and innovations are equally central to the process companies undertake to enhance their social performance and consequently evolve on their sustainability trajectory (Silvestre, 2015a). Similar to green innovations, the simple availability of social innovation is not sufficient (Cajaiba-Santana, 2014). A willingness to adopt and truly incorporate such innovations into business processes (i.e., the willingness to change) is also necessary. These paths to socially responsible behavior also require changes in the mindset of top management and staff within organizations.

3. A typology of innovation for sustainable development

Based on these two key dimensions of SD, a typology of innovation for SD is proposed as a way to describe how these innovations vary in terms of their nature and the primary challenges they aim to address. The notion of innovation adopted in this paper refers to initiatives that are new to the firm/organization that is adopting them. It is often associated in the literature with the ability to recombine existing technologies and knowledge to meet specific economic, environmental, and social needs (Schumpeter, 1934). The extent to which a given innovation addresses the environmental and social challenges of sustainability varies. We use illustrative combinations of a high or low emphasis on environmental and social challenges to illustrate, in a simple and bounded way, how they vary and their implications for the future of the

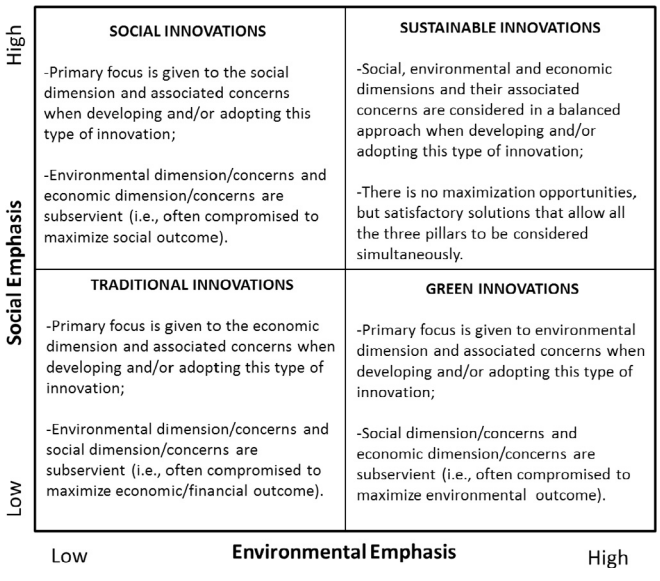

Fig. 1. Typology of innovations for sustainable development.

planet. The result is a typology (see Fig. 1) with four distinct types of innovations: traditional, green, social, and sustainable innovations.

Based on the theoretical model proposed in Fig. 1, an innovation with a low emphasis on both environmental and social challenges is labelled a *traditional innovation*. This type of innovation is consistent with the traditional profit maximizing paradigm, where little attention is given to the potential side effects of an innovation (for a critique of the traditional paradigm, see Dyck and Silvestre, 2018a). The pertinent economic literature relates this type of innovation to the theory of the firm, where it is assumed that firms innovate as they attempt to maximize profits and financial outcomes (Jensen, 1988; McWilliams and Siegel, 2001). For example, Teece's (1986) famous framework primarily explored why and how imitation may prevent innovators from obtaining significant economic returns from their innovations, which implies a sole focus on the economic dimension and financial returns of innovations.

The second type of innovation—*green innovation*—places a high emphasis on environmental challenges, but a low emphasis on social challenges. While the goal is to maximize positive environmental outcomes is laudable, the economic feasibility for such innovation must also be achieved. The literature offers a series of related terms that are often used interchangeably as synonyms for "green innovation" (Chen et al., 2006), including "environmental innovation" (Beise and Rennings, 2005), "eco", "ecological" or "eco-efficient innovation" (Yenipazarli, 2017), "low-carbon innovation" (Uyarra et al., 2016), and "externality reducing innovation" (Dyck and Silvestre, 2018b). Studies define this type of innovation as new products, services, and processes which significantly decrease environmental impacts (Fussler and James, 1996; Bartlett and Trifilova, 2010); this clearly places their primary focus on the environmental dimension of sustainability.

The third type of innovation—*social innovation*—prioritizes social challenges, but puts a lower emphasis on economic and environmental concerns. Again, while the goal to maximize social outcomes is laudable, the economic feasibility for such innovations cannot be ignored. The literature argues that social innovations often aim to contribute to the welfare of society and improve social capital (Dawson and Daniel, 2010; Morais and Silvestre, 2018). Social objectives are the usual drivers behind social innovation (Mulgan, 2006), and these objectives are designed to provide disruption within existing social systems (via changes in their internal institutional logics, norms, and traditions) as a reaction to the negative social externalities of such existing systems (Nicholls and Murdock, 2012).

