Ardian Qorri

MEASURING AND MANAGING SUSTAINABLE DEVELOPMENT IN SUPPLY CHAINS

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Supervisor Professor Andrzej Kraslawski
LUT School of Engineering Science
Lappeenranta-Lahti University of Technology LUT
Finland

Reviewers Professor Ana Carvalho
Department of Engineering and Management
University of Lisbon
Portugal

Professor Antonio Espuña
Department of Chemical Engineering
Technical University of Catalonia
Spain

Opponent Professor Antonio Espuña
Department of Chemical Engineering
Technical University of Catalonia
Spain

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Abstract

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Supply chains are the backbone behind companies. Integrating sustainability in supply chains is difficult but essential to gain competitive advantages. While sustainability recognizes the interdependence of environmental, social, and economic aspects, measuring and managing performance across chain partners is challenging. The information generated from measurement process is used by management to control, communicate, and improve their efforts and relationships with partners. Hence, supply chain sustainability measurement and management are critical in achieving firm's strategic objectives. However, existing performance measurement and management tools fail to consider all sustainability aspects across supply chain practices and partners.

The goal of this dissertation is to explore and develop approaches for measuring and managing sustainability performance of supply chains. By applying a mixed methodology including a systematic literature review, conceptual design, content analysis, meta-analysis, fuzzy Entropy, fuzzy TOPSIS, and sensitivity analysis, I develop a novel and practical method to measure and manage sustainability performance in supply chains.

The results of this dissertation have been published in four articles, for which the data was gathered through several sources. The results show (i) the state of the art of sustainability performance measurement approaches; (ii) the proposed conceptual framework explains new relationships between sustainability performance measurement components and stakeholders; (iii) the effect of social and environmental supply practices on firm performance; and (iv) sensitivity analysis confirm that the proposed measurement approach is practical and generates robust and usable outcomes. The dissertation contributes to the literature by providing new insights for scholars, managers, policymakers, and other stakeholders regarding environmental and social supply practices for achieving sustainable development.

Keywords: Sustainability, strategic supply chain management, sustainability assessment, performance measurement, sustainable supply chain, SSCM

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Publications

List of publications

This dissertation is based on and contains material from four publications. The rights have been granted by publishers to include the following publications in this dissertation.

I. Qorri, A., Mujkić, Z. and Kraslawski, A. (2018) 'A conceptual framework for measuring sustainability performance of supply chains', *Journal of Cleaner Production*, 189(April), pp. 570–584. doi: 10.1016/j.jclepro.2018.04.073.

II. Qorri, A., Mujkić, Z., Gashi, S. and Kraslawski, A. (2018) 'Green Supply Chain Management Practices and Company Performance: A Meta-analysis approach', *Procedia Manufacturing*, 17, pp. 317–325. doi: 10.1016/j.promfg.2018.10.052.

III. Qorri, A., Gashi, S. and Kraslawski, A. (2021) 'Performance outcomes of supply chain practices for sustainable development: A meta-analysis of moderators', *Sustainable Development*, 29(1), pp. 194–216. doi: 10.1002/sd.2140.

IV. Qorri, A., Gashi, S. and Kraslawski, A. (2022) 'A practical method to measure sustainability performance of supply chains with incomplete information', *Journal of Cleaner Production*, p. 130707. doi: 10.1016/j.jclepro.2022.130707.

Author's contribution

In all publications (I – IV), I am the principal author, investigator, and corresponding author. I was responsible for conceptualizing the core research idea and research design as well as conducting the research (literature review, data collection & analysis, writing, and conclusions). The co-authors assisted in data collection, commented on early versions, and assisted in responding to the reviewers.

Supporting publications

Mujkic, Z., Qorri, A., Kraslawski, A. and Gashi, S. (2019) 'Supplier Selection and Optimization of Supply Chains', *International Journal of Management and Sustainability*, 8(2), pp. 98–110.

Mujkić, Z., Qorri, A. and Kraslawski, A. (2018) ‘Consumer Choice and Sustainable Development of Supply Chains’, *Procedia Manufacturing*. V., 17, pp. 1097–1103.

Mujkic, Z., Qorri, A. and Kraslawski, A. (2018) Sustainability and Optimization of Supply Chains: A Literature Review, *Operations and Supply Chain Management: An International Journal*, (August), pp. 186-199.

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Abbreviations

SC	Supply chain
SCM	Supply chain management
GSCM	Green supply chain management
SSCM	Sustainable supply chain management
CLSC	Closed lopp supply chain
TBL	Tripple Bottom Line
KPI	Key perfromance indicator
CSR	Corporate Social Responsibility
GRI	Global Reproting Initiative
SDG	Sustinable Development Goal
UN	Unaited Nations
RBV	Resource based view
NRBV	Natural resource based view
NGO	Non-govermental Organization
MCDM	Multi Criteria Decision Making
ANOVA	Analog to analysis of variance
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

1 Introduction

This chapter presents an overview and a concise background on the research topic and rationale of the study, where I identify several research gaps. The second part presents the study goal and research questions, then the definition of key terms is given followed by the structure of this dissertation.

1.1 Background

It has been estimated that ecological resources used by humans require 1.7 Earths (Global Footprint Network, 2019) and by 2050, the use of materials including metals, fossils, biomass and non-metallic minerals is expected to be doubled (OECD, 2019). Facing such issues many countries, international organizations, and companies have started to look for alternative ways (e.g., investing in greener technologies) for improving efficiency of materials and mitigating their adverse effects on the environment and society, in both production and consumption (Zhu and Sarkis, 2004; Abdul-Rashid *et al.*, 2017).

Almost every activity or process an organization undertakes to make a product or provide a service requires the transformation of material and energy inputs that generate some positive and negative outcomes. In the current globalized economy, material and energy inputs and outputs are sourced from and distributed to numerous countries and continents via long and complicated networks. Such networks usually are called supply chains (SCs), which according to Christopher (2011) can be defined as "*a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate customer*".

While conventional supply chain management (SCM)—the process of planning, implementing, and controlling material and information flows up and down, implies a linear relationship of flows, integrating environmental and social aspects requires SC to be more circular and nonlinear (Sarkis and Dou, 2017, p. 6). This is often named as "closing the loop" or "closed loop supply chain (CLSC)" and is considered as an important element that impacts firm performance (Sroufe, 2003; Nikolaou, Evangelinos and Allan, 2013) and is necessary for achieving sustainable development goals (SDGs) (e.g., SDGs 11, 12 and 14) (Visser, 2018).

The term sustainable development emerged from the report entitled *Our Common Future*, published in 1987 by the United Nations (UN) World Commission on Environment and Development. Sustainable development is usually defined as "*a development which meets* *the needs of the present generation without compromising the ability of future generations to meet their needs"* (WCED, 1987). Later Elkington (1998) highlighted that sustainability should include three dimensions or pillars, namely, environmental, social, and economic aspects. Another frequent concept used to describe sustainability is the Triple Bottom Line (TBL or 3BL), where each aspect is associated with respective capital: environmental (profit), social (people), and economic (growth and competitiveness).

The integration of environmental concerns in SCM is usually described by the concept of Green Supply Chain Management (GSCM) (Srivastava, 2007). Whereas the integration of both environmental and social dimensions in SCM is called Sustainable Supply Chain Management (SSCM) (Seuring and Müller, 2008). In this dissertation, I focus on SSCM literature as by definition it is a wider concept and it includes the GSCM literature, literature dealing with integration of social concerns in SC (Carter and Jennings, 2002; Pullman, Maloni and Carter, 2009), and the CLSC literature (Govindan, Soleimani and Kannan, 2015).

Lambert and Cooper (2000) and Christopher (2011) argue that the competition has shifted from company to SC level. But SCs are getting more complex and so are their performance measurement and management. Such complexity hardens the strategic management that aims to explain the variations in performance (Madsen and Walker, 2016). In other words, SCs are essential to gain competitive advantages (Li *et al.*, 2006). The importance of measuring and managing SC performance is evident, by allowing deployment of strategies without excluding partnering firms and helping the chain to attain its goals (Paulraj, 2011).

While performance measurement and management play a critical role in permitting control and providing a communication mechanism to translate mission and strategy into smart objectives (Magretta, 2012), achieving sustainability requires the participation of each SC firm (Seuring and Müller, 2008). This means assessing social and environmental performance across the SC (Cuthbertson and Piotrowicz, 2011). However, measuring sustainability is challenging (Hassini, Surti and Searcy, 2012) and is a field in transition (Sroufe and Melnyk, 2019), moving from conceptual to empirical research (Piotrowicz and Cuthbertson, 2015).

There is considerable research dealing with a wide variety of theoretical and practical problems and solutions arising from the environmental and social integration concerns in SCM (Seuring and Müller, 2008; Huang, Huang and Yang, 2017). But SC sustainability performance measurement received less attention (Erol, Sencer and Sari, 2011) and relevant measurement tools or methods are not well-developed (Schöggl, Fritz and

Baumgartner, 2016). Many studies have also revealed that the integration of social aspect of sustainability is less researched compared to environmental and economic aspects (Seuring and Müller, 2008; Dubey *et al.*, 2017). However, the TBL approach requires the consideration of all three aspects and the inclusion of all SC partners to successful adoption of sustainability (Eltayeb, Zailani and Ramayah, 2011). A similar pattern is mirrored in studies dealing with sustainability performance measurement of SCs (Beske-Janssen, Johnson and Schaltegger, 2015).

Some of the main indicators used to measure traditional SC performance include costs, flexibility, speed, quality, and dependability (Gunasekaran and Kobu, 2007). When assessing environmental and social outcomes, such indicators are insufficient and should be complemented with other indicators that are able to measure environmental and social performance (Taticchi, Tonelli and Pasqualino, 2013). To bridge this gap, many scholars have proposed various indicators, especially for GSCM, as identified by Hassini, Surti and Searcy (2012) but these indicators are sparsely applied in real case applications (Qorri, Mujkić and Kraslawski, 2018). Additionally, the existing SC performance measurement methods are insufficient to consider interaction with partners and organization's strategic goals (Beamon, 1999).

In this dissertation, I focus on the measurement and management of sustainability performance in SCs. A simple illustration regarding positioning of this dissertation is given in Figure 1. The research problem I investigate is interdisciplinary and integrates at least three fields of research: SCM literature, Sustainability literature, and Performance measurement and management literature. Overall, this study attempts to provide new insights and develop relevant tools that consider environmental, social, and economic pillars to measure sustainability performance and facilitate decision-making in strategic, tactic, and operational levels.

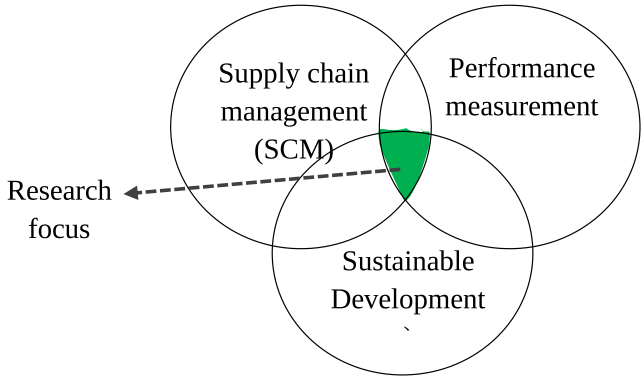


Figure 1. Focus of the research.

Given the importance of SSCM and the critical role of sustainability performance measurement to achieve strategic goals and to reduce (eliminate) waste and pollution, in the following I present the rationale of this study, that is, why measuring and managing SC sustainability performance is important and which research gaps this dissertation addresses.

1.2 Rationale of the study

Aligning SC practices with sustainability dimensions is becoming vital to accommodate the needs of future generations in an efficient and effective way (Pagell and Wu, 2009). Companies (usually manufacturers) that have previously failed to adopt environmental and social practices within their company and across their SC are held accountable for the behavior of their partners (e.g., suppliers) (Esfahbodi *et al.*, 2017). For example, carmakers including VW, BMW, and Vauxall are held responsible for their suppliers, which illegally used child labor and debt bondage in Indian mines (Bengsten and Kelly, 2016). Such issues could probably have been detected and addressed much earlier if these companies had more visibility into activities of their suppliers (Sroufe and Melnyk, 2019). As highlighted by Carter and Rogers (2008), transparency is an important element of SSCM, but increasing the level of transparency requires measuring sustainability of practices and activities within the company and across partnering firms (Beske-Janssen, Johnson and Schaltegger, 2015).

Another aspect that motivates this study is linked to the lack of dedicated research on measurement tools and methods (Hervani, Helms and Sarkis, 2005; Taticchi *et al.*, 2015; Schöggl, Fritz and Baumgartner, 2016). This is different from studies focused on sustainability metrics (Ahi and Searcy, 2015; Tajbakhsh and Hassini, 2015b). Although both measurement approaches and metrics are integrative and crucial elements of a performance measurement system, in this study, I research how to integrate or combine indicators into measurement methods rather than developing new metrics. The importance and the need for developing new methods to aggregate various sustainability indicators for assessing SC performance have been highlighted also by many researchers (e.g., Schaltegger and Burritt, 2014; Beske-Janssen, Johnson and Schaltegger, 2015; Büyüközkan and Karabulut, 2018). It is evident from the literature that there are numerous environmental and social indicators proposed (for a review see Ahi and Searcy (2015)), but it is unclear when and how to combine (aggregate) them for measuring sustainability performance of SCs (Gopal and Thakkar, 2012; Pavláková Dočekalová *et al.*, 2017).

A large stream of SSCM literature deals with the performance outcomes resulting from the implementation of environmental and social practices across the SC (González-Benito and González-Benito, 2005; Green *et al.*, 2012; Wolf, 2014; Mani *et al.*, 2016). However, the results are mixed and contradictory, with many studies reporting positive (e.g., Rao and Holt, 2005; Yang *et al.*, 2013) and negative (e.g., Richey *et al.*, 2005; Large and Thomsen, 2011) correlations. Additionally, almost every study has considered only a limited number of SSCM practices or types of firm performance. Consequently, such results make managers and scholars confused about the impact of SSCM practices on firm performance (Golicic and Smith, 2013). To add clarity to such an important association, I meta-analytically synthesized existing empirical evidence and try to provide a generalizable resolution.

In sum, companies are increasingly scrutinized to implement environmental and social concerns within their activities and across their SCs but without well-developed sustainability performance measurement systems, the management and the transition towards sustainable development proved to be challenging (Roca and Searcy, 2012). It is obvious from the literature that assessing (economic) performance in SCs is difficult (Beamon, 1999; Gunasekaran and Kobu, 2007) but adding environmental and social indicators complicated the performance measurement system in many aspects (Varsei *et al.*, 2014; Santiteerakul *et al.*, 2015). For example, it is difficult to attribute performance to particular SSCM practices (e.g., eco-design, green supplier selection) given numerous interdependencies between them (Matos and Hall, 2007) and sustainability dimensions (Chardine-Baumann and Botta-Genoulaz, 2014).

Additionally, the lack of systematic and integrated sustainability performance measurement methods hinders the successful deployment of sustainability strategies and practices (Ahi, Jaber and Searcy, 2016; Laosirihongthong *et al.*, 2020). To narrow the research gaps listed above, in the following section, I present the aim of this dissertation and the research questions addressed.

1.3 Purpose of the study

Sustainability performance measurement in SC is complex (Sloan, 2010). Measurement tools and methods are little developed and neither all three sustainability dimensions nor all SC partners have been considered (Schaltegger and Burritt, 2014). To address this complexity and bridge above listed gaps, this study focuses on the following:

> *The goal of this dissertation is to explore, analyze and develop approaches for measuring and managing sustainability performance of supply chains.*

1.3.1 Research questions

To fulfil the purpose of this study, I have broken down into three research questions as follows:

RQ1. What methods and tools can be used to assess sustainability performance of supply chains?

RQ2. How can a performance measurement system be developed to evaluate environmental, social, and economic aspects across partnering firms?

RQ3. What is the impact of environmental and social supply chain practices on firm performance, and when such impact is stronger?

This research contributes to such issues by (i) providing state of the art of sustainability measurement methods and tools, (ii) developing a comprehensive method for measuring sustainability performance across SC, and (iii) generalizing the effect of SSCM practices on firm's sustainability performance. Subsequently, I present the definitions of main concepts used in this study.

1.4 Definition of the key concepts

Table 1 lists the main terms and their definitions used in this study. The terms are mostly arranged following the order used in the dissertation. More details are given in relevant sections when they appear.

Table 1. Definition of key concepts.

Terminology	**Definition**	**Reference**
Supply chain management (SCM)	"a systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole"	(Mentzer *et al.*, 2001)
Green Supply Chain Management (SSCM)	"Integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life"	(Srivastava, 2007)

Sustainable Supply Chain Management (SSCM)	"The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term"	(Ahi and Searcy, 2013)
Performance	"achievement of results ensuring the delivery of desirable outcomes for a firm's stakeholders"	(Atkinson, 2012)
Performance measurement	"the process of quantifying the efficiency and the effectiveness of action"	(Neely, Gregory and Platts, 1995)
Performance management	"performance management is using performance measurement information to focus on what is important, manage the organization more effectively and efficiently and promote continuous improvement and learning"	(Atkinson, 2012)

1.5 Structure of the study

This dissertation consists of two parts. Part one provides an overview of the research and is divided into five chapters. The first chapter presents the motivation behind the study, the research goal and questions, followed by definitions of key terms. The second chapter discusses the theoretical framework and briefly reviews the relevant performance measurement literature and SSCM studies. The third chapter describes the research methodology, methods selected, data collected, and discusses the quality of research. The fourth chapter presents a summary of publications included in this dissertation. The last chapter discusses the relevance of findings to theory and practice, notes the study limitations, and describes future research recommendations.

Part two of the dissertation presents individual publications that address research questions posed in this dissertation.

To further clarify the relation between chapters, research questions, and publications, Table 2 illustrates the interplay between these elements.

Table 2. Relation between Chapters, research questions, and publications.

PART I **Overview of the study**			
Chapters	**1.Introduction; 2. Literature review; 3. Methodology; 4. Summary of publications; 5. Discussion and Conclusion.**		
Research Questions	**RQ1:** What methods and tools can be used to assess sustainability performance of supply chains?	**RQ2:** How can a performance measurement system be developed to evaluate environmental, social, and economic aspects across partnering firms?	**RQ3:** What is the impact of environmental and social supply chain practices on firm performance, and when such impact is stronger?
Publication I	✔	✔	
Publication II			✔
Publication III		✔	✔
Publication IV	✔	✔	

✔ = contributes to the research question.

PART II
Individual publications

2 Theoretical framework

This chapter provides a concise overview of SSCM literature and sustainability performance research. A discussion of SSCM practices and a review of studies dealing with measuring sustainability performance in SC is also given. The chapter ends with the conceptual framework developed in this dissertation.

2.1 Green and sustainable supply chain management

In 2010, the Apple cooperation faced harsh criticism about the poor workplace conditions and low wages provided by Foxconn—the Chinese manufacturer where iPhone is made (Merchant, 2017). Numerous other similar sustainability incidents or scandals (e.g., the example given in the Introduction about BMW and VW; Tesco’s horse-burgers; Unsafe For Children: Mattel's Toy Recall, etc.) show that the focal company is often held responsible by non-governmental organizations (NGOs), media and experts for unsustainable practices of companies involved in their SCs. This highlights the importance of integrating environmental and social practices in the extended SC. In SSCM literature, usually, this is emphasised by stating that an organization is no more sustainable than its SC (Gualandris and Kalchschmidt, 2016).

Such problems could have probably been prevented if the focal companies had greater visibility and transparency concerning both the environmental and social practices followed by their SC partners. Transparency and visibility directly rely on the ability of the firm to trace and measure sustainability performance beyond firm boundaries (Beske-Janssen, Johnson and Schaltegger, 2015). However, sustainability performance measurement across firms is difficult and relevant methods and tools are still not well-developed (Taticchi *et al.*, 2015; Qorri, Mujkić and Kraslawski, 2018).

Before 2008, the research focused primarily on the integration of environmental and economic factors on the SC (Seuring and Müller, 2008). This is named as GSCM (Srivastava, 2007). As more research on GSCM is conducted, a growing number of authors started to consider also the social factors besides economic and environmental factors (Varsei *et al.*, 2014), and renamed the field of study as SSCM. The objective of SSCM is to integrate sustainable development into SCM (firm strategy and practices) (Carter and Rogers, 2008). The SSCM literature studies the alternative approaches that would allow developing, protecting, and increasing long-term social, environmental, and economic value for all stakeholders involved throughout the lifecycles of goods and services (Ahi and Searcy, 2013). Thus, SSCM should be a joint effort of all SC members and not only the job of the focal organization (Vachon and Klassen, 2006).

Considerable research conducted in SSCM literature follows the focal firm's perspective and has placed environmental and social interests after economic interests (Seuring and Müller, 2008; Wicher, Zapletal and Lenort, 2019). An alternative approach, named the ecologically dominant logic, is suggested by Montabon, Pagell and Wu, (2016) who puts environmental and social interests before economic interests. Recently, a growing number of studies adopted this integrative TBL approach (Abdul-Rashid *et al.*, 2017; Paulraj, Chen and Blome, 2017). A similar pattern is also mirrored in corporate agendas. While earlier companies used to adopt a reactive sustainability approach that focuses on compliance with laws, recently a growing number of firms are adopting a proactive sustainability approach where environmental and social practices are managed with SC partners to gain or maintain competitive advantages (Ateş *et al.*, 2012; Madsen and Walker, 2016).

At its core SSCM covers the entire life-cycle of the product or service (Schöggl, Fritz and Baumgartner, 2016). Both *upstream practices* related to material sourcing activities and *downstream practices* related to transportation, distribution, consumption, return and disposal, have a huge impact on a company's sustainability performance (Sarkis, 2012). Integrating the TBL approach across such functions requires collaboration and coordination with SC members (Paulraj, 2011; Nematollahi *et al.*, 2018). In practice, the process of working together with SC partners to achieve sustainability requires tackling (i) environmental factors such as water, air, land, and other natural resources; (ii) social factors including equal treatment of all workers, respecting human rights and labour standards; and (iii) economic indicators relating to financial performance and competitiveness (Zhu, Sarkis and Lai, 2012).

The SC play a critical role in achieving SDGs (Sarkis, 2019). This role can be either positive or negative through for instance suppliers and materials selection, product and process design, modal and carrier selection, and packaging choices. Such important decisions rely on information generated by a performance measurement system that should process (incomplete) TBL data for all SC partners. This is in line with Carter and Easton (2011) who highlighted that SSCM promotes measuring sustainability performance.

The SSCM literature includes also reverse SCs research that examines various issues concerned with products that reached the end of their lifecycles, or those returned by consumers. The goal of reverse activities is to extract the remaining value of products for decreasing the consumption of natural resources by closing the loop (Richey *et al.*, 2005; Abdullah and Yaakub, 2014). This is achieved through refurbishing, recycling, reusing, remanufacturing, and other similar activities. Thus, CLSCs are important and can improve economic, social, and environmental performance (Govindan, Soleimani and Kannan, 2015).