The fourth type of innovation—*sustainable innovation*—emphasizes both environmental and social concerns. This type of innovation includes synonymous terms such as "sustainability-oriented innovation" (e.g., Adams et al., 2016) and "socio-ecological innovation" (e.g., Edgeman and Eskildsen, 2014). In this type of innovation, there is no attempt to maximize one single dimension; rather, a satisfactory solution should be targeted (Hall et al., 2012a), and compromises are likely to be required in all three dimensions. This type of innovation is consistent with the triple bottom line of sustainability (Elkington, 1997), and it places equal emphasis on the three pillars of sustainability: economic, environmental, and social. Hall and Vredenburg (2003) argue that this type of innovation is difficult and risky because it is often "more complex (because there is typically a wider range of stakeholders) and more ambiguous (as many of the parties have contradictory demands)" than other types of innovations.

4. An overview of the papers in the Special Volume

This Special Volume (SV) aims to advance a multidisciplinary discussion of innovation for SD and be a vehicle for information exchange and the reporting of research results in this area. In so doing, it should assist in the consolidation and integration of innovation practices and mechanisms that further contribute to the world's sustainable development. This SV is organized by the *Journal of Cleaner Production* and the 3rd International Conference "Information Society and Sustainable Development." It includes articles that were presented at the conference as well as some additional articles that were strongly connected to the topics of innovations for sustainable development.

More than 90 articles were submitted, and 28 of them have been accepted for publication. In these 28 articles, three key interrelated areas are identified that allow organizations, supply chains, communities, and countries to innovate for sustainable development (SD): new management practices for SD, new technologies for SD, and new policy approaches for SD. Articles were classified based on the primary approach they addressed (i.e., technology, management, or policy), although we acknowledge that some articles touch on more than one area (and sometimes all three):

4.1. Subject 1: new management practices for sustainable development

Twelve of the 28 articles focus on new management practices for sustainable development; 10 of these 12 also address both environmental and social challenges in different contexts. Hall et al. (2018) argue that more emphasis should be given to downstream commercialization of sustainable innovations, since regulatory approval costs and other commercialization costs can have a significant impact on their diffusion. Dyck and Silvestre (2018b) propose a new paradigm called Sustainable Innovation 2.0 that seeks to enhance positive socio-ecological externalities while maintaining financial viability. Neutzling et al. (2018) analyze how sustainable innovations influence inter-organizational relationships in sustainable supply chain management. de Vargas Mores et al. (2018) explore the innovation of green plastic (which is made using ethanol from sugarcane) and suggest that collaborations among supply chain members is critical for product development in supply chains. Hong et al. (2018) empirically investigate the impact of sustainable supply chain management (SSCM) practices on a supply chain's dynamic capabilities and enterprise performance; they report a significant positive effect.

Rantala et al. (2018) investigated sustainability factors behind the adoption innovations for SD and found that the more an organization values the economic dimension of sustainability, the greater the likelihood that it will adopt sustainable innovations. Przychodzen and Przychodzen (2018) explore the factors that differentiate and appear to contribute to sustainable innovations at the firm level. They found that sustainable innovation activity is strongly and statistically associated with the sector in which they operate, i.e., sectors with a high level of environmental footprint are likely to innovate for SD in a more frequent fashion. Boscoianu et al. (2018) combine the dynamic capabilities perspective with the paradigm of real options in a framework that proposes the active control over the extended performance of what they call the "innovation enterprise." Behnam et al. (2018) identify and conceptualize four bundles of sustainable innovation capabilities and reveal that for radical innovations, capability reconciliation is required for all key stakeholders involved. Berkowitz (2018) argues that organizing practices are necessary for the development and diffusion of innovations for SD, and proposes a meta-organization approach for the governance of sustainable innovations.

Two of the 12 articles concerned with new management practices for SD focus primarily on the environmental dimension. Motta et al. (2018) offer a conceptual approach and an illustrative case study on the perception of international researchers and

practitioners regarding the relationship between eco-innovation and life cycle assessment (LCA). Saieg et al. (2018) propose an approach to integrate multiple sparse sustainability technologies, methods, and concepts used in the construction industry by proposing a way in which concepts could coexist and complement each other.