While exploring social sustainability measures relevant to SCM, Hutchins and Sutherland (2008) note that the term corporate social responsibility (CSR) is often used as a synonym of ‘social responsibility’. In the SC context, CSR can be understood as a “*chain wide consideration of, and response to, issues beyond the narrow economic, technical and legal requirements of the supply chain to accomplish social (and environmental) benefits along with the traditional economic gains, which every member in that supply chain seeks”* (Spence and Bourlakis, 2009). In a similar fashion, several authors studying how to integrate social sustainability in SCM used the concept of CSR (Balkau and Sonnemann, 2010; Awan *et al.*, 2016). For example, Nikolaou, Evangelinos and Allan (2013) proposed a performance framework using CSR principles in reverse logistics, whereas Awan *et al.* (2016) investigated the correlations between CSR, environmental supplier development, and firm performance.

In sum, integrating the TBL approach in SCM requires adopting SC strategy and practices. This integration is complex and requires the involvement and commitment of all SC partners. When exploring such integration, most authors focused on inter-firm (cross-organizational) practices. These practices are (usually) called GSCM/SSCM practices and are briefly discussed subsequently.

2.1.1 Sustainable supply chain management practices

Sustainability can be integrated into various ways among SC partners. The development and adoption of the sustainability strategy depend on at least three broad settings:

(i) *external*— country legal, economic, industrial, technological factors, etc.
(ii) *internal—*firm characteristics (e.g., size, type of operations) and the relative importance environmental, social, and economic dimensions have in the eyes of the company (self-interest in sustainability) and its stakeholders and
(iii) *the focal firm* — the importance of sustainability dimensions in the eyes of focal company, and its potential to influence SC partners to implement sustainability practices.

Accordingly, SSCM practices (as mechanisms that enable the integration of sustainability) can be and are categorized in various ways by different authors. The lack of a comprehensive framework for SSCM practices has been mentioned also by several authors (e.g., Laosirihongthong, Adebanjo and Choon Tan, 2013). By definition, SSCM practices include cross-functional activities and inter-firm practices to meet stakeholder requirements over the short- and long-term (Ahi and Searcy, 2013). The majority of research categorized GSCM/SSCM practices into three broad groups:

(i) Zhu and Sarkis (2004) proposed this categorization: Eco Design, Green Purchasing, Cooperation with Customers, Internal Environmental Management, and Investment Recovery.
(ii) Rao and Holt (2005) and De Giovanni (2012) suggested categorizing SSCM into Inbound (Internal) and Outbound (External) practices.
(iii) Vachon and Klassen (2006) and Tachizawa, Gimenez and Sierra (2015) proposed to categorize Monitoring-based and Collaboration-based practices.

There are also other frameworks proposed (e.g., Srivastava, 2007) but they usually can be fitted among these ones. In this dissertation, we complemented the first categorization with other practices including Sustainable Manufacturing (Mitra and Datta, 2014; Abdul-Rashid *et al.*, 2017), Sustainable Distribution and Packaging (Awasthi, Chauhan and Omrani, 2011; Lee and Wu, 2014), Reverse Logistics (Gorane and Kant, 2017), Socially Inclusive Practices for Employees and Socially Inclusive Practices for Community (Mani *et al.*, 2016; Das, 2017). More details about these practices are given in Table 3.

The above categorization was chosen for mainly three reasons: (i) they capture key practices in SCM (Green *et al.*, 2012); (ii) these practices and their scales are among the most applied by researchers; and (iii) these practices help to achieve competitive advantages by meeting the casual ambiguity and social complexity properties of strategic resources (Vachon and Klassen, 2006; Kirchoff, Tate and Mollenkopf, 2016).

Table 3. Description of sustainable supply chain management practices.

Practice	***Description***	***References***
Internal Sustainable Management	Refers to strategies, processes and procedures supporting intra-organizational environmental and social objectives.	(Zhu and Sarkis, 2007; Abdul-Rashid *et al.*, 2017; Vanalle *et al.*, 2017)
Sustainable Purchasing	Reflects the importance of cooperating with suppliers for the purpose of developing products that are environmentally and socially sustainable.	(Govindan, Khodaverdi and Jafarian, 2013; Tachizawa, Gimenez and Sierra, 2015; Vanalle *et al.*, 2017)
Sustainable Product Design	The design of products with environmental and social objectives and impacts in mind during their entire lifecycle.	(Eltayeb, Zailani and Ramayah, 2011; Chaturvedi *et al.*, 2017; Ding, 2018)
Sustainable Production	All activities implemented requiring less energy and resource usage and minimizing environmental impacts in manufacturing processes.	(Li and Hamblin, 2016; Abdul-Rashid *et al.*, 2017; Esfahbodi *et al.*, 2017)

Sustainable Packaging and Distribution	Any means of transportation from suppliers to manufacturers to final customers with the purpose of having minimal harmful impacts and packaging usage.	(Eltayeb, Zailani and Ramayah, 2011; Nematollahi *et al.*, 2018; Çankaya and Sezen, 2019)
Customer Sustainable Cooperation	Working with customers to better understand and integrate their sustainability perspectives and assuring high-quality products.	(Esfahbodi *et al.*, 2017; Zahiri, Zhuang and Mohammadi, 2017; Çankaya and Sezen, 2019)
Reverse Logistics	Include activities that aim taking products back or materials from consumers to manufacturers for the purposes of reuse, refurbishing or recycling.	(Sroufe, 2003; Rao and Holt, 2005; Eltayeb, Zailani and Ramayah, 2011; Viegas *et al.*, 2019)
Investment Recovery	Reflects the importance of capturing value through resell and reuse of used materials.	(De Giovanni, 2012; Viegas *et al.*, 2019)
Social Practices for Employees	Firm's efforts to induce socially responsible behaviour in its own operations and the operations of its partners.	(Mani *et al.*, 2016; Das, 2017; Aras, Tezcan and Kutlu Furtuna, 2018)
Social practices for community	Firm's investments in the surrounding community in terms of generation of employment and business opportunities, providing education, training, healthcare facilities, etc.	(Xie and Breen, 2012; Mani *et al.*, 2016; Das, 2017; Milanesi, Runfola and Guercini, 2020)

Source: Modified from Qorri, Gashi and Kraslawski (2021).

Usually, SSCM practices are studied in relation to performance implications (Paulraj, Chen and Blome, 2017). Subsequently, I discuss the significance and dimensions of sustainability performance.

2.1.2 Sustainability performance

The importance of managing and measuring performance is given by the old axiom, "*what gets measured, gets managed*". Following this logic, many organizations are reporting their performance including some environmental and social coverage. According to Sroufe and Melnyk (2019) there are at least two critical factors behind measuring and monitoring sustainability. The first factor is related to the changes in market demand and customer base (increasingly consumers want to know more about the product lifecycle and its impact on the environment and society). The second factor is related to the advent of new technologies such as the Internet of Things and Blockchain technologies (they help in the provision of visibility and transparency required by companies and stakeholders interested in sustainability of SCs).

By definition of the TBL approach, there are three dimensions (environmental, social, and economic) that should be considered when measuring sustainability performance.

Environmental performance is measured by several indicators related to materials, natural resources (e.g., water, air, land) and energy (Santiteerakul *et al.*, 2015). Social performance is measured using metrics related to health and safety, human rights, ethics, and labour practices (Yawar and Seuring, 2017). The economic dimension is measured using financial and non-financial indicators (Taticchi, Tonelli and Pasqualino, 2013).

Several authors divided further economic performance into financial and operational indicators (e.g., quality, efficiency, and flexibility) (Christmann, 2000; Rao and Holt, 2005; Das, 2017). In this dissertation in two publications, I follow the TBL approach and in two other publications, I consider also the operational dimension. The operational dimension is important when examining the impact of SSCM practices on firm performance (Hollos, Blome and Foerstl, 2012). Furthermore, among sustainability dimensions, the measurement of social sustainability in SC is more difficult due to the fact that some indicators are hard to be quantified (Hassini, Surti and Searcy, 2012).

Given that the aim of this dissertation is to study sustainability measurement process (How measurement should be carried?) and not specific metrics, I restrain myself from a detailed discussion covering that topic. However, I want to highlight that I have mostly followed the structure and used indicators proposed by Global Reproting Initiative (GRI), which are broadly used by many scholars and consider all three sustainability aspects.

2.1.3 **Sustainable supply practices and firm performance**

To explain the relationships between SSCM practices and firm performance, scholars usually used the lens of resources-based theories (Sarkis, 2012). According to resources-based theory (RBV) the company can create competitive advantages by owing strategic resources, which are "*valuable, rare, inimitable and non-substitutable*" (Barney, 1991). Resources include both tangible (equipment, capital assets, technology) and intangible (knowledge-based) components. In the sustainability literature, it has been argued that natural resources are rare and valuable. Connecting RBV with natural resources, Hart (1995) proposed the natural resource-based view (NRBV) of the firm that is used to explain the link between SSCM practices and firm performance. Hart proposes three strategies (minimization/elimination of pollution, lifecycle or "cradle to grave" product or service perspective, minimization of environmental impacts) that can be used to gain competitive advantages.

SSCM practices expand beyond firm boundaries and thus the above theories focused on firm-specificity could not be used to explain relationships that span across SC partners. Addressing this issue, scholars used the relational view (Dyer and Singh, 1998). According to this theory, strategic capabilities can be developed beyond firm boundaries by combining resources across SC partners. These theories are used in many studies (Vachon and Klassen, 2006; Paulraj, Chen and Blome, 2017). Thus, combining these theories as many authors, I explain the links between SSCM practices and firm performance in Publications II and III included in this dissertation.

The impact of SSCM practices on firm performance is among the most studied and debated topic in the SSCM literature. Yet the results are mixed and inconsistent, making it harder for managers to know what practices would be beneficial to be implemented (Golicic and Smith, 2013). While the environmental and/or social SC practices are expected to improve environmental/social performance, their effect on the economic performance might be negative (Laari *et al.*, 2016). For example, De Giovanni (2012) report negative and insignificant correlations between external and internal SC practices with economic performance, respectively. The author also found an insignificant effect of external SC practices on social performance. Similar results are reported also by Wang and Sarkis (2013) who found a negative effect on economic performance if only environmental SCM or social SCM practices are adopted separately. However, they also found a positive effect on economic performance from SSCM (adopting jointly environmental and social) practices.

Developing and implementing SSCM practices require the investment of resources that might increase costs over the short-term (Pagell and Wu, 2009) but may mitigate risks related to environmental and social aspects (Shafiq *et al.*, 2017). This is confirmed by many studies that report positive links between environmental SCM practices and firm performance (Zhu and Sarkis, 2004; Rao and Holt, 2005; Green *et al.*, 2012). However, Kim and Rhee (2012) found negative relationships between GSCM practices and financial performance, but positive effects on non-financial performance. Other authors (e.g., Hollos, Blome and Foerstl, 2012) found a positive effect of green practices on both economic and operational performance, but insignificant improvement of economic and operational performance from the implementation of social SCM practices. While Zailani *et al.* (2012) reported a negative effect on environmental performance by implementing green purchasing practices, many other studies found a positive effect (Gimenez and Sierra, 2013; Esfahbodi, Zhang and Watson, 2016). Similarly mixed effects on firm's sustainability performance are also found for other SSCM practices including sustainable design, cooperation with consumers, reverse logistics, and manufacturing practices.

Overall, even a cursory scan of literature shows a large body of studies that found positive, negative, or insignificant relationships between environmental and social SCM practices on different firm's sustainability performance. In an attempt to reconcile such conflicting results and provide answer to the third research question of this dissertation, I use meta-analysis method which is suitable to resolve and provide generalizability of prior mixed relationships (Lipsey and Wilson, 2001; Aguinis, Gottfredson and Wright, 2011). In the following section, I discuss the sustainability performance measurement in SCs.

2.2 Measuring and managing sustainability performance in supply chains

Performance measurement is essential to provide information that reveals progress, diagnose problems, enhance communication, and provides critical feedback in the decision-making process (Chan *et al.*, 2003). In the SC context, successful performance measurement should take a holistic system perspective beyond firm boundaries. Although there is a considerable stream of studies dealing with traditional (economic) performance measurement in SCM (Beamon, 1999; Neely, Adams and Kennerley, 2002; Chan *et al.*, 2003; Gunasekaran and Kobu, 2007), the literature dealing with measurement of environmental and social aspects in SCM is not well developed (Taticchi, Tonelli and Pasqualino, 2013; Piotrowicz and Cuthbertson, 2015).

The performance measurement in SCM is hampered by many factors including lack of connection with strategy, lack of system thinking and loss of SC context, and lack of standardized measures across the SC (Wong and Wong, 2008; Gopal and Thakkar, 2012). While overcoming these challenges is not a trivial issue, a sustainable SC should perform well on traditional measures (e.g., quality, costs) and on the social and environmental dimensions (Linton, Klassen and Jaraman, 2007). A successful performance measurement system facilitates the translation of strategies into measurable goals and actions and allows monitoring and analysing the progress regularly (Björklund, Martinsen and Abrahamsson, 2012).

The relationship between performance measurement and management is stressed by several authors. According to Bititci *et al.* (2011) performance management is a process that uses information generated by performance measurement to guide decision-makers aiming to connect strategy with daily operations. A similar argument is given by Atkinson (2012) who highlighted that performance management is a company-wide shared vision and performance measurement should be dynamic, flexible, and credible to support that vision. Furthermore, Grosvold, Hoejmose and Roehrich (2014) argue that a sustainable SC can be seen as a combination of three components: management, measurement, and performance. SC management and SC measurement influence on each-other in a circular relationship, and in turn both impact SC sustainability performance. Thus, a properly aligned sustainability performance measurement system in the SCM can help in developing collaborative inter-firm practices and processes that would allow a better understanding of SC goals and an enhancement of relationships across partnering firms.

It has been noticed that some companies provide lip service to integrate sustainable practices into their SC operations, suggesting a huge discrepancy between what practitioners say (theory) and do (practice) in reality (Walker and Jones, 2012; Taticchi *et al.*, 2015). This might be because adopting sustainability across SC proved to be challenging (Morali and Searcy, 2013) and partly because many firms don't know what to measure and how to measure their sustainability impacts (Beske-Janssen, Johnson and Schaltegger, 2015). Indeed the lack of measurement methods and tools is confirmed by many reviews focused on sustainability performance measurement of SCs (Taticchi *et al.*, 2015; Schöggl, Fritz and Baumgartner, 2016; Qorri, Mujkić and Kraslawski, 2018). However, as it was argued by several authors (Hervani, Helms and Sarkis, 2005; Maestrini *et al.*, 2017) measuring performance is difficult inside a single company, but when extending to the SC level it becomes highly complex (Sloan, 2010).

Improving competitive advantages requires measuring and managing sustainability across SCs (Qorri, Mujkić and Kraslawski, 2018). While performance metrics and measurement methods or tools are crucial components of the SC performance measurement system, the relevant SSCM literature is mostly focused on the first component. This is echoed by the review of Ahi and Searcy (2015) who identified over 2500 unique metrics, but how to aggregate or combine these metrics (By which method/tool?) into key performance indicators (KPIs) and to build a performance measurement system is rarely considered and thus it is unclear (Beske-Janssen, Johnson and Schaltegger, 2015; Büyüközkan and Karabulut, 2018). The KPIs assist in keeping managers and workers focused on core issues (Bai and Sarkis, 2014). KPIs should be arranged and generated by the performance measurement system to support (and control) managers in decision-making and to communicate SC sustainability performance to other stakeholders.

Another important aspect to highlight before discussing sustainability measurement methods or tools is related to the multidimensionality of both sustainability concept and SCM concept. First, a vast amount of data and information is required to be collected and processed to measure environmental, social, and economic dimensions of sustainability. In addition, each dimension incorporates several aspects (e.g., environmental dimension covers aspects of air, water, land etc.), which in turn are measured through many various metrics. A visual representation of such a nested view of sustainability is best given by GRI (2010). Second, by definition, SC is "*a set of three or more entities (organizations or individuals)…*" (Mentzer *et al.*, 2001), that is, a complex structure of flows and relationships between SC members and their activities. Thus, when developing a performance measurement system, one should consider all these issues and usually in literature such complexity is presented by a hierarchical model. Some authors have also argued that sustainability assessment can be seen as multi-criteria decision-making (MCDM) problem (Diaz-Balteiro, González-Pachón and Romero, 2017). Overall, the idea is how to propose solutions for combining such complex sets of performance data in manageable quantitative or qualitative KPIs. Sustainability measurement methods and tools are used to generate such KPIs, and I briefly review them in the following section.

2.2.1 Methods for assessing sustainability in supply chains

As Beske-Janssen, Schaltegger and Liedke (2019) note the majority of articles dealing with sustainability performance measurement in SCs either do not consider at all or say little about specific measurement methods or tools. A small set of studies that suggest sustainability performance measurement approaches, methods or systems are indeed very different from each-other. The variety of approaches proposed spans from conceptual frameworks (Hassini, Surti and Searcy, 2012) to instruments such as Life cycle assessment (Hutchins and Sutherland, 2008) to modification of existing tools including balanced scorecard (Thanki and Thakkar, 2018) and Supply Chain Operations Reference (Bai *et al.*, 2012).

While another set of studies utilizes the MCDM techniques (Büyüközkan and Çifçi, 2012; Tajbakhsh and Hassini, 2015a), few others authors use also fuzzy set logic (Erol, Sencer and Sari, 2011; Uygun and Dede, 2016) to rank and aggregate sustainability metrics. A slightly different approach is also considered by using different standards and certifications such as International Organization for Standardization (ISO) 26000 (social responsibility), ISO 14032 (Environmental performance evaluation) (Nawrocka, Brorson and Lindhqvist, 2009). Other frameworks proposed by practitioners such as the Carbon Disclosure Project, GRI, and the International Federation of Accountants are sometimes used to measure sustainability performance (Taticchi, Tonelli and Pasqualino, 2013).

The use of such different tools or methods to measure sustainability of SCs, indicates the lack of a comprehensive and practical method or tool, which has been confirmed by several reviews (Sloan, 2010; Beske-Janssen, Johnson and Schaltegger, 2015; Qorri, Mujkić and Kraslawski, 2018). Additionally, the above mentioned tools have been criticized for not including all sustainability dimensions, for partly considering SC members (mainly the measurement is done between manufacturers and suppliers), most of them are developed to measure performance within the company and not across SC, most of them are also static by design and can process only quantitative data (but sustainability performance should also be measured by incomplete and qualitative data) (Piotrowicz and Cuthbertson, 2015; Tajbakhsh and Hassini, 2015b), and other limitations discussed in the previous section. Above all the most important barrier is that the generated results from such approaches are not comparable, inconsistent, difficult to be used or as Büyüközkan and Karabulut (2018) put such results “fail to talk to each-other”.

Additionally, market indices including the Dow Jones Sustainability Index and FTSE4Good Index, do not capture the complexity and challenges of sustainability performance measurement in SCs (Ahi and Searcy, 2015). In spite of the above limitations, a sustainability performance measurement in the SC context should provide reliable, timely, and accurate information to assist in SC performance management, and thus, in this work I have tried to overcome some of the listed drawbacks of prior methods.

2.3 Conceptual framework of the research

To facilitate the understanding of information and concepts presented in this chapter, an illustrative conceptual framework is given in Figure 2. This framework shows an overview of how SSCM practices are conceptualized, which sustainability dimensions are considered, and how sustainability performance in SC is measured to achieve the purpose of this dissertation.

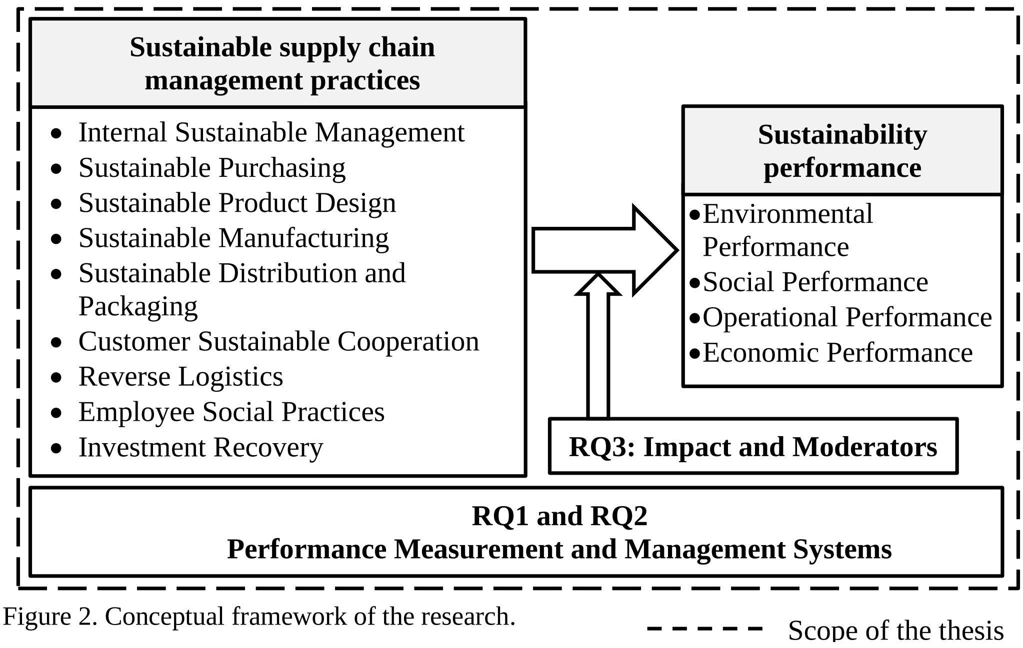


Figure 2. Conceptual framework of the research.

3 Research methodology

In this chapter, the research process, methods used, data collection, and data analysis adopted are discussed. Research usually is defined as a process that aims to broaden the understanding of a phenomenon and "*helps us know what's going on*" (Lune and Berg, 2017). Research design provides an overview of the appropriate research techniques and methods for the research problem. The research design should be aligned with the objective of the study and show the path through which data sources and analysis techniques will be used to generate valid and reliable results. Along with providing a coherent contextual framework that guides the choices a researcher makes (Creswell and Creswell, 2018), the research approach should also disclose enough information related to study outcomes for enhanced understating and to replicate the methodology if needed (Grierson and Brearley, 2009). Subsequently, I present the research process employed in this work, which I aimed to make it as rigorous and transparent as possible.

3.1 Research approach

According to Creswell and Creswell (2018) the research approach represents "*the plans and procedures for the research that span the steps from broad assumption to detailed method of data collection, analysis, and interpretation*". Each research method and methodological choice can be supported by different philosophical views (Eriksson and Kovalainen, 2008). The most commonly philosophical standpoints of scientific research are categorized based on *ontology* or *epistemology* fields. While in ontology the study of being and the nature of reality are studied (*What exists?*), the epistemology is concerned with knowledge and diverse methods of gaining knowledge (*How do we know it exists?*) (Onwuegbuzie, Johnson and Collins, 2009). Besides, ontology and epistemology, there is also another branch of philosophy – *axiology* that studies the nature of value and judgments (*What kinds of things have value?*) in research (Saunder, Lewis and Thornhill, 2012).

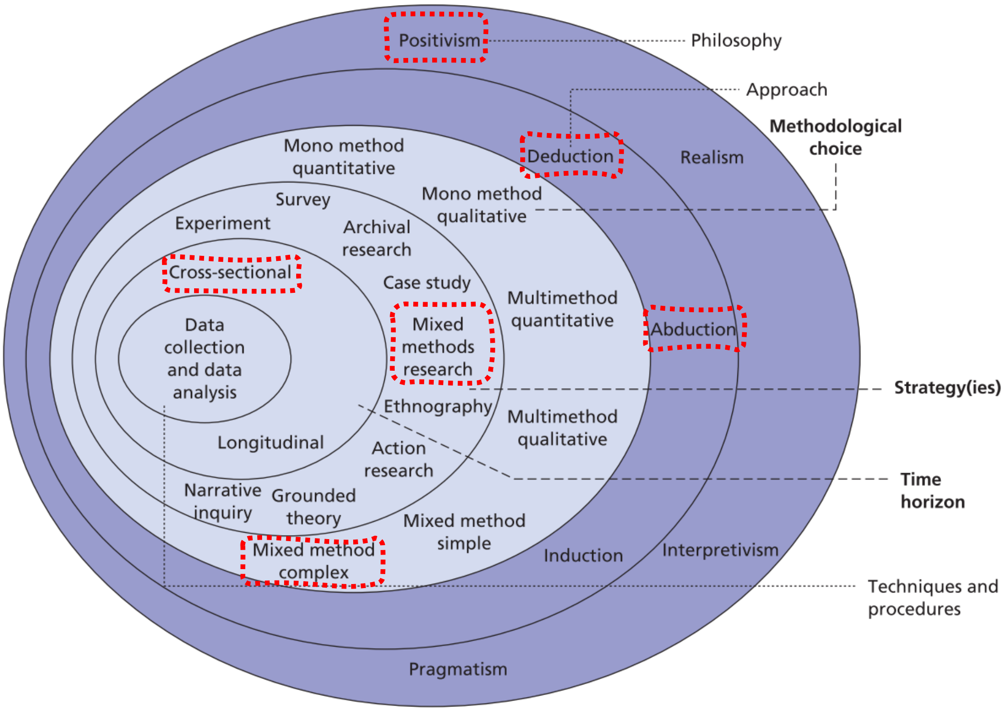
Such philosophical standpoints aim to inform and help in choosing the theoretical perspectives or research philosophies. According to Crotty (1998), a philosophical viewpoint provides knowledge and helps in creating a context for the research, and justifies the logic and criteria used. Research philosophies or paradigms involve ways of seeing the world and can be defined as "*a way of examining social phenomenon from which particular understanding can be obtained about the phenomenon*" (Saunder, Lewis and Thornhill, 2012). Research perspectives or paradigms can be categorized into different groups (e.g., positivism, interpretivism, etc.) and are often seen as rivals (Shepherd and Challenger, 2013). Each research paradigm is categorized by a set of methods for understanding and examining the research phenomenon (Creswell and Creswell, 2018).

While I recognize the distinction between the *logic of justification* and *research methods* (Johnson and Onwuegbuzie, 2004), I refrain to enter into 'paradigm wars' (Shepherd and Challenger, 2013). That is because, although the logic of justification is an important element of epistemology, by no means can force the use of any specific research methods (Johnson and Onwuegbuzie, 2004; Shepherd and Challenger, 2013). Likewise, following the suggestion of Eisenhardt and Graebner (2007) further philosophical arguments are limited in this dissertation to avoid philosophical pitfalls. However, in line with a review on paradigm wars (Shepherd and Challenger, 2013), out of four schools of thoughts (paradigm incommensurability, paradigm integration, paradigm dissolution, and paradigm plurality), I support the arguments of paradigm plurality i.e., by means of 'bridging', 'bracketing' and 'inter-play', leading to stronger theory grounding.

To better explain the relations between building blocks of research design, I utilize a graphical representation of the research onion presented in Figure 3. The red boxes with dashed lines represent where the work done in this dissertation can be placed. The outermost circle provides research philosophies, which are given in the summarized form in Table 4.

In this dissertation, I have mainly adopted positivist viewpoint because the aim was to measure sustainability performance of SCs and thus the focus is on quantitative findings. The positivist paradigm enables the researcher to have more statistical reliance and generalisation of findings by testing theories and hypotheses (Publications II and III). Positivism views the world as deterministic and real, where theories can be derived to examine what can be observed and quantified (Eriksson and Kovalainen, 2008). Utilizing *post-positivism* paradigm (Publications I and IV) that amends positivism by augmenting that people are too complicated to explain only through empiricism (Onwuegbuzie, Johnson and Collins, 2009; Creswell and Creswell, 2018), highlighting the need for data triangulation and validation (Eriksson and Kovalainen, 2008).

The methodological approach can be categorised in *deductive, inductive, and abductive* research strategies. In deductive reasoning, initially hypotheses are developed from existing theory and then tested through empirical data, leading to potential modifications of theories in light of obtained results (Saunder, Lewis and Thornhill, 2012). Conversely, utilizing an inductive strategy the researcher tries to develop theoretical knowledge resulting directly from empirical observations (Eriksson and Kovalainen, 2008). Abductive reasoning combines inductive and deductive strategies, and is useful for investigating further new relationships by considering other variables (Dubois and Gadde, 2002). Publications I and IV can be categorised under the abductive approach, whereas the deductive strategy is used in Publications II and III where the goal of these publications was to generalize the magnitude and direction of the impact of sustainable supply practices on various types of firm's performance.



Source: modified from Saunder, Lewis and Thornhill (2012).

Figure 3. Elements of research methodology illustrated as a Research Onion.

Given that sustainability performance is often expressed by both numerical and verbal measures (Qorri, Mujkić and Kraslawski, 2018), it was necessary to utilize several qualitative and quantitative methods to achieve the aim of this dissertation. While quantitative research is based on empirical data, qualitative research uses non-numeric data (e.g., words, images etc.) and thus data collection techniques and data analysis procedures are fitted for such purposes (Saunder, Lewis and Thornhill, 2012). Consequently, a mixed methodology is utilized across publications in this dissertation. Furthermore, in literature it has been argued that research methods are related to questions, data collection, data analysis, and interpretation (Creswell and Creswell, 2018). Before discussing specific methods applied in this work, it is important to emphasize that choosing a quantitative, qualitative, or multiple methods research design was based on the problems and research questions of individual publications. Knowing that each publication solves a subset or a part of the problem of measuring SC sustainability performance, the systems view of the problem solving discussed subsequently is also used.

Table 4. Summary of theoretical perspectives in management research.

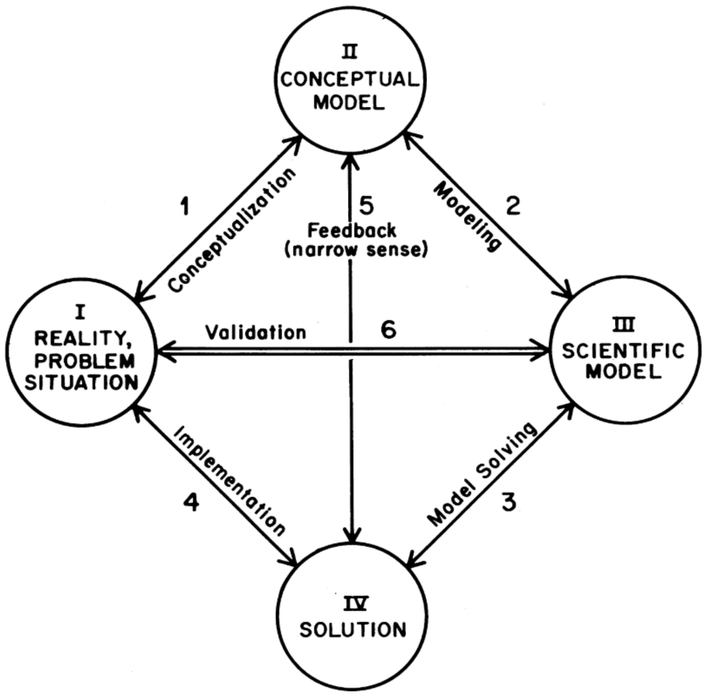
	Pragmatism	Positivism	Realism	Interpretivism
Ontology: the researcher's view of the nature of reality or being	External, multiple, view chosen to best enable answering of research question	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple
Epistemology: the researcher's view regarding what constitutes acceptable knowledge	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data	Only observable phenomena can provide credible data, facts. Focus on causality and law-like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions
Axiology: the researcher's view of the role of values in research	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective
Data collection techniques most often used	Mixed or multiple method designs, quantitative and qualitative	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative

Source: Saunder, Lewis and Thornhill (2012)

3.1.1 Systems view as a research framework

A model is usually conceptualized as a simplified representation of the real research problem and modelling is often used to study the nature of reality across many fields and contexts (Swoyer, 1991). For a given problem (e.g., How to measure sustainability performance of SCs?) various models can be developed, and the complexity of them usually depends on the researcher's aim and tools available. However, in general, a model should strive to represent as good as possible the target system and should include latent relations between elements of the system (Bednarikova, 2015). Modelling is vastly applied in operation management research aiming to support managers in decision making process (Mun, 2012).

Usefulness and validity are essential criteria to be considered when developing a model. In this direction, Mitroff *et al.*, (1974) argued that it is important to study the research problem from a holistic perspective and proposed a systemic view of the problem solving, presented in Figure 4. The work conducted in this dissertation adopted this systematic framework to tackle SC sustainability performance measurement.



Source: Mitroff *et al.* (1974)

Figure 4. A systems view of problem solving.

Initially, in the first phase (*Problem definition*), I have reviewed and analyzed the current understanding of sustainability performance measurement literature, which yielded several important gaps and factors which have not been previously studied. Synthesizing findings from the review enabled me to develop a holistic conceptual model *(second element of the systematic framework*) for assessing sustainability performance of value chains. The proposed models and the outcomes from the literature review are presented in Publications I and II. To demonstrate the applicability of the proposed model in Publications I and IV a novel approach (*third element*) consisting of several methods is developed and applied to assess the sustainability performance of SCs (*fourth element*). Similarly, the conceptual model proposed in Publication II has been further developed to be more comprehensive and utilized in Publication III. In sum, in this work, the research process follows the systems view on measuring sustainability performance to develop systematic and comprehensive models and the results and implications are interpreted.

3.2 Selecting research methods

As discussed above, the problem of measuring sustainability performance of SCs requires a variety of research methods that are apt to deal with qualitative, quantitative, and incomplete data. An overview of research methods employed in the publications included in this dissertation is presented in Figure 5. From this figure, it is evident that a variety of methods are used, and more than one method is applied in each publication. While a detailed description for each method is given in the articles, subsequently I only provide a concise summary of some of these methods.

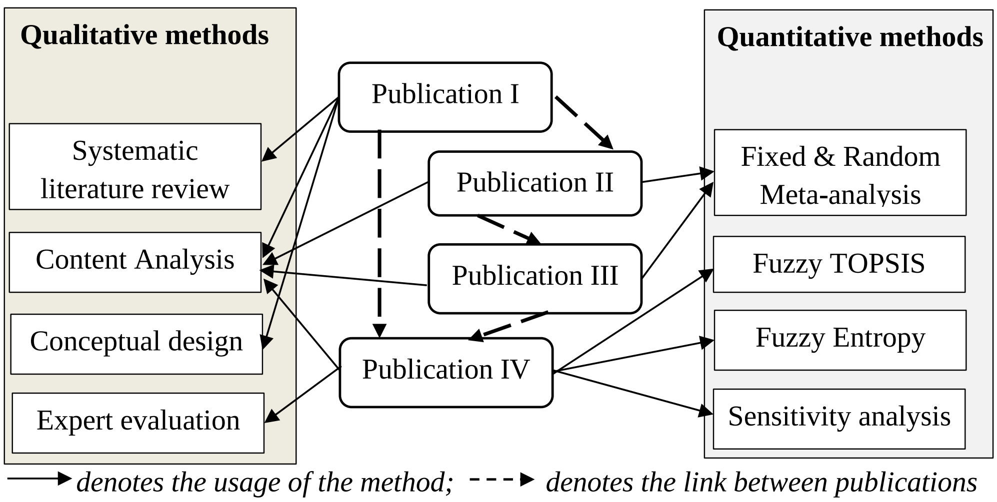


Figure 5. An overview of methods used in each publication.

To better contextualize, identify the research gaps, and position this dissertation in the SSCM literature, *the systemic literature review* method is utilized in Publication I. According to Fink (2019) *"a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners"*. Among other benefits, a review study helps in linking current (and future) research with past studies by avoiding the duplication of research (Tranfield, Denyer and Smart, 2003). Thus, I started this dissertation with a systematic literature review on the tools used to measure sustainability performance of SCs.

Content analysis is a broadly used research technique (Hsieh and Shannon, 2005). The purpose of content analysis is "*to provide knowledge and understanding of the phenomenon under study*" (Downe-Wamboldt, 1992). This technique spans beyond counting words for the purpose of classifying large amounts of textual information into an efficient number of categories with similar meanings (Weber, 1990). In the publications included in the dissertation, content analysis is used to categorize content of textual and numeric data through a systematic process of coding and identifying patterns. Furthermore, in Publications I and III, bibliometric analysis is also used to identify and reveal trends, characteristics, and internal research structure of SC sustainability performance measurement literature. Bibliometric analysis is commonly used to identify core research or authors along with their relationship, by covering a vast number of studies related to a given topic or field (De Bellis, 2009).

Based on the research outcomes from the systematic literature review, a novel *conceptual model* for measuring sustainability performance of SCs is proposed in Publication I. This model broadly outlines the main elements of the system (SC) and their interactions. While conceptual models are useful for providing an overview for the data collection, they do not show the sustainability performance of the targeted system, without combining such data into quantifiable and meaningful results through detailed analysis (Büyüközkan and Karabulut, 2018). Hence, this conceptual model is developed further and is applied in the pharmaceutical sector in Publication IV, which can support the decision-making process (e.g., selection of green supplier).

In the SSCM literature it has been emphasized that sustainability performance is a MCDM problem (Diaz-Balteiro, González-Pachón and Romero, 2017) and sustainability performance is complex, integrated, nonlinear, and difficult to be assessed (Pavláková Dočekalová *et al.*, 2017). Addressing this issue, several studies argued that fuzzy logic can help to integrate uncertainty, intangibility and vagueness of data related to sustainability metrics (Erol, Sencer and Sari, 2011). In this context, in Publication IV, by combining content analysis, *expert's evaluation, fuzzy Shannon's Entropy* (Shannon, 1948), and *fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)* (Hwang and Yoon, 1981; Chan and Qi, 2003), a novel approach to measure the end-to-end SC sustainability performance is proposed. Fuzzy entropy is used to calculate objectively weights of sustainability criteria. Fuzzy TOPSIS is utilized to obtain sustainability performance scores. Such scores are further investigated using sensitivity analysis.

Sensitivity analysis plays an important role in the decision making by determining the impact of potential changes and errors in a decision parameter on the results of the underlying model (Phillis and Davis, 2009). Sensitivity analysis is performed to measure the influence of criteria weights on the final ranking, using different alpha-cutting levels of fuzzy data in the Entropy method. Obtained criteria weights are used to investigate the ranking of companies in the fuzzy TOPSIS in Publication IV. Therefore, we believe that generated results are robust and can help decision-makers to select the best sustainability strategy in the available set of sustainability indicators.

Besides proposing new sustainability performance measurement methods in Publications I and IV, in Publications II and III the aim was to examine the impact of SSCM practices on firm's environmental, social, operational, and economic performance. *Meta-analysis* is a scientific inquiry and theory building method that allows reconciling contradictory empirical findings and conceptually comparable results (Hunter and Schmidt, 2004). We have chosen to use meta-analysis method rather than other techniques such as Structural Equation Modeling or Regression Analysis for the two following main reasons:

(i) Although in recent years the link between SSCM practices and firm's performance received growing attention, the results from primary studies remained mixed and contradictory.

(ii) Due to the relatively small sample size, a single study does not have enough power to explain the magnitude of a statistical relationship (Lipsey and Wilson, 2001).

Therefore, in such problems described above it has been argued (e.g., Aguinis, Gottfredson and Wright, 2011; Foerstl, Franke and Zimmermann, 2016) that a meta-analysis study is the best available method to make numerical generalizations of existing results on a specific topic. In addition to estimating the magnitude and direction of correlations between SSCM practices and performance through fixed (and random) model of meta-analysis in Publication II (Publication III), it is also performed a *moderator analysis* to study the conditions under which such correlations are stronger.

3.3 Data collection, analysis procedure and quality of the research

Different techniques and sources are used for collecting data in this dissertation. Due to the nature of research questions and given that the purpose of the study was to develop a method for measuring sustainability performance of SCs and because related environmental, social, operational, and economic data for each player are available to some degree, only secondary data are used. *Secondary data* are those data that have been collected for other purpose (Creswell and Creswell, 2018). However, such data can be utilized in addressing additional knowledge, interpretations, new ideas, frameworks, and conclusions (Sturgis, Bulmer and Allum, 2009; Willey *et al.*, 2017).

In literature, it has been emphasized that the usage of secondary data is increasing (Windle, 2010) because technological advances have led to vast amounts of data collected and which are accessible to researchers (Doolan and Froelicher, 2009). Some of the advantages of secondary data include the breadth and amount of data available, easy accessibility, professionally collected, and resource-saving (Dunn *et al.*, 2015). While there are various classifications proposed for secondary data by different researchers (e.g., Hakim, 2012), the classification proposed by Saunder, Lewis and Thornhill (2012) into three subgroups, namely, documentary, survey, and multiple sources is the most comprehensive. As with primary data, the secondary data can be either in a qualitative or quantitative format. Sources of such data include scientific journals, databases, commercial research organizations, government sources, and so on.

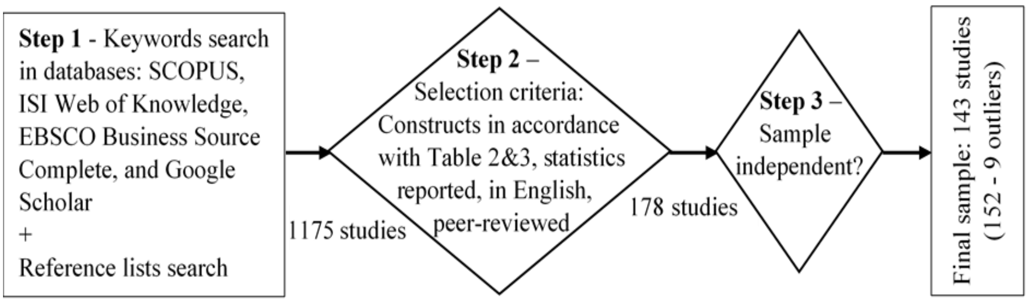
The secondary data used in this study is cross-sectional and not longitudinal. While cross-sectional data represent a snapshot taken at a particular time of the phenomenon, longitudinal can be used to examine change and development over time (Saunder, Lewis and Thornhill, 2012). Several measures have been taken to ensure the selected secondary data are useful and trustworthy.

First, *measurement validity* (Can such data lead to the information to answer research questions?) (Smith, 2008), is evaluated by utilizing large coverage and amount of data as well as mimicking best practices from other researchers who used similar secondary datasets in a similar context. Second, *reliability* (To what extent data collection methods and analysis can produce similar results under consistent conditions?) (Saunder, Lewis and Thornhill, 2012), is checked and enhanced by acceptable values of Cronbach's alpha measures and the selection of high quality of data sources (e.g., peer-reviewed journals). Finally, *validity* (What is the degree of preciseness of the results? Or does the method/concept measure what it is supposed to measure?) (Eriksson and Kovalainen, 2008), is strengthened by an exhaustive literature review and development of constructs used in publications in cooperation with research experts. Therefore, a systematic approach was used in data collection and analysis as well as a coherent detailed presentation and discussion is given in individual publications. Subsequently, I provide an overview of data sources, selection criteria, and coding process followed in publications used in this dissertation.

The data for *Publication I* is collected from SCOPUS database by searching for titles and abstracts of documents with a search string. After dropping retrieved documents which were not published in peer-reviewed academic journals, not written in English, and other inclusion criteria, 104 studies were used for conducting the systematic literature review of tools used to measure sustainability performance of green/sustainable SCs. The content analysis of papers is performed utilizing the content, context, and process framework (Pettigrew, 1985; Cuthbertson et al., 2011). Consequently, several trends and categories are generated, from publication year to journals to tools, techniques, and methods used to measure sustainability of SC. Synthesizing such data and findings, a novel framework was proposed and a guideline for assessing SC sustainability performance is provided.

Publications II and III are meta-analyses studies aiming to synthesize and generalize findings of the effect of GSCM/SSCM practices on firm performance. By definition, a meta-analysis is based on secondary empirical data published in various sources. To ensure the quality of the data used in both publications we decided to restrict the search string to peer-reviewed sources, and to increase the coverage of relevant empirical studies we examined the reference sections of retrieved studies. Searching of literature and selection process of studies used in Publication III is given in Figure 6.

Figure 6 Required data to conduct the meta-analysis are recorded in a spreadsheet according to the coding practices suggested by Lipsey and Wilson (2001). Thus, we used a transparent, coherent, and systematic procedure to extract and record data related to sample size, reliability estimates, correlations or other statistics that can be converted to the effect size, and for moderating variables.



Source: Qorri, Gashi and Kraslawski (2021).

Figure 6. Locating and selection process of documents used in Publication III.

The effect size— the strength of the relationship between two variables (SSCM practices and firm performance) (Borenstein *et al.*, 2009), used in both publications is the Pearson product-moment correlation coefficient, as it is commonly used in operations management research. The meta-analytic procedures proposed by Hedges and Olkin (1985) and recommendations by Geyskens *et al.* (2009) are applied, resulting in a seven steps sequential process as shown in Publication III. Besides estimating the effect sizes for various relationships of interest, in both publications, the role of moderators (*a variable that affects the strength and direction of the relationship between independent and dependent variable(s)*) is examined using the method of analog to analysis of variance (ANOVA). Consequently, several theoretical and managerial implications are obtained and discussed. It is also important to highlight that Publications II and III differ from each-other on the conceptual framework, sample size, moderating variables, and meta-analysis model. While in the latter one we used the random-effect model of meta-analysis, in the first one we applied the fixed-effect model of meta-analysis. More about each meta-analysis model can be read for example in the study of Borenstein *et al.* (2010).

Data for *Publication IV* is collected from sustainability reports obtained from GRI Database (https://database.globalreporting.org/search/) based on the following selection criteria:

- The sustainability report is categorized in the sector of healthcare products
- The sustainability report is prepared in accordance with the latest GRI Standards
- The sustainability report is published by a European pharma firm
- The sustainability report is published from a large or multi-national enterprise
- The sustainability report discloses information for 2017, 2018, or 2019

Sustainability information disclosed in selected reports is evaluated independently by research experts according to predefined criteria discussed in the publication. Such criteria are used to assess sustainability of SCs. Since sustainability reports differ in format and content, and human judgments and preferences are often complex and vague, linguistic ratings predefined in the publication are used by experts to perform the evaluation. Consequently, obtained fuzzy data was analysed using fuzzy Shannon's Entropy to calculate criteria weights, and fuzzy TOPSIS to generate the ranking. Generated results are further investigated using sensitivity analysis by modifying criteria weights. The outcome of this paper is important as it proposes a new practical method to measure sustainability performance of SCs under the condition of partial sustainability data available. In fact, we are confident that the proposed method is useful because sustainability information is almost always incomplete.