4.2. Subject 2: new technologies for sustainable development

Eight of the 28 accepted articles focus on new technologies for sustainable development, and three of them address both environmental and social challenges in different contexts. Zulfiqar and Thapa (2018) explore the "better cotton" technology introduced by the Better Cotton Initiative (BCI) in Pakistan and suggest that the promotion and adoption of innovations for SD requires careful assessment of the nature of technology. Bechtsis et al. (2018) propose a framework to support effective integration of Intelligent Autonomous Vehicles (IAVs) in supply chains; their results indicate that the flexibility resulting from the IAV architecture enables a more dynamic reconfiguration of SC networks. D'Avanzo et al. (2018) propose a framework to support sustainable orthodontic decision-making for solid residues and confirm that the proposed sustainable model minimizes costs, dramatically reduces the environmental impact, and increases patient satisfaction.

Five of the 8 articles concerned with new technologies for SD focus primarily on the environmental side of innovations for SD. Marcilio et al. (2018) explored the behavior of supply chain environmental performance in a road freight transportation system and found that green consumer pressure is more likely to influence the adoption of innovation for SD than other internal factors (e.g., type of vehicle available, fleet age or drivers' behavior). He and Zhan (2018) explore the challenges that inhibit the mass adoption of electric vehicles (EVs) which are designed to reduce the consumption of fossil fuels and the emission of greenhouse gases. Dobrotă and Dobrotă (2018) explore a technology that enables a higher recovery of rubber waste, which offers a clear improvement in terms of sustainable development indicators. Laiola and Giungato (2018) explore the potential of the city of Taranto, Italy, for the implementation of an urban wind energy system, which is emerging as a useful technology for the diffusion of smart grids. Zorpas et al. (2018a) analyzed food waste and green waste generated from households and found that certain prevention activities (e.g., home composting, public awareness events, preparing food from leftovers) can produce a high quality natural fertilizer for in-situ home use.

4.3. Subject 3: new policy approaches for sustainable development

Of the 28 articles accepted, eight focus on new policy approaches for sustainable development, and four of these address both environmental and social challenges in different contexts. López-Iglesias et al. (2018) analyze the case of Valdeorras (Galicia, Spain) and explore different alternatives for public investment in sustainable mobility in rural areas; they also identify the potential benefits of exploiting currently under-utilized transportation assets. Melane-Lavado et al. (2018) correlate foreign direct investment (FDI) and innovation for sustainable development in small- and medium-sized enterprises; their results indicate that FDI can generate positive spillovers in manufacturing, especially when innovation policies and public funding for innovation are in place. Navamuel et al. (2018) argue that policies oriented towards efficiency in residential consumption have been implemented in Spain, but since urban sprawl has been occurring rapidly, electricity demand is likely to increase in the following years. Blanco-Cerradelo et al. (2018) propose an approach to enhance the tourist competitiveness of protected areas in Spain. Their results suggest that the tourist competitiveness of protected areas involves five key dimensions: capability to attract visitors, social welfare of the local community, the preservation of nature in the park, the existence of a sense of community, and the economic welfare of the local community.

Two papers are concerned primarily with the social challenges of innovations for sustainable development. Picatoste et al. (2018) assess citizens' acceptance of restrictive policies on public health expenditures due to an economic crisis. Their results show a general disagreement with the cuts in public health expenditures but in a level strongly related with citizens' own perceptions. Zorpas et al. (2018b) explore the expansion of tourist activities in the city of Agia Napa (Cyprus) and suggest a strategic plan and policy to reverse the decline of the historic center where several SMEs have closed and jobs have been lost, mostly due to an economic recession and competition from other more attractive tourist destinations.

Two other papers are concerned primarily with the environmental challenges of innovations for sustainable development. Fernández et al. (2018) empirically verify whether innovation efforts have a positive effect on reducing CO2 emissions by employing an econometric model for the European Union (15), the United States, and China between 1990 and 2013. Results suggest that spending on R&D contributes positively to the reduction of CO2 emissions for developed countries. Calvo-Silvosa et al. (2018) analyze the electricity generation costs for different technologies, their risks and a set of constraints on the emission of pollutant gases. Their results suggest that the EU technology portfolio is far from efficient, revealing the need to increase the share of renewable energy technologies in the energy mix to reduce the environmental impact.

As can be observed in Table 1, the vast majority of the papers across the three subjects (i.e., management, technology, and policy) describe sustainable innovation approaches (last column of Table 1) which simultaneously considers both the environmental and social dimensions of sustainability and their implications. This is the case for the management subject (first row of Table 1), where the majority of the papers emphasize both environmental and social dimensions of sustainability and their implications. By contrast, the technology subject (second row of Table 1) seems to focus more on the environmental dimension of sustainability, while social challenges are not the focus of any paper. The policy subject (third row of Table 1) is more dispersed in terms of approaches, having representative papers in all 3 categories (i.e., environmental, social and sustainable). As expected, given the nature of this Special Volume, traditional innovations perspectives (lower left quadrant of the proposed typology (see Fig. 1 presented earlier) were not considered a good fit.