4 A summary of publications and their results

This chapter provides an overview of objectives, main results and contribution of each publication included in the second part of this dissertation. While each publication contributes incrementally to fulfil the research goal and answering the research questions, in the following sub-sections details of these studies are presented. This chapter ends with a concise tabulated summary of four individual publications.

4.1 Publication I: A conceptual framework for measuring sustainability performance of supply chains

4.1.1 Background and objective

Responding to increasing scrutiny from various stakeholders about SC environmental and social impacts, companies are devising and integrating different sustainability strategies and practices (Christmann, 2000; Zhu and Sarkis, 2004). Since harmful impacts may be present beyond any single company, such sustainability strategies should span across individual firms and consider all stages of products lifecycle from sourcing to consumption (Linton, Klassen and Jaraman, 2007). Although successful strategy execution highly relies on continuous estimating progress towards sustainability goals, in the SSCM literature there is a lack of a review study that gives an overview of tools and methods used to capture and analyze data across SCs and for each sustainability aspect (Beske-Janssen, Johnson and Schaltegger, 2015; Tajbakhsh and Hassini, 2015b; Ahi, Jaber and Searcy, 2016). Hence, this paper's aim was to analyze existing measurement approaches and to propose a new framework to assess sustainability performance of SCs. Following Bai and Sarkis (2014) who argued that it is important to analyze performance measurement approaches for helping managers to focus on core SC sustainability-related decisions, this paper offers a summary of sustainability performance methods discussed in SSCM literature.

4.1.2 Methodology and principal findings

Utilizing the methodology of systematic literature review proposed by Tranfield, Denyer and Smart (2003), we selected and analysed 104 peer-reviewed articles published from 2005 to 2018. The Content, Context and Process framework (Cuthbertson and Piotrowicz, 2011) was used to examine the content of studies. The synthesis of collected data are presented by various categorization and trends of papers by industry, publication year and outlet, sustainability dimensions, performance measurement methods, and crosstabulation of such categories. The principal finding is that the multi-criteria decision-making methods are growing including Data envelopment analysis, Analytical Hierarchy Process, and Fuzzy set theory. Another important finding is the distribution of studies by measurement approach and SC echelon, stakeholder integration, metrics and data used and real case applications. Finally, based on these outcomes, we proposed a new framework and provided a concise guideline that can be used to measure sustainability performance of SCs.

4.1.3 Contributions

By categorizing, analysing, and synthesizing previous studies, the first publication (Qorri, Mujkić and Kraslawski, 2018) has provided a comprehensive overview of performance measurement methods and tools used to assess sustainability of SCs. First, by focusing on tools and methods rather than on metrics and measures used for assessing SC sustainability, it helps to shift the focus of researchers on another significant aspect of the performance measurement system and consequently, expands the SSCM/GSCM literature. Second, it provides a summary of measurement methods used and various trends of up-to-date relevant literature and thus it might be used as a starting point by practitioners and researchers interested in evaluating sustainability performance of SCs. Third, it proposes a novel and comprehensive framework for measuring sustainability of SCs.

The framework integrates SC members, aggregation of metrics, SC network design, and stakeholders as well as describes relationships between these important building blocks. This framework can be used as a guideline or as a basic design structure of the SC sustainability performance measurement system. Finally, this study contributes by emphasizing that standardization of metrics, data sharing, and collaboration among SC members should be addressed by future research to develop further measurement approaches in SSCM/GSCM literature. Therefore, the results contribute to a better understanding of sustainability performance measurement approaches applied in SSCM literature both in practice and in theory.

4.2 Publication II: Green Supply Chain Management Practices and Company Performance: A Meta-analysis approach

4.2.1 Background and objective

The competition is shifted from firms to SCs competing between each-other (Bai and Sarkis, 2014). Consequently, the focal (manufacturing) firm is often held responsible for the negative environmental impact of all companies or for inter-firm activities/processes across the SC (Vanalle *et al.*, 2017). GSCM practices include different types of activities and initiatives undertaken by companies such as green sourcing, eco-design and manufacturing, green distribution and marketing, and reverse logistics (Eltayeb, Zailani and Ramayah, 2011; Green *et al.*, 2012). Although many studies have investigated the impact of GSCM practices on firm performance, the empirical evidence is mixed and not conclusive, confusing managers which practice(s) generate expected performance. The goal of this study is to provide empirical generalization on the relationship between GSCM practices and firm performance. This study extends and confirms some of the results of prior meta-analyses.

4.2.2 Methodology and principal findings

Based on the data from 85 independent effect sizes and following the fixed model of meta-analysis procedures in Comprehensive Meta-Analysis (CMA) software, we tested the relationship between GSCM practices and firm performance. Specifically, we tested five main hypotheses and 20 sub-hypotheses. The results show that the relationship between GSCM practices and firm performance is positive and significant. Similarly, the outcomes of sub-hypotheses are positive and significant, confirming that implementing GSCM practices firms benefit not only in economic performance but also in environmental, social, and operational performance. Moderator analysis also shows under which conditions such links are stronger. Overall, the results indicate that SC managers of manufacturing firms should adopt a mix of GSCM practices and not only one specific practice to improve firm's performance as well as collaboration with suppliers and consumers is a needed to achieve desired outcomes.

4.2.3 Contributions

The contribution of this study can be listed in four main following points. First, the extensive evidence and findings presented in this study can be used by managers to support their opinions and requests to top-management for future investments in green practices and technologies. Second, benefiting from the results of moderator analysis, practitioners can understand better that there is a need to work together with suppliers and consumers and develop inter-practices. Using outcomes of this study one can also identify which GSCM practices are more important for a specific industry. Third, to the GSCM literature, this study is useful because it provides new insights and extends current understanding relating to the association between GSCM practices and firm performance and provides fruitful future research opportunities. In sum, this study makes a significant contribution to both theory and practice by providing comprehensive and extensive evidence to reconcile differences in previous mixed results and helping to generalize that GSCM practices have a positive and significant impact on firm's social and operational, environmental, and economic performance.

4.3 Publication III: Performance outcomes of supply chain practices for sustainable development: A meta-analysis of moderators

4.3.1 Background and objective

Responding to increasing pressure from different stakeholders for reducing or eliminating negative impacts on society and environment companies are adopting and investing in more sustainable inter-firm practices and technologies (González-Benito and González-Benito, 2005; Paulraj, Chen and Blome, 2017). Such inter-firm practices or initiatives can be diverse from cooperation with suppliers to cooperation with consumers and include both social and environmental aspects of sustainability. While the impact of several SSCM practices (e.g., sustainable design, supplier selection) on firm's economic and environmental performance are studied by many authors (Rao and Holt, 2005; Jabbour *et al.*, 2014; Kirchoff, Tate and Mollenkopf, 2016), other significant practices including sustainable production, sustainable distribution and packaging, social SC practices (Pullman, Maloni and Carter, 2009; Wolf, 2014) are scarcely considered.

The impact of SSCM practices on firm's social and operational performance is less researched and existing findings are contradictory (Mani, Gunasekaran and Delgado, 2018). Additionally, existing meta-analysis (Golicic and Smith, 2013) has a narrower scope or is focused on specific industries, geographical regions, did not include all existing and relevant studies, and lack to consider several important methodological issues (e.g., sample independence, outliers). In sum, a comprehensive and systematic study analyzing green supply practices along with all social supply practices on different firm's environmental, social, economic, and operational performance in SSCM literature is missing. Thus, the purpose of this study is to extend and provide nuanced findings on the SSCM practices and firm performance link utilizing a comprehensive framework and up-to-date empirical evidence by high methodological rigor. This study also answers the question under which conditions the influence of SSCM practices is stronger on firm performance.

4.3.2 Methodology and principal findings

Following the best-practice recommendations for conducting a meta-analysis (Lipsey and Wilson, 2001; Borenstein *et al.*, 2009; Geyskens *et al.*, 2009; Aguinis, Gottfredson and

Wright, 2011), we used the random-effects model and the results are generated from analysing 145 independent samples or 33,886 firms. In the research framework used in this study, we have conceptualized SSCM practices into nine constructs and firm's performance into four constructs. The research hypotheses are grounded based on the NRBV theory and the relational view of the firm. In addition to five main hypotheses, seven moderating variables are examined to understand their impact on the link between SSCM practices and firm performance. The results of four main hypotheses (H1-H4) reveal that companies can improve environmental, social, operational, and economic performance by adopting SSCM practices. The results of each SSCM practice on overall performance (H5) show that firms benefit more when they implement both social and environmental programs together with their value chain partnering firms. Outcomes from moderator analysis indicate that SSCM practices are beneficial for all firm sizes and industry types but there are some important implications discussed in the article. In sum, outcomes from our comprehensive meta-analysis broaden and complement current comprehension about the importance of environmental and social supply practices as well as their implications to sustainability performance.

4.3.3 Contributions

The contribution of the third publication (Qorri, Gashi and Kraslawski, 2021) are important for scholars, managers, and policymakers. First, the results generated by the most up-to-date and extensive empirical SSCM literature show that companies which leverage their resources and capabilities in collaborative practices can create complementary assets and strategic partnerships with their supply partners, which in turn, might improve their performance in several dimensions. This finding helps in validating that SSCM practices might be a source of superior performance. Second, the results of our study provide additional arguments that even firms that do not own or possess all required capabilities or knowledge for planning and implementing sustainable strategies can learn and benefit from experience and lessons of their business partners in developing and adopting sustainability practices into their operations. Third, our study contributes to synthesizing and reconciling conflicting prior findings and provides a richer understating of the variables, constructs, and moderators to the relationship between sustainable supply practices and types of firm performance. Fourth, the significant and positive link between social supply practice and firm's sustainability performance, extends our understanding and presents a unique and important contribution to the SSCM literature. Fifth, managers, policymakers, and scholars can benefit from results of moderator analysis, which provide greater clarity and nuanced views on which and under what factors sustainable supply practices are stronger correlated with firm's environmental, social, operational, and economic performance. Finally, the transparent and stepwise methodology presented in the study can be helpful to future scholars or others when preparing similar studies.

4.4 Publication IV: A practical method to measure sustainability performance of supply chains with incomplete information

4.4.1 Background and objective

Improving sustainability management and transparency of inter-firm activities and processes is difficult and often impossible without a performance measurement system across value chain firms (Beske-Janssen, Johnson and Schaltegger, 2015). Several other authors (Cuthbertson *et al.*, 2011; Ahi and Searcy, 2015) have also highlighted the need for developing such a performance measurement system to clear the ambiguity related to the benefits and costs associated with various SSCM practices adopted to decrease or eliminate negative environmental (e.g., use of toxic substances) and social (e.g., poor labor conditions) impacts (Sroufe, 2003; Ali *et al.*, 2017). However, developing a sustainability performance measurement system for SCs is inherently difficult and complex due to non-standardized metrics (Hassini, Surti and Searcy, 2012), cultural and geographical differences (Hervani, Helms and Sarkis, 2005), and lack of data for many interdependent activities across partnering firms (Qorri, Mujkić and Kraslawski, 2018).

While overcoming such hurdles is not a trivial issue and existing methods fail to evaluate all three sustainability aspects across partnering partners, the significance of assessing sustainability is also emphasized by several international organizations including United Nations in the SDGs (Tajbakhsh and Hassini, 2015a). Hence, the purpose of this study is to develop a new method to measure environmental, economic, and social aspects across each member of the value chain, from raw material providers to consumers to reverse logistics providers. This study is built based on the conceptual framework developed in the first publications (Qorri, Mujkić and Kraslawski, 2018) and on the SSCM practices classifications developed in the third publication (Qorri, Gashi and Kraslawski, 2021). Thus, to help in addressing the complexity of assessing SC sustainability performance, we believe that the outcome of this study is significant, and the practical model proposed can be widely applied.

4.4.2 Methodology and principal findings

Based on the five phases methodology that combines both qualitative and quantitative data analysis techniques such as Content Analysis, Experts Evaluations, fuzzy Entropy and fuzzy TOPSIS, we proposed a practical and novel method to measure SC sustainability performance.

To demonstrate the feasibility and practicality of the proposed method we extracted data from sustainability reports published by large pharmaceutical companies and asked experts to rate each report according to measurement criteria used in the method. The results indicate that the proposed solution can be used by managers, scholars, and policymakers to benchmark SCs and measure the effectiveness of SSCM practices implemented. To check the accuracy and consistency of generated results, sensitivity analysis was used. The sensitivity analysis (usually) investigates differences in the final ranking by changing the criteria weights. Such analysis confirmed that the findings obtained from the proposed method are promising and robust.

4.4.3 Contributions

The proposed method for measuring SCs sustainability performance makes several contributions. First, the practicality of the developed solution helps to lower the resistance in integrating environmental and social practices into operational and strategic levels as it enables tracking their performance across SC partners. Second, the high agility and modularity of the proposed method make it unique in SSCM literature as it can be applied in different SC configurations, contexts, and sectors. Such features are important as they help to overcome problems with previous sustainability assessment methods, which are rarely used in practical applications (Büyüközkan and Karabulut, 2018).

Third, the proposed solution responds to the call for the development of a holistic framework for measuring sustainability performance of pharmaceutical SCs (Singh, Kumar and Kumar, 2016; Milanesi, Runfola and Guercini, 2020). Thus, we provided a practical tool to managers operating in the pharmaceutical industry. Finally, using the proposed solutions, scholars and managers can benchmark and gain a better understating for their overall SC sustainability performance and for their chain partners. This helps managers to focus their energy on devising strategic plans and implementing initiatives for improving sustainability performance of their SCs. In sum, based on the sensitivity analysis and obtained results we are confident that the proposed solution is practically applicable and theoretically sound for measuring sustainability performance of SCs and presents a significant contribution to the SSCM literature.

4.5 Summary of publications

The four publications contribute to our understanding of assessing sustainability performance of systems (e.g., SCs) by providing outputs that facilitate structuring thinking and adding new insights, tools, and relationships between elements of a performance measurement system. A summary of the research aim, main findings, and contribution of each publication included in this dissertation are presented in Table 5.

Table 5. Summary of publications included in the dissertation.

Publication	Objective	Main findings	Contributions
I: A conceptual framework for measuring sustainability performance of supply chains	To review the literature and analyse measurement approaches that are used to assess sustainability performance of supply chains	Related research trends are identified, and an overview of methods used to assess sustainability is given. A novel conceptual framework and a concise guideline for measuring sustainability of supply chains are provided.	It extends the current understanding of how existing studies assess sustainability of supply chains. New insights into the relationship between measurement tools, metrics, supply chain configurations, and stockholders are given.
II: Green Supply Chain Management Practices and Company Performance: A Meta-analysis approach	To synthesize empirical findings related to the effect of GSCM practices on firm performance.	A total of 25 hypotheses are tested for the relationships between Upstream Supplier Facing, Eco-Design, Green manufacturing, and Downstream Consumer Facing and firm performance.	Findings contribute to supporting previous observations that GSCM practices have a positive impact on firm performance. The automotive industry benefits the most from implementing GSCM practices.
III: Performance outcomes of supply chain practices for sustainable development: A meta-analysis of moderators	To reconcile contradictory results between SSCM practices and firm's environmental social, operational, and economic performance. To examine under what condition the link between SSCM practices and firm performance is stronger.	Based on the largest empirical evidence in the literature, the results showed significant and positive correlations between environmental and social supply practices and several types of firm performance. Several moderators such as industry, ISO certification, source of performance data, and	By combining existing frameworks into one comprehensive framework used in the study, we contributed to defining the boundaries of the SSCM more rigorously. Results supported the view that SSCM practice can be considered as bundles of strategic resources.

		time evolution yielded significant impacts on the examined link.	Managers and scholars can use the study to know more when payoffs are higher from SSCM practices.
IV: A practical method to measure sustainability performance of supply chains with incomplete information	To propose a method for measuring sustainability performance from the perspective of extended supply chain.	We developed a practical method and applied it in the pharmaceutical sector. The obtained results are investigated further using sensitivity analysis, which confirmed that the proposed solution generates consistent and robust results.	The proposed method allows comprehensive assessment of a supply chain sustainability performance even when partial data are available. Due to the high-level of agility and modularity, this method can be used in various supply chain configurations. The results of the proposed method contribute to improving transparency, sustainability management, and can support managers to make more informed decisions in their supply chains.

5 Discussion and Conclusion

This chapter provides answers to the research questions. It also discusses theoretical and practical implications resulting from findings generated and ends with a synthesises of main limitations as well as it offers some fruitful research directions for scholars interested in examining sustainability assessment of systems and inter-firm processes.

5.1 Answering research questions

The primary goal of this dissertation was to explore, analyse and develop approaches for measuring and managing sustainability performance of supply chains. To fulfil this goal, we have broken down it into three research questions as posed in the Introduction section of this dissertation.

The first question "*What methods and tools can be used to assess sustainability performance of supply chains?"* is addressed in Publication I (Qorri, Mujkić and Kraslawski, 2018). This study presents a comprehensive review of the SSCM and GSCM literature dealing with performance measurement approaches. The findings are generated and presented based on several clusters, categorizations, and cross-tabulations of sustainability dimensions, industrial sectors, measurement approaches, SC echelons, stakeholders, metrics used, and sources of data collected. Accordingly, the publication identifies, highlights, and discusses several trends, issues, and relationships between elements of the performance measurement system. Results show that the most used approaches include Analytical Hierarchy Process, Fuzzy set approach, Balanced Scorecard, Life Cycle Assessment, and Data envelopment analysis. Furthermore, the study proposes a novel conceptual framework to measure sustainability performance of SCs, which helps in structuring thinking and facilitates decision-making process about sustainability assessment across SC in operational, tactical, and strategic levels. Besides summarizing sustainability measurement approaches, this publication emphasizes the importance of collaboration and data sharing among decision-making levels and partnering firms of the value chain.

The second question "*How can a performance measurement system be developed to evaluate environmental, social, and economic aspects across partnering firms?*" is tackled in Publication IV. This article develops a practical method that measures environmental, social, and economic sustainability aspects across all partnering firms, from raw material providers to consumers to reverse logistics providers. The conceptual framework proposed in Publication I (Qorri, Mujkić and Kraslawski, 2018) is used as a design structure and the SSCM practices identified in Publication III (Qorri, Gashi and

Kraslawski, 2021) are used as measurement criteria. To overcome the availability issue of incomplete information related to sustainability aspects for each SC partner, the proposed solution utilizes fuzzy set theory concepts and is applied based on data collected from sustainability reports of large companies in the pharmaceutical industry. The robustness of the results is confirmed by sensitivity analysis. The proposed method responds to the call of developing a practical solution that enables assessing sustainability of SCs and can be applied in any context, level, and SC design because the performance calculation procedure remains untouched and only measurement criteria should be modified. Thus, the proposed method can be generalized and overcomes the problem of aggregating different indicators expressed in various units and forms, resulting in comparable outputs that are able to "talk to each-other" (Büyüközkan and Karabulut, 2018) and might be used by decision-makers to make more informed sustainability-related decisions.

The answer to the third question "*What is the impact of environmental and social supply chain practices on firm performance, and when such impact is stronger?*" is addressed in Publication II (Qorri *et al.*, 2018) and in Publication III (Qorri, Gashi and Kraslawski, 2021). While in the second publication we consider only green SC practices that are operationalized in four constructs, in the third publication we analysed all environmental and social SC practices presented in SSCM literature. Benefiting from large empirical evidence that consists of 145 independent effect sizes or 33,886 firms, the results indicate that firms receive positive payoffs in social, environmental, economic, and operational performance from implementing SSCM practices. Findings showed also that such practices can be considered as bundles of strategic resources and firms can develop them by collaborating and combining their resources and compatibilities. Additionally, this publication highlights the role of both approaches, namely, (i) *inside-out*—embracing and implementing sustainability principles within the company, from top-management to the daily operational activities, and to partnering firms; (ii) *outside-in*—usually the focal firm (manufacturer) in the SC collaborates and requires from their suppliers to adopt and develop their sustainability practices, resulting in performance improvements for all parties involved. The answer to this question was important because as noted in a large body of relevant literature (Eltayeb, Zailani and Ramayah, 2011; Green *et al.*, 2012; Paulraj, Chen and Blome, 2017), the link between SSCM practices and firm performance was unclear and several studies reported conflicting findings, leaving managers confused to which practice to implement. Hence, the outcomes from these publications will be handy for scholars and managers. Additionally, in the third publication moderator analysis indicates that the impact of SSCM practices on performance is stronger if firms operate in manufacturing sector vs. service sector and several other contingencies.

5.2 Theoretical implications

This dissertation is an effort to advance the field of sustainability performance measurement and management of SCs. In doing so, the results are published in four publications, each of which adds to the relevant literature. The main theoretical contribution from this dissertation speaks to at least four streams of GSCM/SSCM literature.

First, this research contributes to sustainability performance literature by providing an introduction and a detailed analysis of the measurement approaches used in the previous studies. In Publication I (Qorri, Mujkić and Kraslawski, 2018), we examined more than 100 peer-reviewed studies and identified key trends, highlighted main challenges, and extended current understanding and knowledge related to assessing and managing sustainability of SCs. The adding value to the literature from this study is that for the first time our study is focused on the ***process*** (*How is the sustainability assessment carried out? Or by which methods or tools?*) and ***context*** (*Under what condition does the measurement take place*? *Or which factors or stakeholders influence the most?*), and not in the ***content*** (*What is measured*? Or *which metrics?*) (Ahi and Searcy, 2015). Thus, researchers can find this publication useful as it provides new insights and highlights new dimensions that need to be considered when evaluating and managing sustainability performance. Additionally, the state-of-the-art research recommendations are discussed to help scholars focus their future work.

Second, the conceptual framework proposed in Publication I and further developed into a practical solution in Publication IV (Qorri, Gashi and Kraslawski, 2022) sheds light on the sustainability assessment across the SC. While the conceptual framework adds to the theoretical understanding of assessing sustainability, the developed method extends the knowledge by uncovering new interactions among elements of a performance measurement system. This is important as the results from Publication I identified several measurement approaches, but they were limited either by considering only subsets of sustainability dimensions and SC echelons or by being dependent on a few indicators that cannot be generalized, resulting in a sparse application, and generating not so useful results. Conversely, the proposed method generates comparable and easy to understand outcomes and is applicable in any SC configuration and context as well as it works also even if only partial sustainability data are available. Thus, taken together these proposed solutions help researchers to better understand the complexities, interactions, elements, and many other aspects for a successful design and adoption of a sustainability performance measurement system that should generate usable and important outputs and signals on continuous/periodic timeframes.

Third, the large empirical evidence used to generate results in Publication II (Qorri *et al.*, 2018) and in Publication III (Qorri, Gashi and Kraslawski, 2021) helps in reconciling a much debated issue related to mixed prior evidence, whether SSCM practices positively contribute in firm performance. Our findings indicate that both green and social SC practices are significantly and positively associated with firm's social, environmental, economic, and operational performance. Performance gains mostly come in two forms: (i) directly within a company, by investing and adopting different sustainability practices aiming to reduce costs, energy and material usage, waste generation, and to improve efficiency, labour practices and safety procedures; and (ii) across the SC, by combining resources and compatibilities in collaborative sustainable practices with SC partners aiming to source, design, manufacture, transport, and use products with less material inputs and reduced or zero harmful elements. Such findings reveal that competitive advantages may emerge from exploiting resources and knowledge within and beyond firm boundaries, confirming that both intra- and inter-firm practices including internal sustainable management, eco-design, sustainable purchasing, cooperation with consumers, and reverse logistics can be considered as strategic resources. The latter argument is in line with the resource-based theories, namely, NRBV theory and the relational view theory.