5. What has been learned

Although each one of these three specific types of innovations for SD (i.e., green, social, and sustainable) focuses on key challenges and contributes in important ways for a sustainable future, there is a need to move research and practice toward a more comprehensive view of sustainability discourse and practice. There is a need for more holistic approaches to SD (i.e., approaches considering all three dimensions of the triple bottom line). More specifically, it is important to move toward approaches to sustainable innovations (Fig. 1), which simultaneously address the social, environmental, and economic challenges and the implications of such challenges.

This paper offers three key contributions to the literature. First, since innovation uncertainty still remains as one of the most important issues that prevents innovations for SD from being

Table 1
Studies in the Special Volume.

	Environmental	Social	Sustainable
MAN	Motta et al. (2018) Saieg et al. (2018)		Hall et al. (2018) Dyck and Silvestre (2018b) Neutzling et al. (2018) Hong et al. (2018) Rantala et al. (2018) Przychodzen and Przychodzen (2018) Boscoianu et al. (2018) Behnam et al. (2018) de Vargas Mores et al. (2018) Berkowitz (2018)
TECH	Marcilio et al. (2018) He and Zhan (2018) Dobrotă and Dobrotă (2018) Laiola and Giungato (2018) Zorpas et al. (2018a)		Zulfiqar and Thapa (2018) Bechtsis et al. (2018) D'Avanzo et al. (2018)
POL	Fernández et al. (2018) Calvo-Silvosa et al. (2018)	Picatoste et al. (2018) Zorpas et al. (2018b)	López-Iglesias et al. (2018) Melane-Lavado et al. (2018) Navamuel et al. (2018) Blanco-Cerradelo et al. (2018)

developed, adopted, and diffused, it is important to connect the innovation for SD discourse to the TCOS framework (Hall et al., 2011) as we have done in this paper. Depending on the nature of the innovation (i.e., traditional, green, social, or sustainable) a different type of uncertainty (or uncertainties) might be evident in each. For example, while green innovations may face more challenging technological uncertainties (the "T" of the TCOS acronym) due to the need to develop and improve such innovative technologies (e.g., carbon capture, fuel cells, and battery technologies), social innovations might fail more often due to commercial uncertainties (the "C" of the TCOS acronym) since financial viability is usually more difficult to achieve. This contribution suggests that understanding the differences among the various types of innovations might help scholars and managers to find better ways to see and manage them.

Second, enhanced sustainability performance requires deep changes in organizations, supply chains, and communities, and this can only happen through learning and innovation. This paper combines the innovations for SD discourse and the notion of sustainability trajectories (Silvestre, 2015a), and this suggests that as the nature of the innovation differs (i.e., traditional, green, social, or sustainable), organizations, supply chains, and communities might have to evolve differently on their sustainability trajectories. This is because different types of innovations might enhance different types of learning that might be more conducive to different opportunities for innovations for SD. We also argue that the notion of evolution of organizations, supply chains, and communities on their sustainability trajectory converges with the path dependence literature, where current innovation opportunities are bounded by past decisions, experiences, and innovations (Martin and Sunley, 2006). This contribution is important because contextual and historical factors must be taken into consideration when addressing innovations for SD.

Third, communities, cities, and regions can benefit from even more radical perspectives. While sustainable innovations are often seen as consistent with the triple bottom line, recent sustainability studies go even further and suggest that there is a need to move toward more radical approaches to sustainability if we truly aim to address the pressing social and environmental challenges we are currently facing. This perspective is compatible with the term coined by Dyck and Silvestre (2018b) called Sustainable Innovation 2.0. The authors argue that social and environmental dimensions must jointly be the primary focus of innovations for SD (i.e., a double bottom line), while the economic dimension must not be ignored, but become subservient to the other two primary dimensions (Dyck and Silvestre, 2018b).

Based on these contributions, multiple opportunities for future research can be identified. First, we call for further research on how innovations for SD vary in the broad literature within these three subjects (i.e., technology, management, and policy), and how innovation types (i.e., traditional, green, social, and sustainable) are spread across these themes. This will provide a more fine-grained understanding of what type of innovations are most relevant and can actually help research and practice to advance to resolve the pressing matters of sustainability society is currently facing.

Second, we call for further understanding on how different types of innovations (i.e., traditional, green, social, sustainable) and their focus (i.e., technology, management, policy) impact the four TCOS innovation uncertainties (i.e., technological, commercial, organizational, and societal). This opportunity can provide us with practical insights on how to mitigate or eliminate uncertainties given the type and focus of a specific innovation for SD.

Third, this research opens up promising research opportunities for enhancing our understanding of how the type and focus of innovations for SD can actually provide additional insights on what managers should expect in terms of maximizing their sustainability trajectory and the best managerial approaches and perspectives that could be employed in each case.

Fourth, we argue that more radical approaches to sustainability are required and we call for further research on this topic. More specifically, it is important to identify and assess the boundaries and factors behind novel sustainability perspectives such as Sustainable Innovation 2.0 and its "double bottom line" approach in terms of refining them and testing them empirically.

We hope that this paper will become inspirational for researchers, practitioners, and policy-makers who are involved in the sustainable development discourse. We believe an important and challenging mind-set change and paradigm shift must still happen for us as a society to be able to truly move toward a sustainable society.

References

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., Overy, P., 2016. Sustainability-oriented innovation: a systematic review. Int. J. Manag. Rev. 18 (2), 180–205.
Aghion, P., Hepburn, C., Teytelboym, A., Zenghelis, D., 2014. Path Dependence, Innovation and the Economics of Climate Change. Policy Paper. Centre for Climate Change Economics and Policy and Grantham Research Institute on

Climate Change and the Environment. A Contributing Paper to: the New Climate Economy. Retrieved from: www.newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/Path-dependence-and-econ-of-change.pdf. on September 15, 2018.
Almeida, C.M.V.B., Bonilla, S.H., Giannetti, B.F., Huisingh, D., 2013. Cleaner Production initiatives and challenges for a sustainable world: an introduction to this special volume. J. Clean. Prod. 47, 1–10.
Anderson, P., 1999. Perspective: complexity theory and organization science. Organ. Sci. 10 (3), 216–232.
Bartlett, D., Trifilova, A., 2010. Green technology and eco-innovation: seven case-studies from a Russian manufacturing context. J. Manuf. Technol. Manag. 21 (8), 910–929.
Bechtsis, D., Tsolakis, N., Vlachos, D., Srai, J.S., 2018. Intelligent Autonomous Vehicles in digital supply chains: a framework for integrating innovations towards sustainable value networks. J. Clean. Prod. 181, 60–71.
Behnam, S., Cagliano, R., Grijalvo, M., 2018. How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development? J. Clean. Prod. 170, 950–965.
Beise, M., Rennings, K., 2005. Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. Ecol. Econ. 52 (1), 5–17.
Berkowitz, H., 2018. Meta-organizing firms' capabilities for sustainable innovation: a conceptual framework. J. Clean. Prod. 175, 420–430.
Blanco-Cerradelo, L., Gueimonde-Canto, A., Fraiz-Brea, J.A., Diéguez-Castrillón, M.I., 2018,. Dimensions of destination competitiveness: analyses of protected areas in Spain. J. Clean. Prod. 177, 782–794.
Boscoianu, M., Prelipcean, G., Lupan, M., 2018. Innovation enterprise as a vehicle for sustainable development–A general framework for the design of typical strategies based on enterprise systems engineering, dynamic capabilities, and option thinking. J. Clean. Prod. 172, 3498–3507.
Buchholz, T.S., Volk, T.A., Luzadis, V.A., 2007. A participatory systems approach to modeling social, economic, and ecological components of bioenergy. Energy Pol. 35 (12), 6084–6094.
Bush, R., 2010. Food riots: poverty, power and protest. J. Agrar. Change 10 (1), 119–129.
Calcott, P., Walls, M., 2000. Can downstream waste disposal policies encourage upstream “design for environment”? Am. Econ. Rev. 90 (2), 233–237.
Cajaiba-Santana, G., 2014. Social innovation: moving the field forward. A conceptual framework. Technol. Forecast. Soc. Change 82, 42–51.
Calvo-Silvosa, A., Antelo, S.I., Soares, I., 2018. Power generation and pollutant emissions in the European Union: A mean-variance model. J. Clean. Prod. 181, 123–135.
Canan, P., Andersen, S.O., Reichman, N., Gareau, B., 2015. Introduction to the special issue on ozone layer protection and climate change: the extraordinary experience of building the Montreal Protocol, lessons learned, and hopes for future climate change efforts. J. Environ. Soc. Sci. 5 (2), 111–121.