Fourth, besides helping to generalize the link between SSCM practices and firm performance, findings from moderator analysis reveal nuanced views. In Publication III, we identified and tested several moderators or contingency factors, including firm characteristics and methodological choices. Obtained results add to the body of relevant literature by revealing the conditions in which firms benefit the most from implementing SSCM practices. Additionally, for the first time in the SSCM literature in the third publication, we synthesised empirical evidence and tested the impact of social supply practices on various types of firm's sustainability performance. Another important implication from this study is the demonstration that social and green SC practices result in a "win-win" situation, contrasting the view of trade-offs between environmental, economic, and social performance (Schaltegger and Burritt, 2014; Adebanjo, Teh and Ahmed, 2016). In sum, these findings add to the literature by uncovering new relationships, proposing new methods, and reconciling conflicting views and thus help researchers to expand and structure their understanding of how to make SC more manageable and sustainable.

5.3 Managerial implications

The importance of accurate, credible, and timely information is essential for informed decision-making. Performance measurement is a mean that supports managers and complements their intuition to make right choices. This dissertation is focused on evaluating SC sustainability performance, and thus naturally has several implications for managers and other stakeholders who are trying to make their firms and SCs more sustainable.

First, this dissertation builds over the most extensive and holistic literature dealing with sustainability performance measurement, aiming to provide some practical insights and contributions to the performance management and decision-making process. Measurement approaches, current and future trends, and the list of literature given in Publication I, can help managers to familiarize and refresh their understanding about what has been previously done and what should be considered when designing their SC sustainability performance measurement. Additionally, managers benefit from the practical and concise guideline provided, which explains how to modify existing performance systems inside companies for integrating sustainability aspects and practices.

Second, the proposed conceptual framework systematically integrates SC members, measurement tools, sustainability metrics, and stakeholders. This framework and the discussion of relationships between these components can be used by managers and other industry experts as a guideline or as a broad design structure for developing a sustainability performance measurement system across SCs. The relevant discussion provides further arguments why the measurement approach should also be apt to include and process incomplete sustainability data and how to solve this issue.

Third, the proposed method in Publication IV equips managers with a handy tool to assess sustainability of their SC from suppliers to reverse logistics. The demonstration in the publication shows that it is practical and applicable, as well as it generates consistent and comparable results. Consequently, generated scores can be used by managers to benchmark SCs, discover which criteria are more important, and identify which SC partners are well/poorly aligned with the firm's environmental and social objectives.

Fourth, findings in Publications II and III show that an organization can fulfil several sustainable development objectives through implementation of green and social SC practices, leading to improved value for all stakeholders. Additionally, results outline that managers should develop various skills and structures for managing intra- and inter-firm activities including collaboration with suppliers and consumers. Outcomes from moderator analysis give new insights and expand current knowledge on which conditions the payoffs are higher from adopting SSCM practices.

Overall, the contribution of this dissertation in practice is to (i) help decision-makers in understanding the importance of sustainable supply practices to improve environmental, operational, social, and economic performance; (ii) and to expand their knowledge about evaluating sustainability performance across entire SC by focusing their attention on key issues.

5.4 Policy implications

This dissertation provides important implications for policy. The proposed method in Publication IV provides some guidance for policy makers on assessing the effect of policies on environmental, social, and economic aspects of sustainability. Likewise, this method combined with insights from the conceptual framework proposed in Publication I, can be used by governments to further adjust policy incentives, environmental policies, regulations, and measures. Requiring and/or promoting the implementation of sustainable initiatives usually is in two forms: (i) by imposing higher green taxes on firms that are hesitant to adopt sustainability practices; and (ii) by rewarding top firm performers with various subsidies or reducing their tax burden.

Besides developing mechanisms that control and regulate issues relating to environmental and social aspects, governments should provide financial and technical assistance to organizations for developing green capabilities and expertise. Another important aspect is the need to invest in green technologies and infrastructure. Thus, authorities should embrace a dual approach and our results in Publication III indicate that SSCM practices can accelerate the economic growth and moderator analysis gives some insights on how to allocate resources more efficiently and effectively.

5.5 Main limitations

While the goal of this dissertation is achieved and answers are given to the posed questions, there are some limitations worth to be mentioned. They are related either with the focus of the research or with the methods selected and data used.

The first limitation comes from the focus of the first publication on the methods and tools used to measure sustainability of SCs and not in the metrics or indicators. I can be argued for one or the other, but we choose to analyse measurement methods as there was no prior study that did so.

The second limitation is related to the empirical data used and the research framework applied in the second and third publications. Although we did our best to develop the most holistic and comprehensive framework to categorize SSCM practices, other researchers might argue that some constructs operationalized in the framework might be less or more specific and relevant with a given context. The issue of the data collection is directly linked with the research framework, and thus might present a potential limitation, despite that our study is based on huge empirical evidence (33886 firms).

The third limitation comes also from the second and third publications because one might argue that a meta-analysis study suffers from inherent limitations. On the one hand, by definition, the meta-analytic findings depend on the quality of secondary data (available primary studies) used. Several steps are taken to address this issue and relevant explanations are given in individual publications. On the other hand, the combination of apples and oranges, or trying to synthesize results from studies that might not be conceptually comparable. Again, to overcome this issue we followed the most recent recommendations from prominent authors in the field and provided a detailed and transparent explanation of the methodology followed.

The fourth limitation is related to data used to demonstrate the proposed sustainability measurement method in Publication IV. Although some assumptions are made and many steps to curate the data as much as possible are taken, the procedure we followed to extract sustainability data from GRI sustainability reports might be debatable. Thus, although the data used may, or may not be different from a real-life case, we are confident that the proposed method is robust as shown by sensitivity analysis.

Overall, when scrutinizing results from this dissertation one should consider such limitations despite promising findings drawn from extensive sources and empirical evidence.

5.6 Future research recommendations

The recognition of the above-mentioned limitations presents opportunities for potential future work.

One fruitful direction is to extend the proposed method in Publication IV by adding additional techniques to deal with uncertainty and/or aggregation of criteria into key performance indicators. Other techniques could potentially improve the measurement model and generate more accurate and pertinent results.

Another research direction is to try and collected sustainability performance-related data directly from managers or databases owned by organizations. The utilization of such data could shed light on hidden interactions on sustainability dimensions and would uncover more insights that could be used to improve further the proposed solution.

Future work can also focus on the validation of the proposed method in different SC configurations and industries. For example, applying it in the oil and gas industry or in the construction sector might lead to interesting findings. Although the proposed solution uses SSCM practices as measurement criteria, other researchers can try to develop a set of standardized indicators that can be used in various processes and industries. The proposed method can also process such indicators without any modification needed.

Finally, fruitful research directions include the examination of relationships between SC design or configuration with the performance measurement approaches listed in Publication I. The integration of the proposed solution into a software management system would be very significant as it would allow quick, easy, and real-time performance measurement and monitoring. This in turn would allow to make more informed decisions and improve sustainability management of SCs.

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Publication I

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A conceptual framework for measuring sustainability performance of supply chains

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Review

A conceptual framework for measuring sustainability performance of supply chains

Ardian Qorri [a, *], Zlatan Mujkić [a], Andrzej Kraslawski [a, b]

[a] School of Business and Management, Industrial Engineering and Management, Lappeenranta University of Technology, P.O. Box 20, FI-53581 Lappeenranta, Finland
[b] Faculty of Process and Environmental Engineering, Technical University of Lodz, Poland

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A B S T R A C T

Supply chains are critical driving forces behind business competitive advantages, hence their sustainability measurement and management is vital. Determining the sustainability performance of supply chains is challenging. It requires appropriate tools for capturing and analyzing data for every supply chain activity and for each sustainability aspect. This study analyzes measurement approaches that are used to assess sustainability performance of supply chains. Using Content, Context and Process framework, we have studied 104 peer-reviewed articles, published in the literature on sustainable supply chain management (SSCM) and green supply chain management (GSCM). The results show that various measurement approaches are used to assess sustainability in different sectors and supply chain echelons. The application of multi-criteria decision-making methods is increasing and several promising measurement frameworks have been proposed. The most used approaches include Life Cycle Assessment, Analytical Hierarchy Process, Fuzzy set approach, Balance Scorecard, and Data envelopment analysis. Additionally, this study proposes a novel conceptual framework and provides a concise guideline for assessing sustainability of supply chains. Key challenges that need to be solved by future measurement approaches include sustainability data collection and sharing, metrics standardization, and collaboration among supply chain members per se and stakeholders. This study creates better comprehension of how existing approaches evaluate sustainability of supply chains and provides new insights into sustainability performance measurement approaches, supply chain configuration, and metrics selection.

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* Corresponding author.
E-mail address: ardian.qorri@lut.fi (A. Qorri).

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1. Introduction

In today's competitive business environment, many corporations including IBM, Hewlett Packard, Xerox, Walmart, and BMW have started to integrate sustainability principles into their supply chains (SCs) (Rajeev et al., 2017). Because of serious misconducts related to sustainable practices, Walmart stopped working with suppliers in Uzbekistan and Bangladesh in 2008 and in 2011, respectively (Varsei et al., 2014). Walmart estimated that over 90 percent of its total emissions are related to SC operations (Birchall, 2010; Dubey et al., 2017). Likewise, Carbon Disclosure Project (2011) estimated that more than 20 percent of global greenhouse gases emissions are produced from 2500 largest global companies, and their SCs are responsible for a large proportion of emissions (Dubey et al., 2017).

In response to growing concerns about SCs environmental and social impacts, various stakeholders such as government regulators, consumers, non-governmental organizations (NGOs), the media, and community activists are putting pressure on organizations to reduce harmful impacts in their SCs (Delai and Takahashi, 2011; Hassini et al., 2012). Several authors (e.g., Seuring and Gold, 2013; Winter and Knemeyer, 2013) argue that sustainability extends beyond the boundaries of any single firm and harmful impacts occur across all stages of products lifecycle (Linton et al., 2007). Consequently, companies are now held responsible for their SCs and are increasingly obliged to measure, control, and disclose, their own sustainability performance as well as their entire SC sustainability performance (Rao, 2014; Taticchi et al., 2013).

Searcy (2017) notes that five out of six companies listed in the S&P 500 published a sustainability report in 2015. However, such sustainability reports often are uncompleted and uncoordinated due to missing standards (KPMG, 2011; Reefke and Sundaram, 2017). Likewise, Morali and Searcy (2013) emphasize that SC sustainability reporting needs to be refined. Furthermore, several authors (Bai and Sarkis, 2014; Taticchi et al., 2013) highlight that competition shifted from individual organizations competing against each other to SCs competing against each other.

To improve the competitive advantages, organizations need to measure and manage effectively and efficiently (Neely et al., 2002; Shepherd and Günter, 2006) their SC sustainability performance. Assessing and improving the performance requires the development of the SC performance measurement system. Performance metrics and measurement methods or tools are an integral part of the system. Thus, it is important to analyze performance measurement (PM) approaches that can support managers to focus on core SC sustainability-related decisions (Bai and Sarkis, 2014).

Some of the approaches that have been proposed for evaluating sustainability performance of the SC include Balanced Scorecard (BSC) and its modifications (Duarte and Cruz-Machado, 2015; Shafiee et al., 2014; Thanki and Thakkar, 2018), Life Cycle Assessment (LCA) and its modifications (Arcese et al., 2017; Cucchiella et al., 2014; Wang et al., 2016), Fuzzy set approaches (Chithambaranathan et al., 2015; Sabaghi et al., 2016; Uygun and Dede, 2016), Data Envelopment Analysis (DEA) (Mirhedayatian et al., 2014; Tajbakhsh and Hassini, 2015a), Supply Chain Operations Reference (SCOR) model (Bai et al., 2012; Taticchi et al., 2013), Analytic Hierarchy/Network Process (AHP/ANP) (Agrawal et al., 2016; Büyüközkan and Çifçi, 2012), and a few conceptual PM frameworks (Hassini et al., 2012; Schöggl et al., 2016; Sloan, 2010).

These methods have been criticized for not taking all three sustainability aspects into consideration (Hassini et al., 2012; Seuring, 2013) and most of them lack to incorporate all SC members (Ahi and Searcy, 2015). Another issue is the selection of metrics as there is a myriad of proposed metrics for SSCM or GSCM (Ahi and Searcy, 2015; Hassini et al., 2012). Additionally, the majority of PM approaches have been initially developed for evaluating performance within organizations and not across organizations. For these reasons various authors highlight the need for further research in assessment frameworks and analytical models that can integrate and measure sustainability performance of SCs (Bai and Sarkis, 2014; Björklund et al., 2012; Bulsara et al., 2016; Matos and Hall, 2007; Morali and Searcy, 2013; Reefke and Sundaram, 2017; Seuring, 2013; Taticchi et al., 2015; Varsei et al., 2014).

Given the importance of measuring sustainability performance of SCs and potential tools with their limitations, this study focuses on the call for investigation of PM systems for advancing GSCM and SSCM (Bai and Sarkis, 2014; Reefke and Sundaram, 2017). Therefore, the purpose of this study is to examine PM approaches that have been published in the peer-reviewed academic literature on SSCM and GSCM.

To fulfill this research objective, the authors analyzed, classified and synthesized PM approaches presented in 104 peer-reviewed articles published from 2005 to the end of March 2018, in the literature on GSCM and SSCM. The Content, Context, and Process framework was used for papers content analysis. This article makes the following contributions to GSCM and SSCM literature. First, by summarizing and categorizing an extensive number of studies on PM of SSCM and GSCM, this paper creates better comprehension of how existing studies assess sustainability of SCs. Second, a novel conceptual framework for measuring sustainability performance of SCs is proposed. The framework provides new insights into the relationships between sustainability PM approaches, SC design, and metrics selection. Third, it provides a concise guideline for measuring sustainability performance of SCs. Fourth, this paper highlights that standardization of metrics, data sharing, and collaboration among SC members are key challenges to current measurement approaches in SSCM and GSCM. Thus, this study extends understanding about methods and tools that have been used to assess sustainability performance of SCs and draws some conclusions that can inform practitioners and scholars.

Following the introduction, the study continues with a concise literature review (2) on sustainability PM of SCs. Next, the methodology (3) applied in the study is presented, followed by the section of results (4). The study ends with a discussion (5) of results, further research recommendations, and conclusions (6).

2. Sustainable supply chain performance measurement

The literature on PM of SCs is rich and have been researched extensively in last three decades (e.g., Beamon, 1999; Gunasekaran and Kobu, 2007; Neely et al., 2002; Shepherd and Günter, 2006). In contrast, literature on PM of SSCM and GSCM is fragmented (Taticchi et al., 2013) and limited, despite several contributions (e.g., Ahi et al., 2016a; Ahi and Searcy, 2015; Erol et al., 2011; Grosvold et al., 2014; Hassini et al., 2012; Izadikhah and Saen, 2017; Marconi et al., 2017; Varsei et al., 2014; Xing et al., 2016). Some of the contributions are literature reviews, which will be discussed in the following section.

2.1. Related reviews and the rationale for this study

To position this study in the literature we analyze previous literature reviews closely related to the aim of this study. In other words, only literature reviews on sustainability PM of SCs that cover at least two sustainability dimensions are considered. Interested readers on literature reviews focused only in economic sustainability of SCs are recommended to read following reviews (Akyuz and Erkan, 2010; Balfaqih et al., 2016; Gopal and Thakkar, 2012; Gunasekaran and Kobu, 2007; Maestrini et al., 2017; Shepherd and Günter, 2006).

Existing reviews on sustainability PM of SCs examine different aspects but none of them study sustainability measurement approaches. Previous reviews are focused either on metrics identification (Ahi and Searcy, 2015; Cuthbertson and Piotrowicz, 2011; Hassini et al., 2012; Tajbakhsh and Hassini, 2015b); bibliometric and co-citation analysis (Taticchi et al., 2015, 2013); or on a broad overview on PM of SSCM and GSCM (Beske-Janssen et al., 2015; Björklund et al., 2012; Bulsara et al., 2016; Hervani et al., 2005). Table 1 presents previous literature reviews on sustainability PM of SCs. Some of the limitations of these reviews include (i) they review some papers that cover only economic dimension of sustainability; (ii) the majority of the studies focus on identification and discussion of metrics or measures and miss the SC context; (iii) article's selection criteria in some works are unclear; and (iv) methodology followed to develop the review is not explained or illustrated.

This study aims to overcome previous limitations by reviewing an extensive number of papers and explaining in detail the research methodology. Specifically, this study differs from previous reviews for the following reasons: (i) it is focused on sustainability measurement tools and not on indicators, measures or metrics; (ii) includes a comprehensive up-to-date list of studies that assess sustainability of SCs; and (iii) proposes a comprehensive framework for measuring sustainability performance of SCs.

Since, four previous literature reviews (Ahi and Searcy, 2015; Hassini et al., 2012; Hervani et al., 2005; Tajbakhsh and Hassini, 2015b) have proposed conceptual PM frameworks for measuring sustainability of SCs, it's important to analyze in greater detail elements of these frameworks. Specifically, the framework proposed by Hervani et al. (2005) does not explicitly mention SC members but it implies that, at least, can be used to measure economic and environmental sustainability between suppliers and manufacturers. A list of environmental metrics is provided and a short discussion about the influence of stakeholders is reported. There are no details how to select pertinent metrics and how these metrics can be aggregated into key performance indicators (KPIs). In the framework proposed by Hassini et al. (2012) all sustainability dimensions and SC members including suppliers, manufacturers, distributors, retailers, and consumers are considered. This framework is supplemented with metrics for each SC member by Tajbakhsh and Hassini (2015b). However, the aggregation of these measures into KPIs or composite indicators is scarcely discussed, and the influence of stakeholders is not considered. The conceptual framework proposed by Ahi and Searcy (2015) includes all sustainability dimensions and SC members but it lacks to discuss the aggregation of individual metrics into KPIs. In other words, it does not reveal how sustainability of SCs should be measured.

In sum, the main issues with previous sustainability PM

Table 1
Previous literature reviews on measuring sustainability performance of SCs.

Study	Time range	Number of papers	Article selection/Database	Sustainability dimensions	Outcome
Hervani et al. (2005)	Not specified	Not specified	Not specified	Environmental Economic	Hurdles related to PM of SCs are presented and a ***framework*** for planning PM system is proposed.
Cuthbertson and Piotrowicz (2011)	1998–2009	45	Keyword/database is not specified	Environmental Economic Social	Articles are classified according to their research methodology, a case study is discussed, and several metrics are listed.
Björklund et al. (2012)	1998–2008	17	Keyword/database is not specified	Environmental Economic	Studies are categorized based on stakeholder perspective, the purpose of measuring, managerial levels of measuring, measuring across SC, and the combination of measurements.
Hassini et al. (2012)	2000–2010	87	Keyword/Scopus	Environmental Economic Social	Papers are classified based on their research methodology, industry, SC drivers, and partners. A conceptual *PM* ***framework*** is provided.
Taticchi et al. (2013)	1970–2012	205	Keyword/Isi Web of Science	Environmental Economic Social	Articles are analyzed using citation and co-citation techniques and a research agenda is provided.
Tajbakhsh and Hassini (2015b)	1994–2013	140	Keyword/Google Scholar	Environmental Economic Social	Articles are classified based on their research methodology, industry, and sustainability dimensions. The study proposes *a* ***framework*** with focus on metrics.
Taticchi et al. (2015)	2000–2013	384	Keyword/Isi Web of Science	Environmental Economic Social	Bibliometric analysis such as analysis of publication, citations and research methods. The focus is in the intersection of decision support tools and performance measurement.
Ahi and Searcy (2015)	To the end of 2012	445	Keyword/Scopus	Environmental Economic Social	Frequency analysis of metrics used in the literature of SSCM or GSCM. A conceptual *PM* ***framework*** is proposed.
Beske-Janssen et al. (2015)	1995–2014	149	Keyword/EBSCO Business Source, Emerald, Science Direct, and Wiley	Environmental Economic Social	Bibliometric analysis and qualitative data covering what is measured; who is measuring; how is it measured. It is focused on the evolution of PM in SSCM.
Bulsara et al. (2016)	To the end of 2014	112	Keyword/Database is not specified	Environmental Economic Social	Articles are categorized into three groups: scope of the study, research methodology and the sustainability focus of the study.

frameworks are that they partly consider components of sustainability PM of SCs, and they lack to highlight the significance of relationships between SC members, sustainability metrics, and stakeholders. Furthermore, tools for aggregating individual sustainability metrics into KPIs are not provided. These tools are at the core of this study, and KPIs are critical elements on PM process because they help SC managers to focus on central activities (Bai and Sarkis, 2014). Therefore, this paper reviews relevant literature and proposes a novel conceptual framework for measuring sustainability performance of SCs. Next, we present the benefits and challenges of measuring sustainability performance of SC and discuss some relevant measurement approaches.

2.2. The advantages of measuring SC sustainability performance

Previous research reports important outcomes from assessing the SC sustainability performance. In their review, Beske-Janssen et al. (2015) emphasize that central elements of SSCM, such as collaboration, transparency, supplier evaluation are only feasible if related performance measurement and management tools are implemented. Additionally, measuring sustainability performance of SCs urges supply chain innovation (Schaltegger and Burritt, 2014).

On one hand, measuring and managing sustainability of SCs guides organizations towards eliminating and reducing risks and confirming compliance with standards and regulations (Bulsara et al., 2016; Seuring and Müller, 2008; Taticchi et al., 2013), on the other hand, PM signals organizations for opportunities and trade-offs (Schaltegger and Burritt, 2014).

Thus, measuring and managing sustainability of SCs is more than dealing with risk and compliance because organizations reduce costs, increase efficiency, strengthen competitive advantages, facilitate sustainability reporting, sharpen operational performance, and support the implementation of the SC strategy (Björklund et al., 2012; Chithambaranathan et al., 2015; Hervani et al., 2005; Shepherd and Günter, 2006).

2.3. The challenges of measuring SC sustainability performance

Evaluating sustainability performance of SCs across multiple members such as suppliers, manufacturers, distributors, and consumers is complex and challenging (Sloan, 2010). In a large set of existing sustainability metrics (e.g., Ahi and Searcy, 2015; Tajbakhsh and Hassini, 2015b), SC managers should select and aggregate metrics into KPIs, in a way that would facilitate decision making in all managerial levels. Social indicators sometimes are challenging to be quantified and are often prone to subjectivity (Schaltegger and Burritt, 2014). Other problems highlighted by Brewer and Speh (2000), Hervani et al. (2005), and Wong and Wong (2008) on PM systems in SCs include:

- Managers lack understanding of metrics applied in multi-organizational context.
- Managers and organizations lack the control of inter-organizational metrics.
- Different goals and objectives among organizations in the chain result with different measures.
- Incompleteness and inconsistencies on PM among SC partners.
- Information systems are incapable of gathering non-traditional information relating to SC performance.
- Lack of standardized performance measures in terms of units to use, structure, format etc.

Additionally, existing PM methods and tools should be adjusted to integrate environmental, social and economic measures (Olugu et al., 2011; Reefke and Trocchi, 2013) in a balanced way in order to create synergetic effects (Beske-Janssen et al., 2015) or triple win-win solutions (Seuring and Müller, 2008).