Chen, Y.S., Lai, S.B., Wen, C.T., 2006. The influence of green innovation performance on corporate advantage in Taiwan. J. Bus. Ethics 67 (4), 331–339.
Dahlsrud, A., 2008. How corporate social responsibility is defined: an analysis of 37 definitions. Corp. Soc. Responsib. Environ. Manag. 15 (1), 1–13.
D'Avanzo, E., D'Antò, V., Michelotti, A., Martina, R., Adinolfi, P., Madariaga, A.C.P., Zanoli, R., 2018. A collaborative web service exploiting collective rules and evidence integration to support sustainable orthodontic decisions. J. Clean. Prod. 176, 813–826.
Dawson, P., Daniel, L., 2010. Understanding social innovation: a provisional framework. Int. J. Technol. Manag. 51 (1), 9–21.
de Vargas Mores, G., Finocchio, C.P.S., Barichello, R., Pedrozo, E.A., 2018. Sustainability and innovation in the Brazilian supply chain of green plastic. J. Clean. Prod. 177, 12–18.
Dobrotă, D., Dobrotă, G., 2018. An innovative method in the regeneration of waste rubber and the sustainable development. J. Clean. Prod. 172, 3591–3599.
Dyck, B., Silvestre, B.S., 2018a. A novel NGO approach to facilitate the adoption of sustainable innovations in low-income countries: lessons from small-scale farms in Nicaragua. Organ. Stud. https://doi.org/10.1177/0170840617747921.
Dyck, B., Silvestre, B.S., 2018b. Enhancing socio-ecological value creation through sustainable innovation 2.0: moving away from maximizing financial value capture. J. Clean. Prod. 171, 1593–1604.
Edgeman, R., Eskildsen, J., 2014. Modeling and assessing sustainable enterprise excellence. Bus. Strat. Environ. 23 (3), 173–187.
Elkington, J., 1997. Cannibals with Forks: the Triple Bottom Line of 21st Century. Capstone, Oxford, UK, ISBN 1-900961-27-X.
Epstein, M.J., Buhovac, A.R., 2014. Making Sustainability Work: Best Practices in Managing and Measuring Corporate Social, Environmental, and Economic Impacts. Berrett-Koehler Publishers, San Francisco, CA, USA.
European Union, 2014. Report on the EU and the Global Development Framework after 2015 (2014/2143(INI)). European Unión. Committee on Development. Retrieved from. www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2014-0037+0+DOC+XML+V0//EN. on May 8th, 2017.
Fernández, Y.F., López, M.F., Blanco, B.O., 2018. Innovation for sustainability: the impact of R&D spending on CO2 emissions. J. Clean. Prod. 172, 3459–3467.
Franceschini, S., Faria, L.G., Jurowetzki, R., 2016. Unveiling scientific communities about sustainability and innovation. A bibliometric journey around sustainable terms. J. Clean. Prod. 127, 72–83.
Freeman, C., 1982. The Economics of Industrial Innovation. Pinter, Indianapolis, IN, USA.
Fussler, C., James, P., 1996. Driving Eco-innovation: a Breakthrough Discipline for Innovation and Sustainability. Pitman, London, UK.
Giuliani, E., 2016. Human rights and corporate social responsibility in developing countries' industrial clusters. J. Bus. Ethics 133 (1), 39–54.
Greenstone, M., Hanna, R., 2014. Environmental regulations, air and water pollution, and infant mortality in India. Am. Econ. Rev. 104 (10), 3038–3072.
Hall, J.K., Martin, M.J., 2005. Disruptive technologies, stakeholders and the innovation value-added chain: a framework for evaluating radical technology development. R D Manag. 35 (3), 273–284.
Hall, J., Matos, S., Gold, S., Severino, L.S., 2018. The paradox of sustainable innovation: the ‘Eroom’effect (Moore's law backwards). J. Clean. Prod. 172, 3487–3497.
Hall, J., Matos, S., Silvestre, B., 2012a. Understanding why firms should invest in sustainable supply chains: a complexity approach. Int. J. Prod. Res. 50 (5), 1332–1348.
Hall, J., Matos, S., Sheehan, L., Silvestre, B., 2012b. Entrepreneurship and innovation at the base of the pyramid: a recipe for inclusive growth or social exclusion? J. Manag. Stud. 49 (4), 785–812.
Hall, J., Matos, S., Silvestre, B., Martin, M., 2011. Managing technological and social uncertainties of innovation: the evolution of Brazilian energy and agriculture. Technol. Forecast. Soc. Change 78 (7), 1147–1157.