2.4. Performance measurement approaches in GSCM and SSCM

Sustainability PM approaches applied in SCs are diverse in nature. They include environmental management standards (e.g., ISO 14001), international reporting standard (e.g., GRI – Global Reporting Incentive), SCOR framework, BSC, LCA, multi-criteria decision making (MCDM) tools (e.g., AHP, ANP, DEA), Rough set theory, Fuzzy-set approach, Composite Indicators, and Conceptual Frameworks.

AHP is an easy and flexible multi-criteria decision-making technique that combines subjective managerial inputs and objective factors in multiple criteria decision-making. Selecting KPIs and ranking metrics in SC is a key to success (Gunasekaran and Kobu, 2007) and AHP can be a good tool to choose and prioritize metrics. It is a technique that helps managers to understand the trade-offs between sustainability aspects and allows the active participation of decision-makers in making rational decisions and reaching agreements (Schaltegger and Burritt, 2014). Dey and Cheffi (2013) developed an innovative green supply chain performance measurement framework by integrating SC processes with organizational decision levels employing AHP. Singh et al. (2007) proposed a conceptual PM framework using AHP.

LCA is widely used by different authors and often serves as a background for other modeling approaches (Seuring, 2013). Croes and Vermeulen (2015) extended LCA to measure product sustainability. In their work, they emphasized that LCA lacks a measuring standard, does not include the social aspect, is limited to a top-down approach, is based on complex impact data, and has difficulties with data maintenance. Matos and Hall (2007) proposed an analytical framework to analyze the appropriateness of LCA in the assessment of complex and novel technologies for sustainable development by considering a rugged landscape as an adequate approach for high performance. They applied a design structure matrix to identify parameters and interdependencies between sustainability dimensions. Simão et al. (2016) used European Platform on Life-Cycle Assessment of European Life-Cycle Database to evaluate performance postponement strategies in green supply chain design. Park et al. (2016) using an input-output-based ecological lifecycle assessment framework evaluated the ecological performance of the US agriculture and food sectors. Acquaye et al. (2014) developed a systematic benchmarking approach which combines the Multi-Regional Input–Output (MRIO) and LCA as a basis for developing supply chain maps for industrial-level carbon emissions performance measurement.

SCOR is not specifically designed for PM but is one of the most implemented frameworks across industries (Taticchi et al., 2013). The SCOR divides the supply chain into six phases – plan, source, make, deliver, return, and enable an added-in version. The generic performance metrics for every phase are cost, time, quality, flexibility, and innovation (Taticchi et al., 2013). Bai et al. (2012) introduced a seven-step methodology for joint environmental and business PM and they proposed a core set of essential measures for sustainable SCs. Two years later, Bai and Sarkis (2014) developed a methodology for determining and applying sustainable supplier key performance indicators. They utilized SCOR and neighborhood rough set theory to identify KPIs and data envelopment analysis to benchmark and evaluate the relative performance of KPIs.

BSC, developed by Kaplan and Norton (1992), initially was not designed for SC evaluation. BSC integrates financial and non-financial aspects in the PM process and provides feedback for continuous improvement. The scorecard measures organizational performance from the financial perspective, customer perspective, internal process perspective, and learning and growth perspective. Several authors have modified BSC to incorporate sustainability dimensions and to make it applicable in SCs. Reefke and Trocchi (2013) customized BSC for SSCM and provided six potential development steps for implementation in practice, but their model lacks measures, composite indicators or KPIs for each respective perspective. Shaw et al. (2010) proposed an aggregated strategic environmental supply chain performance index incorporated within BSC. Tseng et al. (2015) developed a hybrid quantitative BSC to evaluate SSCM in a closed-loop hierarchical structure using Fuzzy Delphi Method and ANP. They employed ANP to consider interdependences among measures and to assess the final performance score by integrating importance and performance weights.

Nawrocka et al. (2009) highlighted that ISO 14001 is often used as a proof of environmental performance in supplier selection. Vermeulen and Metselaar (2015) proposed a methodology for improving the sustainability performance of SCs by employing private certification standards. Tajbakhsh and Hassini (2015a) proposed a multi-stage DEA model that simultaneously assesses the sustainability performance of both the overall efficiency score of the SC and the individual efficiency score of its partners. Mirhedayatian et al. (2014) using DEA suggested an innovative model for assessing GSCM. Jakhar (2014) developed a model for green SC performance measures. The model combines the methodologies of structural equation modeling. AHP, and multi-objective linear programming. Hadiguna et al. (2011) discussed the failure to develop performance measures and metrics for a pan SC in the automotive industry using the system approach thinking. Zhang et al. (2016) analyzed green SC performance with cost learning and operational inefficiency effects and found that forward-looking behavior is preferred to myopic one for channel members of the SC. Likewise, Erol et al. (2011) developed a model for measuring sustainability performance of SCs based on fuzzy approach. Varsei et al. (2014) proposed a conceptual framework that can be used for initial sustainability assessment of SCs.

In sum, several researchers have tried to combine or modify existing tools (e.g., Badiezadeh et al., 2017; Bai and Sarkis, 2014; Bhattacharya et al., 2014; Fornasiero et al., 2017; Lau, 2011; Sahu et al., 2015; Yakovleva et al., 2012) while other researchers have proposed new frameworks (e.g., Azevedo et al., 2017, 2013; Goyal et al., 2018; Lee and Wu, 2014; Santiteerakul et al., 2015; Shokravi and Kurnia, 2014; Sloan, 2010) to measure sustainability performance of SCs. Next, the methodology of this study is presented, which describes how some of these articles are analyzed and classified into different categories.

3. Research methodology

The research methodology was adopted to provide a contemporary overview of the field and to identify articles on PM of sustainable and green SCs. In conducting a literature review, Tranfield et al. (2003) suggest to follow five methodological steps:

- identification of research aim
- selection of articles
- quality assessment of studies
- data extraction and
- synthesis of data and reporting

Based on this approach, a database of articles was created, which was examined to provide answers to the research objective. Similar approaches utilizing literature reviews have been used in other studies for data collection and evaluation of SSCM or GSCM (e.g., Ahi and Searcy, 2015; Beske-Janssen et al., 2015; Hassini et al., 2012; Tajbakhsh and Hassini, 2015b).

The review process was initiated by searching for titles and abstracts of documents in SCOPUS database using the following search string:

> *("Sustainable" OR "Sustainability" OR "Green" OR "Environmental" OR "Social") AND "Supply Chain" AND "Performance" AND ("Management" OR "Measurement" OR "Assessment" OR "Evaluation") AND ("Framework" OR "System" OR "Method" OR "Tool" OR "Concept" OR "Standard")*

Inclusion criteria were used to narrow down the number of documents to those relating to the focus of this study and to papers published in the highest quality peer-reviewed academic journals. Conference papers, conference reviews, books and book chapters, sources not written in English, and documents categorized in subject areas other than business, management and accounting, and decision sciences were excluded. As most of the documents relating to sustainability performance measurement were published after 2004 (Ahi and Searcy, 2015; Tajbakhsh and Hassini, 2015b), the publishing period was limited from 2005 until the end of March 2018. The narrowed-down search resulted in 373 peer-reviewed journal articles.

The review process was continued by reading the abstract of each paper and skimming its content. Only, articles that cover at least two dimensions of sustainability and measure performance of SCs were selected for inclusion in the final sample. This procedure yielded 91 papers. Using snowballing technique or checking reference lists, we located another 13 relevant studies. Thus, the total number of reviewed studies is 104, which are marked with an asterisk symbol (*) in the reference list. To increase the reliability of the research, individual papers were checked for inclusion in the study by a second researcher as suggested by Tranfield et al. (2003).

The content, context, and process (CCP) framework which was first developed in strategic management (Pettigrew, 1985), is used for papers content analysis. The framework, presented in Fig. 1, has been used on PM of SC by Cuthbertson and Piotrowicz (2011). The framework considers the context in which measurement takes place. Examination of context is also suggested by GRI, which states that organizations should consider their performance in wider context of sustainability. Furthermore, Cuthbertson and Piotrowicz (2011) point out that the CCP framework incorporates the following elements:

- *Content* – metrics, their levels, categories, and dimensions.
- *Context* – factors that impact PM of SC, are separated into two groups:
  - organizational factors include strategy, structure, culture, company size management methods and philosophy, experience and
  - SC factors include industry, number of participants, maturity, products, stakeholders, geographical coverage, and strategic goals.
- *Process* – methods, tools, and frameworks used to measure SC performance; the way that data are captured, presented and used; as well as the development of the measurement system.

In line with the aim of this study, the research focus is on the ***process*** component of CCP framework. The selected papers are analyzed and classified according to the publication year and source, sustainability aspects studied, the industry investigated and the measurement approach used or proposed.

The classification was implemented in the following way. First, out of the 104 articles, eight studies are excluded from analysis of sustainability aspects, industry and measurement approach

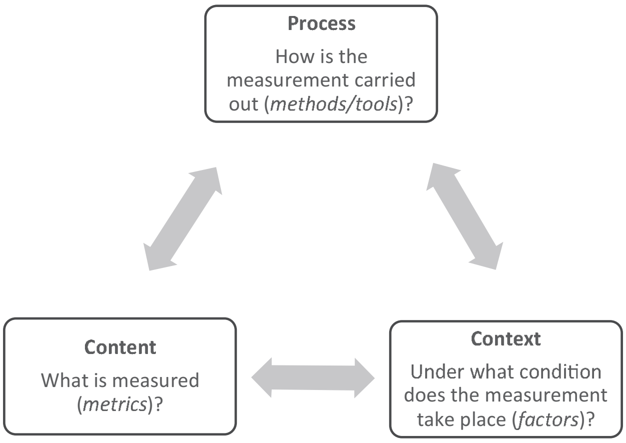

Fig. 1. The Content, Context, and Process framework for performance measurement in supply chain.
Source: Adapted from Cuthbertson and Piotrowicz (2011).

because six are literature reviews (see Table 1) that do not propose a framework and two other works (Grosvold et al., 2014; Schaltegger and Burritt, 2014) are more theoretical in nature. Second, articles that measure economic and environmental dimensions together are classified under the *Environmental* category, while papers that measure social and economic aspects are classified under the *Social* category. Third, papers that measure all three sustainability aspects are classified under the *TBL (triple-bottom-line)* category. When considering the industry covered, papers that do not state the specific industry are classified under the *General* category. Finally, in the measurement approach classification, articles are classified based on the main method used to measure sustainability of SCs.

4. Results

4.1. Descriptive analysis

The growing interest of scholars on PM of SSCM and GSCM is evident by the number of publications on a yearly basis, illustrated in Fig. 2. It is worth noting that increasing trend is steeper in the last five years.

Fig. 3 presents the distribution of papers by journal, where three or more articles are published. The top five journals contribute with 44 percent or 46 papers, while 31 other studies are published in 31 different journals, and 27 remaining articles are published in nine different journals. Thus, 104 papers included in our sample are published in 46 journals. This indicates the heterogeneity and distribution of the research on measuring sustainability performance of SCs.

4.2. Analysis of studies by industry and sustainability dimension

Table 2 shows the classification of papers by industry and sustainability aspect. Each paper is classified in one industry and in one sustainability aspect. We believe that classification by industry is important because SC activities and SC configurations are different among industries. Therefore, the measurement approach differs, both in tools and sustainability metrics used. Around one-third of the reviewed papers do not specify the industry and we found only

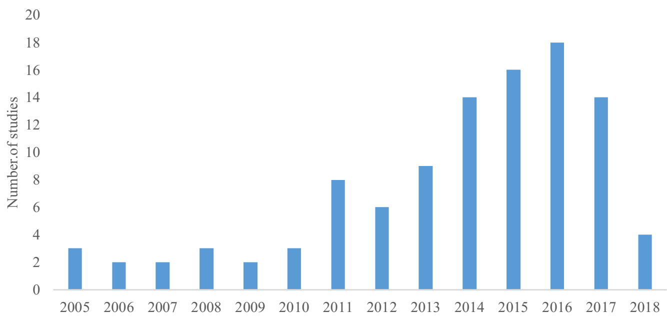

Fig. 2. Distributions of papers by publication year (n = 104).

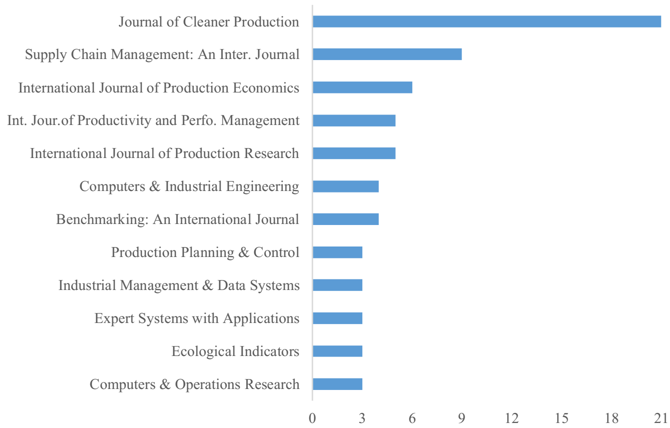

Fig. 3. Journals where three or more articles are published (n = 104).

Table 2
Distribution of studies by industry and sustainability dimensions.

	Environmental[a]	Social[b]	TBL[c]	Total
Retail	1		1	**2**
Steel	3		1	**4**
Service	1		3	**4**
Agriculture	2	1	2	**5**
Textile-footwear	4		1	**5**
Automotive	8		1	**9**
Food and Beverage	6		4	**10**
Electro-electronic	4	2	6	**12**
Manufacturing	8		6	**14**
General	14	2	15	**31**
Total	**51**	**5**	**40**	**96**

Notes.
[a] Articles that measure economic and environmental dimensions together.
[b] Articles that measure economic and social dimensions together.
[c] Articles that measure economic, social and environmental dimensions.

four studies (Chithambaranathan et al., 2015; Jauhar et al., 2017; Tajbakhsh and Hassini, 2015a; Tseng et al., 2018) that cover service sectors including Banking and Education. Regarding sustainability aspects, environmental is still leading, followed by TBL. We note also that in the reviewed literature there is no paper that studies only social and environmental dimension of sustainability.

Sustainability dimensions studied on yearly basis in reviewed papers are presented in Fig. 4. The results indicate that the number of papers that measure TBL and environmental aspects increased in last five years. It is worth noting that, in 2015, the number of papers that cover all three sustainability aspects is higher than the number of papers that cover environmental and economic aspects.

4.3. Analysis of SC sustainability measurement approaches

Classification of the papers based on the measurement approach

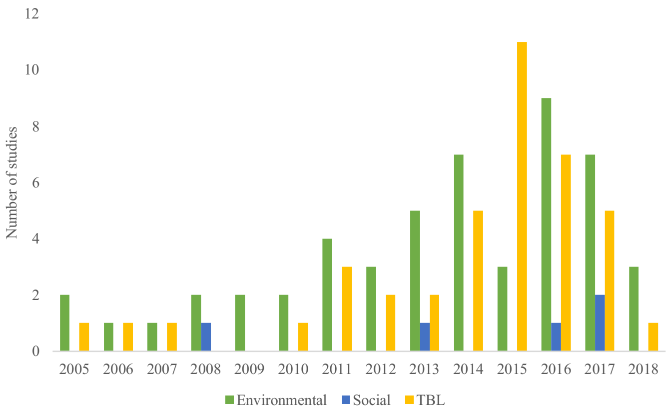

Fig. 4. Distribution of sustainability aspects covered in the reviewed articles by year (n = 96).

Table 3
Distribution of reviewed studies by measurement approach and sustainability aspects.

	Environmental[a]	Social[b]	TBL[c]	Total
SCOR and Rough set theory	1		1	**2**
Multi-objective and Goal Programming	1		2	**3**
Multi-Regional Input-Output (MRIO)	2		1	**3**
ISO Standards, Surveys, and Interviews	1		3	**4**
Composite performance index	3		4	**7**
Data envelopment analysis (DEA)	5		4	**9**
Fuzzy-set approach	7		3	**10**
Balanced Scorecard (BSC)	6		4	**10**
Analytical Hierarchy/Network Process (AHP/ANP)	4		7	**11**
Life Cycle Assessment (LCA)	11	4	1	**16**
General performance measurement framework	10	1	10	**21**
Total	**51**	**5**	**40**	**96**

Notes:
[a] Articles that measure economic and environmental dimensions together.
[b] Articles that measure economic and social dimensions together.
[c] Articles that measure economic, social and environmental dimensions.

and sustainability aspects is shown in Table 3. Majority of papers propose or develop a performance measurement framework, but the proposed approaches are seldom implemented in real cases. However, it is interesting to note, the equal number of studies (10) of proposed PM frameworks that consider all three sustainability aspects and studies that consider environmental and economic dimensions. The results also reveal that in the reviewed literature all PM approaches have been tailored to measure all three sustainability aspects.

Fig. 5 presents the distribution of measurement methods by year. To improve clarity, AHP and ANP, Composite performance index, DEA, Fuzzy-set approach, MRIO, Rough set theory, SCOR, Multi-objective and Goal Programming have been grouped together under '*Math focused*' category; BSC, Standards, and Surveys are grouped under one category; and other measurement approaches are presented individually. SCOR has been grouped under '*Math focused*' since is often used with other multi-criteria methods.

Methods grouped under '*Math focused*' are used in 47 percent of the reviewed papers (e.g., Acquaye et al., 2017, 2014; Agrawal et al., 2016; Büyüközkan and Çifçi, 2012; Harik et al., 2015; Jakhar, 2015, 2014; Kazancoglu et al., 2018; Rodríguez-Serrano et al., 2017; Schmidt and Schwegler, 2008; Tsoulfas and Pappis, 2008; Zhang, 2017) and, since 2011, the usage and development of these methods is rising. In 2005, two works (Hervani et al., 2005; Labuschagne et al., 2005) proposed conceptual frameworks to measure sustainability of SCs. After 2005, in the reviewed literature we did not find any framework proposed, until in 2010, when a framework was proposed by Sloan (2010). However, since 2010, the interest of scholars To develop such PM frameworks is growing. From 2005 to 2014, LCA is used in six studies (e.g., Balkau and Sonnemann, 2010; Brent, 2005; Hutchins and Sutherland, 2008; Kainuma and Tawara, 2006), whereas from 2015 until 2018 is used in ten studies (e.g., Egilmez et al., 2016; Kulak et al., 2016; Park et al., 2016; Tsalis et al., 2017).

Categorization of articles by measurement approach and type of industry are presented in Table 4. In two studies (Bai et al., 2012; Bai and Sarkis, 2014) the industry is not specified, where SCOR with Rough-set theory are combined to measure sustainability of SCs. Multi-objective and Goal Programming is used in manufacturing (Yousefi et al., 2017), agriculture (Boukherroub et al., 2015), and in electronic industry (Tsai and Hung, 2009). Based on MRIO analysis three studies (Acquaye et al., 2017, 2014; Rodríguez-Serrano et al., 2017) measure the environmental performance of electro-electronic and steel industries. Several studies combined standard 14001 with interviews or surveys and such studies are applied in agriculture industry (Vermeulen and Metselaar, 2015), food and beverages (Vasileiou and Morris, 2006), and in two studies (Nawrocka et al., 2009; Piotrowicz and Cuthbertson, 2015) the industry was not specified. The logic of composite performance index is used in food and beverage (Manning and Soon, 2016), in manufacturing (Lau, 2011), and in four studies (e.g., Azevedo et al., 2017; Tsoulfas and Pappis, 2008) the industry was not specified. DEA is used in service industries (Jauhar et al., 2017; Tajbakhsh and Hassini, 2015a), in food and beverage industries (e.g., Kahi et al., 2017; Mirhedayatian et al., 2014), in electro-electronic industry (Tavana et al., 2013), in manufacturing (Izadikhah and Saen, 2016), and in one study (Amini et al., 2016) the industry is not specified. Fuzzy-set approach is used in automotive industry (Olugu and Wong, 2012), in manufacturing (Kazancoglu et al., 2018; Sabaghi et al., 2016; Sahu et al., 2013), in service industries

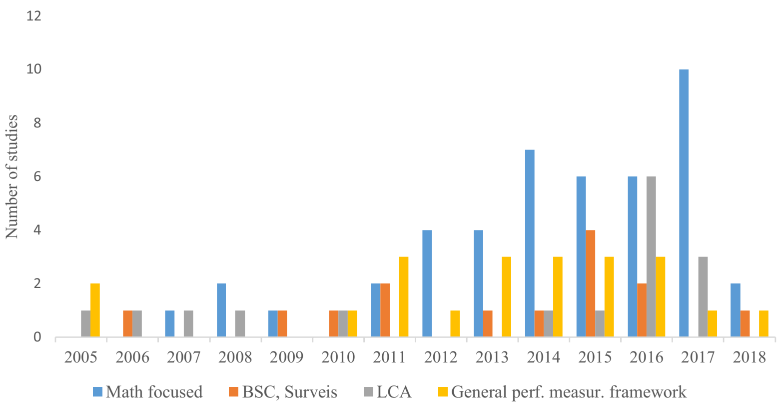

Fig. 5. Distribution of measurement approaches by year ("Math focused" groups AHP/ANP, Composite performance index, DEA, Fuzzy set approach, Rough set theory, Multi-objective and goal programming).

Table 4
Distribution of studies by measurement approach and industry.

	Retail	Steel	Service	Agriculture	Textile-footwear	Automotive	Food and Beverage	Electro-electronic	Manufacturing	General
SCOR and Rough set theory										2
Multi-objective and Goal Programming				1				1	1	
Multi-Regional Input-Output (MRIO)		1						2		
ISO Standards, Surveys, and Interviews				1			1			2
Composite performance index							1		1	5
Data envelopment analysis (DEA)			2				4	1	1	1
Fuzzy-set approach	1	1	2			1			3	2
Balanced Scorecard (BSC)					1	1	1	2		5
Analytic Hierarchy/Network Process (AHP/ANP)		1			2	1	1	2	4	
Life Cycle Assessment (LCA)				3	1	2	1	2	3	4
General performance measurement framework	1	1			1	4	1	2	1	10
Total	**2**	**4**	**4**	**5**	**5**	**9**	**10**	**12**	**14**	**31**

(Chithambaranathan et al., 2015; Tseng et al., 2018), in retail industry (Erol et al., 2011), in steel industry (Zhang, 2017), and in two papers (Sahu et al., 2015; Uygun and Dede, 2016) the industry is not specified. BSC is used in electro-electronic industries (Hsu et al., 2011; Tseng et al., 2015), automotive (Ferreira et al., 2016), food and beverage (Shafiee et al., 2014), textile and footwear (Thanki and Thakkar, 2018), and in five studies (Duarte and Cruz-Machado, 2015; Haghighi et al., 2016; Naini et al., 2011; Reefke and Trocchi, 2013; Shaw et al., 2010) the industry is not specified. AHP or ANP is used in electro-electronic industry (Felice et al., 2013), in manufacturing (e.g., Bhattacharya et al., 2014; Sari, 2017) and in few other industries. LCA is applied in agriculture (e.g., Park et al., 2016), textile and footwear (Fornasiero et al., 2017), automotive (Brent, 2005; Simão et al., 2016), food and beverage (Kulak et al., 2016), electro-electronic (Tsalis et al., 2017; Wang et al., 2016), manufacturing (e.g., Xing et al., 2016), and in four articles the industry is not specified (e.g., Hutchins and Sutherland, 2008). Finally, ten studies (e.g., El Saadany et al., 2011; Hassini et al., 2012; Nikolaou et al., 2013; Schöggl et al., 2016) propose PM frameworks for not a specific industry, four studies (Azevedo et al., 2013; Hadiguna et al., 2011; Lee and Wu, 2014; Olugu et al., 2011) propose frameworks in automotive industry, two studies in electro-electronic industries (Hassini et al., 2012; Rao, 2014), one study in manufacturing (Labuschagne et al., 2005), one in retail (Zhang et al., 2016), one in food and beverages (Manzini and Accorsi, 2013), one in steel (Goyal et al., 2018), and one study (Marconi et al., 2017) proposed a framework for textile and footwear industries.