Hall, J., Vredenburg, H., 2003. The challenge of innovating for sustainable development. MIT Sloan Manag. Rev. 45 (1), 61–71.
He, X., Zhan, W., 2018. How to activate moral norm to adopt electric vehicles in China? An empirical study based on extended norm activation theory. J. Clean. Prod. 172, 3546–3556.
Hilgartner, S., Bosk, C.L., 1988. The rise and fall of social problems: a public arenas model. Am. J. Sociol. 94 (1), 53–78.
Hong, J., Zhang, Y., Ding, M., 2018. Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. J. Clean. Prod. 172, 3508–3519.
Huang, J., Yu, H., Guan, X., Wang, G., Guo, R., 2016. Accelerated dryland expansion under climate change. Nat. Clim. Change 6 (2), 166.
Huisingh, D., Tukker, A., Lozano, R., Quist, J., 2013. Knowledge collaboration and learning for sustainable innovation: an introduction to this special volume (Editorial). J. Clean. Prod. 48, 1–2.
Jensen, M., 1988. Takeovers: their causes and consequences. J. Econ. Perspect. 2 (1), 21–44.
Joyce, A., Paquin, R.L., 2016. The triple layered business model canvas: a tool to design more sustainable business models. J. Clean. Prod. 135, 1474–1486.
Khan, M.S., Johansson, E., Zaman, S., Unemo, M., Rahat, N.I., Lundborg, C.S., 2010. Poverty of opportunity forcing women into prostitution—a qualitative study in Pakistan. Health Care Women Int. 31 (4), 365–383.
Laiola, E., Giungato, P., 2018. Wind characterization in Taranto city as a basis for innovative sustainable urban development. J. Clean. Prod. 172, 3535–3545.
López-Iglesias, E., Peón, D., Rodríguez-Alvarez, J., 2018. Mobility innovations for sustainability and cohesion of rural areas: a transport model and public investment analysis for Valdeorras (Galicia, Spain). J. Clean. Prod. 172, 3520–3534.
Marcilio, G.P., de Assis Rangel, J.J., de Souza, C.L.M., Shimoda, E., da Silva, F.F., Peixoto, T.A., 2018. Analysis of greenhouse gas emissions in the road freight transportation using simulation. J. Clean. Prod. 170, 298–309.
Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. J. Econ. Geogr. 6 (4), 395–437.
Matos, S., Silvestre, B.S., 2013. Managing stakeholder relations when developing sustainable business models: the case of the Brazilian energy sector. J. Clean. Prod. 45, 61–73.
McAra, L., McVie, S., 2016. Understanding youth violence: the mediating effects of gender, poverty and vulnerability. J. Crim. Justice 45, 71–77.
McWilliams, A., Siegel, D., 2001. Corporate social responsibility: a theory of the firm perspective. Acad. Manag. Rev. 26 (1), 117–127.
Melane-Lavado, A., Álvarez-Herranz, A., González-González, I., 2018. Foreign direct investment as a way to guide the innovative process towards sustainability. J. Clean. Prod. 172, 3578–3590.
Morais, D.O., Silvestre, B.S., 2018. Advancing social sustainability in supply chain management: lessons from multiple case studies in an emerging economy. J. Clean. Prod. 199, 222–235.
Motta, W.H., Issberner, L.R., dos Rios Prado, P., 2018. Life cycle assessment and eco-innovations: what kind of convergence is possible? J. Clean. Prod. 187, 1103–1114.
Mulgan, G., 2006. A Manifesto for Social Innovation: what it Is, Why it Matters and How it Can Be Accelerated. The Young Foundation, London, UK.
Nair, S., Paulose, H., 2014. Emergence of green business models: the case of algae biofuel for aviation. Energy Pol. 65, 175–184.
Navamuel, E.L., Morollón, F.R., Cuartas, B.M., 2018. Energy consumption and urban sprawl: evidence for the Spanish case. J. Clean. Prod. 172, 3479–3486.
Neutzling, D.M., Land, A., Seuring, S., do Nascimento, L.F.M., 2018. Linking sustainability-oriented innovation to supply chain relationship integration. J. Clean. Prod. 172, 3448–3458.
Nicholls, A., Murdock, A., 2012. The nature of social innovation. In: Social Innovation. Palgrave Macmillan, London, UK, pp. 1–30.
Nunes, B., Bennett, D., 2010. Green operations initiatives in the automotive industry: an environmental reports analysis and benchmarking study. Benchmarking Int. J. 17 (3), 396–420.
Ousey, G.C., Kubrin, C.E., 2018. Immigration and crime: assessing a contentious issue. Annual Rev. Criminol. 1, 63–84.
Picatoste, J., Ruesga-Benito, S.M., González-Laxe, F., 2018. Economic environment

and health care coverage: analysis of social acceptance of access restrictive policies applied in Spain in the context of economic crisis. J. Clean. Prod. 172, 3600–3608.
Przychodzen, W., Przychodzen, J., 2018. Sustainable innovations in the corporate sector–The empirical evidence from IBEX 35 firms. J. Clean. Prod. 172, 3557–3566.
Rantala, T., Ukko, J., Saunila, M., Havukainen, J., 2018. The effect of sustainability in the adoption of technological, service, and business model innovations. J. Clean. Prod. 172, 46–55.
Saieg, P., Sotelino, E.D., Nascimento, D., Caiado, R.G.G., 2018. Interactions of building information modeling, lean and sustainability on the architectural, engineering and construction industry: a systematic review. J. Clean. Prod. 174, 788–806.
Schrempf-Stirling, J., Palazzo, G., Phillips, R.A., 2016. Historic corporate social responsibility. Acad. Manag. Rev. 41 (4), 700–719.
Schumpeter, J., 1934. Capitalism, Socialism, and Democracy. Harper & Row, New York, USA.
Seuring, S., Muller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16 (15), 1699–1710.
Seyfang, G., Smith, A., 2007. Grassroots innovations for sustainable development: towards a new research and policy agenda. Environ. Polit. 16 (4), 584–603.
Shively, G.E., 2004. Poverty and forest degradation: introduction to the special issue. Environ. Dev. Econ. 9 (2), 131–134.
Silvestre, B.S., 2015a. Sustainable supply chain management in emerging economies: environmental turbulence, institutional voids and sustainability trajectories. Int. J. Prod. Econ. 167, 156–169.
Silvestre, B.S., 2015b. A hard nut to crack! Implementing supply chain sustainability in an emerging economy. J. Clean. Prod. 96, 171–181.
Silvestre, B.S., Silva Neto, R., 2014a. Capability accumulation, innovation, and technology diffusion: lessons from a Base of the Pyramid cluster. Technovation 34 (5), 270–283.
Silvestre, B.S., Silva Neto, R., 2014b. Are cleaner production innovations the solution for small mining operations in poor regions? The case of Padua in Brazil. J. Clean. Prod. 84, 809–817.
Silvestre, B.S., Monteiro, M.S., Viana, F.L.E., de Sousa-Filho, J.M., 2018. Challenges for sustainable supply chain management: when stakeholder collaboration becomes conducive to corruption. J. Clean. Prod. 194, 766–776.
Srivastava, S.K., 2007. Green supply-chain management: a state-of-the-art literature review. Int. J. Manag. Rev. 9 (1), 53–80.
Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Res. Pol. 15 (6), 285–305.
United Nations, 2016. Working Arrangements for the 2016 Session of the Economic and Social Council, 24 July 2015-27 July 2016. Retrieved from: www.un.org/ecosoc/en/sustainable-development. on May 8th, 2017.
Utterback, J., 1994. Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change. Harvard Business School Press, Boston, USA.
Uyarra, E., Shapira, P., Harding, A., 2016. Low carbon innovation and enterprise growth in the UK: challenges of a place-blind policy mix. Technol. Forecast. Soc. Change 103, 264–272.
van der Have, R.P., Rubalcaba, L., 2016. Social innovation research: an emerging area of innovation studies? Res. Pol. 45 (9), 1923–1935.
WCED, 1987. World Commission on Environment and Development. Our Common Future. Oxford University Press, New York, USA.
Wheeler, T., Von Braun, J., 2013. Climate change impacts on global food security. Science 341, 508–513.
Wong, C.W., Lai, K.H., Shang, K.C., Lu, C.S., Leung, T.K.P., 2012. Green operations and the moderating role of environmental management capability of suppliers on manufacturing firm performance. Int. J. Prod. Econ. 140 (1), 283–294.
Yenipazarli, A., 2017. To collaborate or not to collaborate: prompting upstream eco-efficient innovation in a supply chain. Eur. J. Oper. Res. 260 (2), 571–587.
Yunus, M., Moingeon, B., Lehmann-Ortega, L., 2010. Building social business models: lessons from the Grameen experience. Long. Range Plan. 43 (2–3), 308–325.
Zachariadis, T., 2016. Climate change impacts. In: Climate Change in Cyprus. SpringerBriefs in Environmental Science, Springer, New York, USA, pp. 25–49.
Zorpas, A.A., Lasaridi, K., Pociovalisteanu, D.M., Loizia, P., 2018a. Monitoring and evaluation of prevention activities regarding household organics waste from insular communities. J. Clean. Prod. 172, 3567–3577.
Zorpas, A.A., Voukkali, I., Pedreño, J.N., 2018b. Tourist area metabolism and its potential to change through a proposed strategic plan in the framework of sustainable development. J. Clean. Prod. 172, 3609–3620.
Zulfiqar, F., Thapa, G.B., 2018. Determinants and intensity of adoption of “better cotton” as an innovative cleaner production alternative. J. Clean. Prod. 172, 3468–3478.