Table 5 reveals the categorization of articles by measurement approach and SC level, stakeholders, categories of metrics, data collection, and implementation of the measurement approach. For simplicity of illustration, the SC has been divided in upstream echelon – PM of suppliers and manufacturers, and in downstream echelon – PM from manufacturers to the reverse logistics (Olugu et al., 2011). Metrics are classified into metric categories and in specific metrics. The difference between these two groups is that the first category does not provide specific measures while articles classified in the second category list specific metrics. It is important to point out that, although, two third of the reviewed studies apply the measurement approach used in the study, the implementation is done only for illustrative purposes. Note that each number in Table 5 shows the number of times a measurement approach is used in a specific category and a single study might have been classified in more than one category as they are mutually exclusive.

5. Discussion

The objective of this study was to analyze PM approaches published in peer-reviewed academic literature on SSCM and GSCM. By categorizing and synthesizing previous articles, this paper has provided a thorough overview of PM methods and tools used to assess sustainability of SCs. The findings thus contribute to a better understanding of PM approaches applied in SSCM and GSCM both in theory and in practice.

Results presented in Fig. 2 and in Fig. 3, indicate that literature on sustainability PM of SCs is flourishing but is fragmented, limited and scattered in many journals. Similar results are reported by Taticchi et al. (2013) and Beske-Janssen et al. (2015). Searcy (2017) notes that more than 80 percent of companies listed in the S&P 500 published a sustainability report in 2015. However, results (see Table 2) show that industry-specific studies are sparsely present in

Table 5
Distribution of studies by measurement approach and SC echelon, stakeholders, categories of metrics, data collection, and implementation.

	Upstream	Downstream	Stakeholders	Categories of metrics	Specific metrics	Data collection and sharing	Implemented
SCOR and Rough set theory	2[a]			2	1		
Multi-objective and Goal Programming	3	2		2	1	1	2
Multi-Regional Input-Output (MRIO)	3	1	2	2	3	2	3
ISO 14000 Standards, Surveys, and Interviews	4	2	1	4	3	1	4
Composite performance index	7	3	1	6	4	3	1
Data envelopment analysis (DEA)	6	7	1	5	4	2	8
Fuzzy-set approach	8	5	3	10	6	1	8
Balanced Scorecard (BSC)	10	5	6	10	8	2	7
Analytic Hierarchy/Network Process (AHP/ANP)	10	9	4	10	8	2	10
Life Cycle Assessment (LCA)	15	7	5	14	9	6	11
General performance measurement framework	18	14	8	17	13	5	11
Total	**86**	**55**	**31**	**82**	**60**	**25**	**65**

Note.
[a] It shows how many times a measurement approach is used in a specific category.

the literature reviewed. This is in contradiction with a large number of sustainability reports. One explanation might be that practitioners are leading with sustainability reports while scholars are focused on developing general frameworks to assess SC sustainability performance (see Table 3). Another explanation might be that sustainability reports published by companies present only partial information about their companies, and not for their entire SC. This is supported by KPMG (2011) and Morali and Searcy (2013) who found that sustainability reports often are uncompleted.

Even though studies that incorporate all three sustainability dimensions are increasing (see Fig. 4), still the social dimension lacks behind environmental and economic aspects. Similar results have been observed at least a decade ago (e.g., Seuring and Müller, 2008). One reason that explains this issue might be that social indicators sometimes are missing and often are challenging to be quantified as well as are often prone to subjectivity (Schaltegger and Burritt, 2014). Another reason is that, in past, there has been higher attention devoted to environmental aspect by governments and other stakeholders. However, recent studies (e.g., Popovic et al., 2018) have proposed specific measures for assessing social sustainability of supply chains.

5.1. Performance measurement approaches used to assess sustainability of SCs

PM tools used to evaluate sustainability of SCs are diverse (see Table 3). To help SC managers and scholars, this study has presented and synthesized several methods (e.g., AHP, ANP, DEA, Goal programming, Fuzzy set approach, Rough sets theory, LCA) with related articles that measure sustainability performance of SCs. In planning and designing a PM system, a good starting point is to read existing publications that are in the same or similar industry, in which the SC exist. In this direction, this study has classified PM methods and tools, both by sustainability dimension and industry. Thus, interested readers can refer to Tables 3 and 4 for specific results. Furthermore, Fig. 5 illustrates the trend that '*Math focused*' methods and tools used to measure sustainability of SCs, is sharply increasing. Likewise, a considerable attention of scholars is also on the development of conceptual PM frameworks.

The majority of the studies measure the SC sustainability performance between suppliers and manufacturers (e.g., Brent, 2005; Lee and Wu, 2014; Singh et al., 2007) while few PM frameworks (e.g., Ahi and Searcy, 2015; Chardine-Baumann and Botta-Genoulaz, 2014; Hassini et al., 2012; Olugu et al., 2011; Santiteerakul et al., 2015) have wider focus by including suppliers, manufacturers, retailers, and consumers. Surprisingly, less than one -third of studies (e.g., Hervani et al., 2005; Labuschagne et al., 2005; Varsei et al., 2014) incorporate stakeholders (see Table 5) in their measurement approach and even fewer studies list sustainability metrics per SC member (e.g., Olugu et al., 2011; Tajbakhsh and Hassini, 2015b). Likewise, the reviewed literature barely discuss how inter-organizational metrics should be developed and selected as well as how pertinent data should be collected. Furthermore, a discussion of the relationships between SC configuration and sustainability metrics as well as stakeholder participation are very sparsely present in the reviewed literature.

However, among many existing methods, a practitioner might ask "What is the best tool to use?" The answer to this question is tricky because there is no best method. For a classic discussion related to the best MCDM method, we recommend reading (Ignizio, 1983). The manager should choose the tool s/he knows the best and is the most suitable for the characteristics of the problem. In the case of sustainability PM of SCs, features of the problem include number of stakeholders, number of SC members and their related activities, the number of indicators, and the data required for indicator calculation. In principle, if the manager is in a situation where the interactions between decision factors are high, he should choose ANP over AHP. Likewise, if uncertainty and vagueness of decision factors are high, then the chosen method (AHP, ANP, DEA etc.) should be combined with fuzzy set theory. Usually, when measuring sustainability performance of SCs, both, the interactions among decision factors and level of uncertainty are high. Therefore, there is a need to combine the chosen tool(s) with fuzzy logic to increase the accuracy of the measurement system.

Overall, this study highlights that the selected PM approach must be compatible with the measurement systems both at the company level and at the SC level. The selected inter-organizational metrics must capture sustainability performance data across the entire SC and any measurement approach should take into account relationships between SC design, metrics selection, and SC context. In an attempt to clarify these issues, in next section, this study proposes a novel framework for evaluating sustainability performance of SCs.

5.2. A conceptual framework for measuring sustainability performance of SCs

Measuring sustainability performance of SCs is inherently complex and multi-dimensional (Sloan, 2010). Previous frameworks and tools proposed to measure sustainability performance of SCs do not consider all elements and complexity of this issue. Therefore, this study proposes a novel and comprehensive framework to assess SC sustainability. The proposed framework illustrated in Fig. 6, represents an overview of elements and their interactions that should be considered when developing a PM system for evaluating sustainability of SCs. In contrast, with the focus of the majority of the reviewed studies, represented by the dotted line, the proposed framework has a broader view by incorporating all three dimensions of sustainability, SC members, and stakeholders.

The first element of the framework represents SC members including raw material extractors, suppliers, focal company, distributors, retailers, consumers and reverse logistics. Each member has its own goals which influence and are influenced by internal stakeholders such as workers, investors, owners and managers and external stakeholders such as governments, regulators, competitors, media, and NGOs. The double-headed arrows between SC members indicate forward and reverse flows. Since all members belong to the same SC, they should cooperate and share their goals to formulate SC strategy. In the SC strategy managers need to define what is understood by sustainability performance and what has to be measured (Hervani et al., 2005; Wong and Wong, 2008). The SC strategy is mostly shaped by the focal company or manufacturer which usually has higher influence on other SC members. Thus, the proposed framework connects sustainability PM with SC strategy and overcomes this issue identified by Brewer and Speh (2000) and Shepherd and Günter (2006).

"What should be measured?" is represented by the second element of the framework. The double-headed arrow connects this element with the SC strategy, from where sustainability inter-organizational metrics should be derived. On one hand, measures should include environmental, social and economic dimensions of sustainability, on the other hand, measures should be able to overcome existing hurdles (see section 2.3). One way to overcome obstacles is to select metrics by incorporating a so-called "twin approach" (Beske-Janssen et al., 2015) which combines an outside-in approach and inside-out approach (Schaltegger and Wagner, 2006). Both approaches are represented in the framework by the hierarchy of measures. SC strategy should align goals with respective metrics from different SC members (inside-out) and metrics

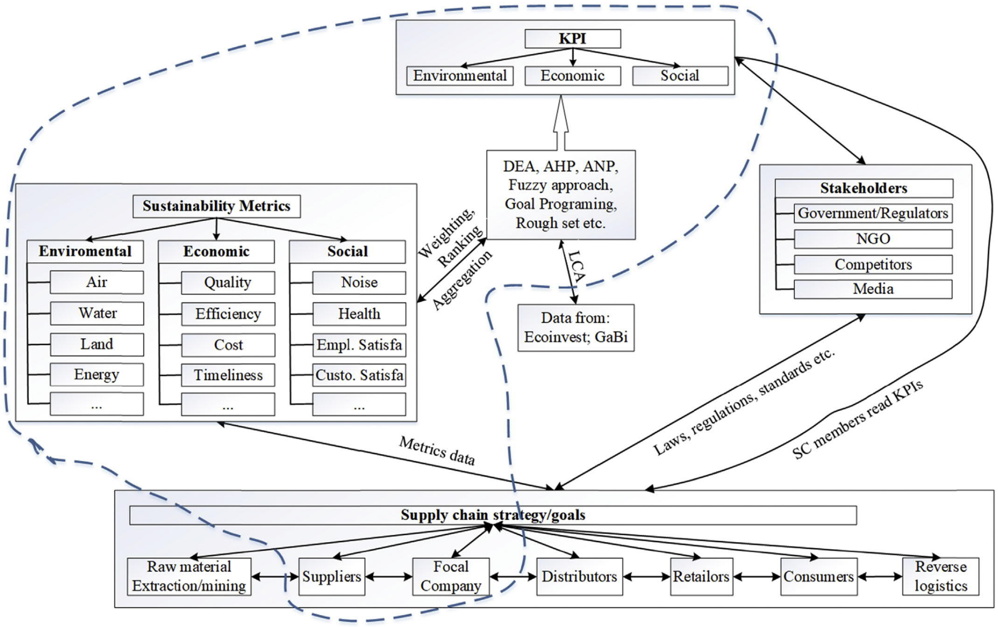

Fig. 6. A conceptual framework for measuring sustainability performance of SCs.

resulted from requirements of external stakeholders (outside-in). When selecting metrics, practitioners and scholars (e.g., Matos and Hall, 2007; Varsei et al., 2014) are also interested in the interdependencies between environmental, economic and social dimensions to overcome trade-offs and create win-win solutions (Beske-Janssen et al., 2015; Seuring and Müller, 2008). This is supported by the broadly integrated approach of the framework. Thus, the standardization and consistency of inter-organizational sustainability metrics are ensured, at least to an acceptable degree, which is a necessary requirement for aggregation or conversion of individual metrics into KPIs.

Data required for each metric and who should measure these metrics are not explicitly mentioned in the reviewed literature. Beske-Janssen et al. (2015) highlight that the majority of existing tools imply that the focal company assesses sustainability performance of its SC. Challenges with this approach include difficulties in collecting data from the second or third tier of suppliers as the influence of focal company decreases and the reliability of data is hard to be insured. Another possible approach is that all SC members measure for themselves sustainability performance and then pass to the next tier. A challenge with this approach is that the meaning of sustainability for different SC members is not the same and as a result, different members measure and report different sustainability aspects and metrics. Consequently, aggregation of these metrics is difficult or even impossible. A third possible approach to measure sustainability is by involving an organization which is not part of the SC. Examples of this approach include the Sustainable Apparel Coalition for apparel industry, and the Business Social Compliance Initiative for textile industry (Beske-Janssen et al., 2015).

All these three possible approaches are supported by the framework. However, this study emphasizes that first, there is a need to align intra-organizational metrics within the company, and then inter-organizational sustainability metrics across SC members by considering requirements from SC stakeholders. Then every SC member individually collects related data on intra-organizational and inter-organizational sustainability metrics. Thus, the collected data would be standardized. Next, this data should be sent to a Sustainability Metrics database which might be owned by the focal company or a third party organization specialized in measuring sustainability performance. This database might also get data from existing LCA based database such as *Ecoinvent* and *Gabi*. Finally, these data would be calculated in relevant metrics and aggregated into KPIs or Composite Indicators. KPIs should be accessible to every SC member. Consequently, every member can check and improve its sustainability performance and in turn, the sustainability of entire SC would also be improved.

Methods and tools reviewed in this study including AHP/ANP, DEA, Goal Programming, Rough Sets and Fuzzy approaches can be used for weighting, ranking and aggregating individual metrics into KPIs. The necessity of aggregating individual metrics into KPIs or composite indicators has also been highlighted by earlier researchers (Bai and Sarkis, 2014; Hassini et al., 2012; Sloan, 2010). However, in contrast with several authors (e.g., Hassini et al., 2012) who propose to aggregate all three dimension into a single composite indicator, the framework proposes to have at least one KPI or a composite indicator per sustainability dimension and one per SC member. A larger number of KPIs would enable the focal firm to have a broader view and a better understanding of its SC. This would help manufacturers to identify and to take necessary actions towards SC members which are causing higher negative and positive impacts. Measuring positive impacts would guide focal companies to intensify collaboration with the 'best' suppliers, distributors and so on. However, a larger number of KPIs would make it harder to benchmark SCs.

The proposed framework systematically integrates three major components of the SC sustainability performance assessment – SC members, sustainability metrics, and stakeholders. A unique feature of the framework is that explicitly depicts relationships between these components at a macro level, and provides the variety of PM tools that have been developed to date. It can be used as a decision-supporting tool and as a design structure at the early development stages of the sustainability PM system in SCs. Although the framework does not provide specific sustainability metrics, it serves as guidance on how and what needs to be measured and, thus, can also be used as an initial point for inter-organizational sustainability metrics development.

In sum, as Matos and Hall (2007) and Varsei et al. (2014) emphasize that having a broad integrated approach to examine interactions among environmental, economic and social dimensions is better than applying deep, but disconnected expertise in each one. Likewise, this study hopes that the proposed framework, despite its abstraction level, would help practitioners and scholars to structure thinking and to "provide lens" (Sloan, 2010) on measuring sustainability performance of SCs.

5.3. A concise guideline for developing the SC sustainability performance measurement system

The starting point for the PM process is to analyze existing PM systems inside organizations which are members of the SC. During this phase, managers should determine what metrics are already in use and by which department as well as supplement and modify existing PM systems with environmental and social metrics. Next, SC practitioners should develop a sustainability policy and determine the scope of measurement, identify major performance processes and decompose them into sub-processes and activities, set objectives, select sustainability measures, use tools presented in this paper to aggregate individual metrics into KPIs, measure and track sustainability performance, report results, and finally review and improve sustainability PM system.

Process decomposition can be divided into further sub-steps (Chan and Qi, 2003; Cuthbertson et al., 2011, pp. 75–76):

1. Identification and linkage of all inter- and intra-organizational processes
2. Definition of core processes
3. Derivation of missions, responsibilities, and functions of core processes
4. Sub-processes decomposition
5. Derivation of responsibilities and functions of sub-processes
6. Identification and decomposition of main activities
7. Create links between processes, activities and their goals

After this step is finished for the focal company, the same process can be repeated for other SC members to identify sustainability measures for the inter-organizational processes by considering requirements of SC stakeholders (Cuthbertson et al., 2011). The proposed framework can serve as a design structure for at least several steps including sustainability metrics development and selection, creating KPIs, reporting and reviewing PM results. Furthermore, the framework highlights that all these steps should be in accordance with SC stakeholders.

Finally, since, measuring SC sustainability performance is inherently challenging (Sloan, 2010), these steps should be implemented in a software according to the proposed framework and the above listed steps.

5.4. Limitations

There are some limitations to this study that must be borne in mind. First, the authors only considered peer-reviewed journals in the SCOPUS database. Important and relevant knowledge may be found in other sources such as conference papers, books or PhD dissertations. Second, although the authors tried their best to use accurate search terms in the search string, there might be other important terms that were not included. Sometimes articles might address the topic of this study using different keywords. Third, although SCOPUS covers a wide range of peer-reviewed journals in the scientific, technical, and social sciences, it does not include all reputable peer-reviewed journals. Fourth, the study period of 13 years was considered valid for this study but other authors may investigate the field over a time-scale longer than a decade. Finally, the selection of the articles included in the database for review could be considered subjective, although the papers were reviewed by two researchers independently.

5.5. Future research recommendations

The main drawback of the proposed framework is that it does not provide specific inter-organizational sustainability metrics, but it highlights that these metrics should incorporate all sustainability dimensions and their interdependencies, as well as metrics should be developed and selected by involving SC stakeholders. In this direction, although, various authors (e.g., Ahi and Searcy, 2015; Bai et al., 2012; Bai and Sarkis, 2014; Hervani et al., 2005; Tajbakhsh and Hassini, 2015b) have listed sustainability performance measurement metrics, there is, however, still a lack of consensus on which metrics should be used in specific industries and SCs. In other words, standardized SC sustainability metrics need to be proposed by future research. Hints on this significant component of PM system can be found in these papers (Ahi et al., 2016b; Delai and Takahashi, 2011; Piotrowicz and Cuthbertson, 2015; Santiteerakul et al., 2015; Tajbakhsh and Hassini, 2015b).

Thresholds or limits for specific sustainability metrics are also rarely or not present in the reviewed literature. However, GRI guidelines are probably the best approach to follow (Beske-Janssen et al., 2015). Likewise, we also found that there is a lack of studies in the service sectors such as banking, educations or medical services and the majority of the proposed measurement frameworks are not tailored to a specific industry. Therefore, there is a need for more research on sector-specific sustainability measures together with their thresholds, and the validation of the proposed framework.

Future research should also investigate the possibilities to integrate different measurement tools under a single framework, in such a way that aggregation of individual metrics into KPIs to be as precise as possible. Another important aspect when considering the measurement approach is the configuration of SC itself. However, the majority of the papers reviewed in this study surprisingly do not discuss the SC design. This is in line with Pagell and Wu (2009) who highlight that the design structure and function of the SC are rarely taken into account when measuring sustainability performance. Thus, future research should investigate relationships between SC design and PM approach. In this direction, it is important to develop some guidance which measurement approach is suitable for a specific SC configuration.

The success of the measurement system in the SC is dependent on the ability of information systems of each SC member, to capture data related to sustainability dimensions for every SC activity. These data are used to calculate sustainability metrics. How these data and metrics should be shared among SC members per se and SC stakeholders are not present in the reviewed literature. Despite this, surprisingly, information systems are seldom mentioned in reviewed papers. Thus, these important issues should be investigated in detail by future research. Consequently, the proposed framework and outcome of the proposed research would facilitate inter-organizational sustainability metrics selection and collaboration between SC members and external stakeholders. Furthermore, standardization in data collection is seen as a facilitator for data exchange along the supply chain (Beske-Janssen et al., 2015).

6. Conclusions

The review of the literature indicates that research on measuring sustainability performance of SCs is scattered, fragmented, incomplete and relatively new research area. The results indicate that various PM have been proposed, but their implementation in real life cases is sparsely provided. So far, the majority of proposed measurement approaches are focused on measuring sustainability performance between suppliers and manufacturers. Furthermore, the PM approaches based on MCDM methods and fuzzy set theory are thriving, and the number of papers that incorporate all three aspects of sustainability is approximately equal with the number of studies that incorporate environmental and economic aspects of sustainability.

To expand sustainability PM across entire SC, and to help focus attention of practitioners and scholars on key issues of PM, this study proposes a novel conceptual framework and provides a concise guideline for measuring sustainability performance of SCs. The proposed framework systematically integrates SC members, sustainability metrics, and stakeholders as well as explicitly depicts their relationships. It can be used as a design structure at the early development stages of the sustainability PM system in SCs. Additionally, we believe that this study is important and a good starting point for managers and researchers to familiarize with existing measurement approaches used to assess sustainability performance of SCs.

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Publication II

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Green Supply Chain Management Practices and Company Performance: A Meta-analysis approach

Ardian Qorri[a,*], Zlatan Mujkić[a], Saranda Gashi[b], Andrzej Kraslawski[a,c]

[a]*School of Engineering Science, Industrial Engineering and Management, Lappeenranta University of Technology, P.O. Box 20, FI-53581 Lappeenranta, Finland*
[b]*Facoltà di Economia "Giorgio Fuà" - Università Politecnica delle Marche, Italy*
[c]*Faculty of Process and Environmental Engineering, Technical University of Lodz, Poland*
**Corresponding author: E-mail: ardian.qorri@lut.fi*

Abstract

Varying conceptualizations of green supply chain management (GSCM) practices can be observed in extant literature and there is evidence of mixed results relating GSCM practices to firm performance. These inconclusive findings have often confused managers which practices would yield desired performance outcomes. Hence, by applying meta-analysis approach in 85 independent effect sizes with a total sample size of 20011 firms, we tested the impact of GSCM practices on firm performance. Findings indicate that the relationship between GSCM practices and firm performance is positive and significant, providing empirical generalization and support to practitioners and scholars. Likewise, the GSCM practices positively and significantly influence environmental, social, operational and economic performance. This relationship is moderated by geographical region, industry type and firm size. Future studies should test how ascendants of GSCM practices affect firm's sustainability performance.

Keywords: Green supply chain management, GSCM; performance; meta-analysis; sustainability; green; supply chain, practices.

1. Introduction

Environmental management is an important issue in supply chain management (SCM) [1]. The SCM requires integration and coordination of inter-organizational processes and strategy alignment across all companies in the supply chain (SC) for the purpose of satisfying the final consumer [2]. Organizational processes include sourcing,

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manufacturing, distribution, marketing, information systems [2], and reverse logistics. All these processes should be strategically aligned with environmental standards and concerns from government regulators, customers, and competitors [3] to mitigate the risk of environmental hazards and reduce adverse publicity due to non-compliance with associated government penalties as well as improve SC performance. With competition at SC level [4] and since the focal company is often held responsible for the adverse environmental impacts of all organizations in its SC [3], it is necessary to identify and adopt GSCM practices that yield competitive advantages. In this direction, the research on GSCM is attracting a growing interest in academic literature [5].

Beamon [6] defined green SC as "*the extension of the traditional supply chain to include activities that aim at minimizing environmental impacts of a product throughout its entire cycle, such as green design, resource saving, harmful material reduction and product recycle and reuse.*" Thus, GSCM practices consist of different types of activities and initiatives undertaken by companies to cope with institutional pressure and to improve the overall performance of the company and in turn the overall SC performance. Although many studies have studied the influence of GSCM practices on performance, the outcomes are mixed and not conclusive. While the majority of studies found positive relationship [2,3,7–9], several studies have found negative [10–12] or no significant relationship [13–16] between GSCM practices and corporate performance. Other studies including Azevedo et al. [1] and Wu and Pagell [17] found a mix of positive and other relationships. However, results from two previous meta-analysis [18,19] found a positive and significant relationship between GSCM practices and performance.

The meta-analysis by Golicic and Smith [18] tested only the relationship between GSCM practices and firm's financial performance but no relationship between GSCM practices and environmental, social, or operational performance is tested. The meta-analysis by Geng et al. [19] tested the relationship between GSCM practices and economic, environmental, social, and operational performance but their sample includes only studies from Asian emerging economies in the manufacturing sector. Another factor that motivates our study is that both previous meta-analyses violate the condition of independent samples [20] by using the same sample published in two or more studies as independent samples.

To reconcile differences in these mixed results, several studies [1–3,5,21,22] have stressed the need for further research on this topic. Additionally, GSCM practices have been operationalized differently and previous meta-analyses are limited; hence, *this study aims to provide new insights and empirical generalization on the relationship between GSCM practices and firm performance.*

To fulfill the research objective this study examined the empirical literature in the link on GSCM practices and firm performance. This study followed the methods of meta-analysis recommended by Hunter and Schmidt [23] and Geyskens et al. [20]. It contributes to theory and to practice by generalizing that GSCM practices have a positive and significant impact on firm's economic, environmental, social and operational performance. In doing so, SC managers, using this study can identify GSCM practices that lead to desirable firm performance. Scholars find this study useful because it provides new insights into the link between GSCM practices and firm performance and suggests possible future research directions.

The remainder of this paper is organized as follows. The research framework adopted for this study is presented in Section 2 followed by research methodology described in Section 3. The results of the study and their implications are depicted and discussed in Section 4. The study ends with future research recommendations and conclusions.

2. Theoretical framework and hypotheses development

GSCM practices are initiatives that companies adapt to comply with environmental legislation, to minimize negative impacts of their operations [16], and to improve their performance [9] as well as SC performance [1]. GSCM practices include both coercive and vulnerary initiatives [7,11] and should incorporate both inter-organizational practices [24,25] and intra-organizational practices [3]. These practices require that the focal company (manufacturer) to collaborate with suppliers and consumers [26].

It is worth to note that various papers use different conceptual frameworks to test the relationship between GSCM practices and corporate performance. Consequently, there is no universally accepted framework of GSCM practices [14,16]. Based on the study by Golic and Smith [18], this paper operationalizes GSCM practices into four constructs–*Upstream Supplier Facing, Eco-Design, Green manufacturing, and Downstream Consumer Facing*; firm performance includes four constructs–*Environmental, Social, Operational, and Economic Performance*. Fig 1 presents the theoretical research framework used in this study. The constructs of GSCM practices are the independent variable and constructs of firm performance represent the depended variable. Control variables in primary studies are usually considered as moderating variables in meta-analysis [18]. A moderating variable in the meta-analysis is a third variable that may affect the relationship or correlation between independent and depended variables [19,23]. In this study, we tested three moderating variables: (i) firm size, (ii) geographical region, and (iii) industry type. Firm size is tested as moderator since larger firms have more resources to implement GSCM practices [13]. Industry type and geographical region are used as moderators since primary studies are drawn from various samples in both industry type and country.

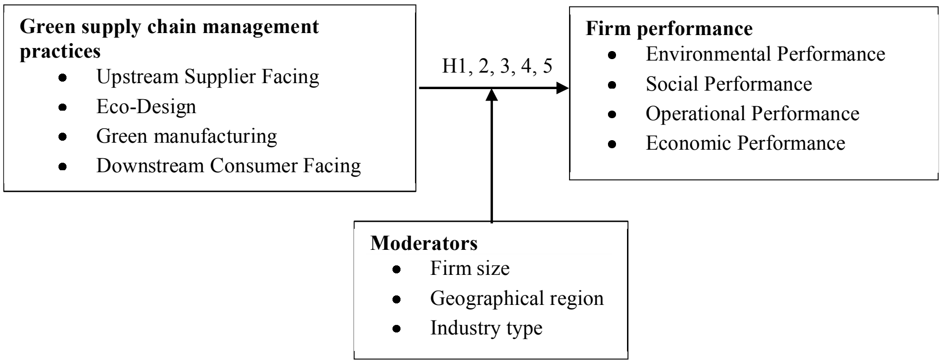

Fig 1. Research framework.

Upstream supplier facing includes activities that aim to ensure the purchased items are reusable, recyclable, and do not contain hazardous material [3,7,21]. Eco-Design is the design of products and services with environmental objectives and impact in mind [26–28]. Green manufacturing includes activities that aim for continues improvements of products and industrial processes to minimize harmful environmental impacts [22,29,30]. Downstream consumer-facing includes activities that aim to improve environmental capabilities of distributors, retailers, and consumers [1,16,21,31]. Environmental performance is concerned with saving energy and reducing emissions, pollution, and waste [7,11,14,19]. Social performance includes items such as corporate image improvement, reduction in environmental risks, improvement of the quality of life and health of workers and community through cleaner air and water, reduced emissions [3,21,22] etc. Operational performance is measured by cost reductions, product quality improvements, and improvements in delivery and flexibility [7,9,14,16,21]. Economic performance includes financial benefits such as an increase in market share, productivity, and sales [7,21,32,33].

Based on the definition of constructs of GSCM practices and firm performance in previous paragraph and literature reviewed several hypotheses are developed. Because the majority of the reviewed studies found a positive correlation between GSCM practices and firm performance including economic performance [34], environmental [7,21], social [3,22], and operational performance [2,21], the first hypothesis is proposed:

H1: Implementation of GSCM practices positively impact firm performance.

Zhu and Sarkis [7] found a positive relationship between the adaptation of GSCM practices and improvements in environmental and economic performance. Similarly, Zhu et al. [27,35] and other studies [18,19,21] found a positive and significant relationship between GSCM practices and economic and operational performance. Gimenez and Tachizawa [36] and several other articles [3,9,21,33] found that the implementation of GSCM practices positively impacts social and economic performance. Vachon and Klassen [16,37] found that cooperation with consumers and suppliers improves operational and economic performance. In sum, based on the above discussion and literature reviewed, it is hypothesized that:

H2: Implementation of GSCM practices positively impact environmental performance.
H3: Implementation of GSCM practices positively impact social performance.
H4: Implementation of GSCM practices positively impact operational performance.
H5: Implementation of GSCM practices positively impact economic performance.

It is worth noting that for each of the above hypothesis, we have tested four other sub-hypotheses, which consider one by one constructs of GSCM practices and constructs of firm performance used in this study. Thus, in total, we have tested 25 hypotheses, and the outcomes of these hypotheses are presented in Section 4 of this study.

3. Methodology

Since the aim of this study is to synthesize and generalize the effect of GSCM practices on firm performance, a meta-analysis of empirical research [20] is the best approach to test our hypotheses. A meta-analysis of effect sizes of the focal link is conducted following recommendations from several studies [20,23] which can be used to generalize quantitative results of previous research [19]. The effect size used in this study is the Pearson product-moment correlation coefficient (*r*), which have been used mostly in operations management research [20].

3.1. Data collection and inclusion criteria

In line with the research objective of this study, we searched for empirical studies using keywords in SCOPUS and Web of Knowledge databases. The keywords used in the searching procedure include *sustainability, environmental, green, social, corporate social responsibility, supply chain, value chain, performance, outcome, benefit, practices, initiatives, activities, empirical, and quantitative.* These terms were combined using Boolean logic and references from two previous meta-analyses [18,19] were queried to look for any omitted study.

This searching process resulted in 350 articles after dropping the papers written in other languages than English and published in not peer-reviewed sources. To obtain only papers that test the link between GSCM practices and firm performance we read each abstract and screen content of each paper. This phase yielded 98 papers. Next, we started to extract and code data from each article and looked for possible articles that use the same sample. This is a critical step in meta-analysis since it ensures the independence of samples [20]. After removing articles that used the same sample and used the same constructs in more than one study [38], 85 independent studies were left for conducting the meta-analysis. We coded data from each article per each construct of GSCM practices and firm performance as well as data relating to moderating variables used in this study. The correlation coefficient was directly recorded if it was provided in the primary studies or it was derived from other statistics using formulas given by Lipsey and Wilson [44, p. 201].

3.2. Meta-analysis procedures

Every effect size is first transformed into Fisher's *z* and after analyses were performed all results are transformed back to r correlation [20]. We used the fixed-effects model of meta-analysis because the selected papers included in this study examine the link between GSCM practices and firm performance [18]. If multiple effect sizes per study were reported in the primary articles, a single composite effect size is calculated using formulas by Hunter and Schmidt [23]. Next, we meta-analytically estimated mean correlation and calculated 95% confidence interval around the mean correlation. To examine the existence of moderators, a chi-square distributed statistic with $k - 1$ degrees of freedom or *Q*-statistic is calculated [23], where *k* is number of samples. Finally, to provide confidence that publication bias is not a concern, we calculated the so-called file drawer number and Egger's regression. The failsafe analysis estimates the number of unlocated studies that would affect the overall significance of our findings [18,23]. Egger's regression test is often used to detect publication bias in meta-analyses [40]. In other words, if p-value of Egger's test is not significant, it means that there is no evidence to indicate publication bias. Analyses were performed in *Comprehensive Meta-Analysis (CMA)* software.

4. Results and their implications

To test our study's hypotheses, the correlation between multidimensional constructs of GSCM practices and firm performance was calculated.
Table 1 depicts meta-analytic results. For each relationship we report: the number of independent samples (*k*), total sample size (*N*), the mean correlation (*r*), the standard deviation (*SE*), the 95% confidence interval around the mean (*CI*), the chi-square statistic for heterogeneity (*Q*), the failsafe number (N_{fs}), and the Egger's regression intercept p-value (E_p).

The total number of independent effect sizes is 85 with a sample size of 20011 firms. The overall association between GSCM practices and firm performance is significant and positive (r = 0.2912, p<0.001). This indicates that adaptation of GSCM practices is fruitful for companies and provides evidence in support of H1. Similar results are reported by previous meta-analysis [18,19]. Results also indicate that separately each GSCM practice is positively and significantly correlated with overall firm performance, but Eco-design has the highest impact on firm performance ($r = 0.3604$, $p<0.001$). Similar results are also found in other studies [7,21].

The overall impact of GSCM practices on environmental performance is positive and significant *(r = 0.3144, p<0.001)*, with a sample size of 12089 firms. This supports H2 and among GSCM practices, green manufacturing and eco-design have the highest impact on environmental performance, with a mean correlation of *0.5007* and *0.4883*, respectively.

Table 1. Bivariate meta-analytic results.

	k	N	r	SE	5% CI	95% CI	Q	N_{fs}	E_p
H1: GSCMP[a] → firm perf	85	20011	0.2912	0.009	0.277	0.306	975.62***	5416	0.2750
H1a: UppSt → firm perf	53	13784	0.2650	0.011	0.248	0.282	727.20***	1938	0.0921
H1b: EcDsg → firm perf	45	8416	0.3604	0.013	0.339	0.382	330.34***	2117	0.4171
H1c: GrPrd → firm perf	26	5872	0.2582	0.016	0.232	0.284	216.64***	431	0.7424
H1d: DwnSt → firm perf	40	7795	0.3121	0.013	0.290	0.334	210.03***	1755	0.4651
H2: GSCMP → env perf	51	12089	0.3144	0.012	0.295	0.333	966.05***	1573	0.4283
H2a: UppSt → env perf	36	9518	0.2435	0.013	0.222	0.265	733.72***	647	0.2102
H2b: EcDsg → env perf	23	3623	0.4883	0.019	0.457	0.520	160.73***	900	0.9985
H2c: GrPrd → env perf	15	2388	0.5007	0.024	0.461	0.541	109.31***	315	0.4209
H2d: DwnSt → env perf	20	3347	0.3887	0.020	0.356	0.421	111.49***	514	0.7992
H3: GSCMP → soc perf	14	2313	0.3240	0.025	0.283	0.365	45.14***	232	0.8478
H3a: UppSt → soc perf	6	928	0.4481	0.038	0.386	0.511	16.57**	82	0.4120
H3b: EcDsg → soc perf	8	1491	0.2915	0.031	0.240	0.343	17.68*	89	0.9436
H3c: GrPrd → soc perf	4	580	0.2635	0.052	0.178	0.349	1.35	36	0.5711
H3d: DwnSt → soc perf	7	1158	0.2516	0.035	0.194	0.309	13.57	50	0.7949
H4: GSCMP → opr perf	39	8524	0.2913	0.013	0.270	0.312	343.83***	1211	0.1153
H4a: UppSt → opr perf	26	5229	0.3070	0.016	0.281	0.333	258.62***	483	0.2381
H4b: EcDsg → opr perf	24	5233	0.3020	0.017	0.274	0.330	147.08***	601	0.0479
H4c: GrPrd → opr perf	10	3589	0.1690	0.020	0.135	0.203	76.35***	54	0.2735
H4d: DwnSt → opr perf	24	4978	0.2647	0.017	0.237	0.293	95.02***	628	0.2756
H5: GSCMP → eco perf	53	12652	0.2888	0.011	0.271	0.307	558.56***	1938	0.7548
H5a: UppSt → eco perf	33	9521	0.2752	0.013	0.254	0.297	440.22***	709	0.7017
H5b: EcDsg → eco perf	32	4952	0.3415	0.016	0.314	0.369	226.73***	853	0.3930
H5c: GrPrd → eco perf	16	2355	0.2991	0.024	0.260	0.339	138.09***	85	0.5458
H5d: DwnSt → eco perf	26	4628	0.3201	0.017	0.292	0.348	156.63***	628	0.7835

Notes: [a]GSCMP means green supply chain practices; *p < 0.05; **p < 0.01; ***p < 0.001

There are only 14 studies that have studied the link between GSCM practices and social performance. Our results suggest that this correlation is significant and positive (*r = 0.3240, p<0.001*) and adopting green purchasing practices as well as collaborating with suppliers has the highest impact on social performance (*r = 0.4481, p<0.001*). Thus, results provide evidence for supporting H3.

Our results indicate that correlation between GSCM practices and firm's operational performance is significant and positive (*r = 0.2913, p<0.001*) and is tested in *39* studies, with a total sample size of *8524* firms. This result provides support for H4. Green purchasing and eco-design are the most positively correlated GSCM practices with operational performance with a mean correlation of *0.3070* and *0.3020*, respectively. Similar results were reported by Rao and Holt [33], and Younis et al. [9].

The relationship between GSCM practices and economic performance is strong and positive with a mean correlation of *0.2888* (*p<0.001, N=12656*). All other GSCM practices are significantly and positively correlated with economic performance. Economic performance benefits more from eco-design (*r=0.3415, p<0.001*) compared to other GSCM practices. Consequently, H5 is confirmed and results show that the adoption of GSCM practices is beneficial.

Publication bias is not a concern for our meta-analysis since failsafe numbers range between *36* to *5416*, which indicate the number of studies to be found in the literature that are not included in our meta-analysis. Furthermore, none of the correlations have a significant Egger's regression p-value. Therefore, we may conclude that our results are robust.

A significant *Q* (*p<0.05*), suggests the existence of possible moderators. *Table 2* shows the results of moderator analysis. Results indicate that mean correlation (*r = 0.2781, p<0.001*) of large corporations is smaller than mean correlation (*r = 0.2962, p<0.001*) of companies which are not large. This is in contrast with our expectations since large companies have more resources to implement GSCM practices [13]. Next, we grouped studies based on the geographical continent and results indicate that almost two-thirds of studies were conducted in Asia, with a mean correlation of *0.4412*. This correlation is the highest among other continents and similar results are reported by Golic and Smith [18]. Two papers are classified under "World" as they include companies from different continents. Finally, moderator analysis indicates that companies in the automotive industry have the highest correlation (*r = 0.4977, p<0.001*) between GSCM practices and performance compared to other industries. This is in line with results from the previous meta-analysis by Geng et al. [19] and Golic and Smith [18]. In this direction, Zhu et al. [27] highlighted that GSCM practices are widely adopted in the automotive industry.

Table 2. Results of moderator analysis.

	k	N	r	SE	5% CI	95% CI	Q	N_{fs}	E_p
Large companies	25	5385	0.2781	0.017	0.251	0.306	171.97**	499	0.1810
Other companies	60	14626	0.2962	0.010	0.279	0.313	802.64**	2601	0.6458
America	15	4380	0.1718	0.018	0.142	0.202	92.04**	133	0.4347
Europe	16	2820	0.3006	0.022	0.264	0.337	77.49**	298	0.0203
Asia	52	8315	0.4412	0.013	0.420	0.462	311.31**	4022	0.7018
World	2	4497	-0.0607	0.023	-0.098	-0.024	5.76*	N/A	N/A
Automotive	11	1200	0.4977	0.035	0.440	0.555	81.88**	82	0.4312
Electronics	8	1569	0.3979	0.030	0.348	0.448	33.16**	90	0.0905
Various industries	66	17242	0.2639	0.009	0.248	0.279	785.5**	3242	0.0612
Notes: *p < 0.05, **p < 0.001; N/A – not enough data to be calculated.									

This study makes a significant contribution in supporting previous results that GSCM practices have a positive impact on firm performance. The results from four constructs of GSCM practices in this study indicate that environmental sustainability incorporates all companies in the SC. Other studies might analyze GSCM practices under different constructs to examine if there is a difference between results presented in this study. Moderator analysis suggests that correlations of different firm sizes are almost the same, but correlations differ by a larger degree regarding the geographical region and industry type. We identified only two studies that investigated companies from more than one continent, thus we recommend to scholars to include companies in various geographical regions. This is necessary because global SCs include companies from different geographical regions. Likewise, results indicate that SC managers working in the automotive industry are more interested and have higher pressure to implement GSCM practices. Additionally, the results of this study reveal that SC managers of manufacturing firms should adopt a mix of GSCM practices and not only one specific GSCM practice to improve the firm performance. Thus, in this direction, the results from this study can be used to support SC practitioners in their reports and requests to top-management of the company, that there is a need to work together with suppliers and consumers in the same time to achieve the desired sustainability performance.

It is worth to highlight that this study has several limitations. First, the decision about the studies included in the meta-analysis might be considered subjective, although a-priory constructs of both GSCM practices and firm performance are developed based on the literature reviewed. Second, although there is no indication of publication bias in our analysis, there might be other studies not included in our study that examine the link between GSCM practices and firm performance. Finally, we did not correct correlation coefficients in meta-analysis for any artifacts including measurement error, range restriction, and dichotomization of a truly continuous variable.

5. Conclusions and future research recommendations

This study synthesized the empirical literature on the relationship between GSCM practices and firm performance. Both GSCM practices and firm performance are operationalized using four constructs. The results show that the overall association between GSCM practices and performance is positive and significant. Findings also indicate that there is a need to work together with suppliers and consumers to achieve desired environmental, social, economic, and operational performance.

Because only 14 studies examined the effect of GSCM practices on social performance, we suggest future studies to be conducted in this direction. Future research should also consider if there is a difference in performance based on the pressures for implementing GSCM practices. It is also worthwhile to analyze in more detail the reasons why some industries and geographical regions have higher benefits from adopting GSCM practices. Only around half of the studies specify the underpinning theories for the link of GSCM practices and firm performance and various constructs were used to test this relationship. Thus, there is a need to develop a theoretical background and a more comprehensive framework of constructs. Finally, future research should expand GSCM practices to include social SC practices and test their impact on different dimensions of firm performance.

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Publication III

Qorri, A., Gashi, S. and Kraslawski, A.

Performance outcomes of supply chain practices for sustainable development: A meta-analysis of moderators

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RESEARCH ARTICLE

Performance outcomes of supply chain practices for sustainable development: A meta-analysis of moderators

Ardian Qorri[1] | Saranda Gashi[1] | Andrzej Kraslawski[1,2]

[1]Industrial Engineering and Management, LUT University, Lappeenranta, Finland
[2]Faculty of Process and Environmental Engineering, Technical University of Lodz, Lodz, Poland

Correspondence
Ardian Qorri, Industrial Engineering and Management, LUT University, P.O. Box 20, FI-53581 Lappeenranta, Finland.
Email: ardian.qorri@lut.fi

Abstract

Sustainable supply chain management (SSCM) practices have received growing attention but their consequences on firm performance yielded mixed outcomes. This study aims to synthesize quantitative research and to analyze potential moderators on the link between SSCM practices and firm performance. This study draws upon resource-based view of the firm with the extensions of natural resource-based view and relational view to underpin study hypotheses. The analysis is based on data collected from 145 independent samples composed of 33,886 firms. The research hypotheses are tested using meta-analytical procedures. The results show that SSCM practices are significantly and positively correlated with firm's social, operational, economic, and environmental performance dimensions. Additional findings from moderator analysis provide nuanced views of SSCM practices-performance link. This paper contributes to the literature by underlining the relevance of SSCM, identifying and classifying SSCM practices into a coherent framework. The research findings help policy makers, practitioners and other stakeholders to better understand benefits from the adoption of SSCM practices. Additionally, to the best of authors' knowledge, this is the first study that meta-analytically combined existing empirical evidence of the social supply practices on various types of firm's sustainability performance.

KEYWORDS
environmental sustainability, firm performance, meta-analysis, SSCM practices, supply chain management, sustainable development

1 | INTRODUCTION

Increasingly firms are held responsible for the behavior of their supply chain (SC) partners (i.e., suppliers) and are under intense scrutiny from various stakeholders to decrease or eliminate negative impacts on health, environment, and society (Esfahbodi, Zhang, Watson, & Zhang, 2017; Jawaad & Zafar, 2020). In response, firms have started to integrate sustainability principles in inter- and intra-organizational practices by adopting various initiatives including sustainable sourcing, eco-design, sustainable manufacturing, collaboration with consumers, and reverse logistics (Paulraj, Chen, & Blome, 2017; Vachon & Klassen, 2006; Zhu & Sarkis, 2004). While such practices and their impact on firm performance (FP) have been extensively studied in the green and sustainable supply chain management (SSCM) literature, results are still contradictory as some studies found positive (Huang & Li, 2017; Laari, Solakivi, Töyli, & Ojala, 2016; Rao & Holt, 2005), negative (Large & Thomsen, 2011; Richey, Chen, Genchev, & Daugherty, 2005) and insignificant relationships (De Giovanni, 2012; González-Benito & González-Benito, 2005), leaving managers confused as to which practice(s) lead to desired performance. However, many scholars have suggested potential superior FP from implementation of SSCM practices (SSCMP) and call for further investigation in this regard, especially between social SC practices and firm's environmental, social, and economic performance (Huang, Huang, & Yang, 2017; Kirchoff, Tate, & Mollenkopf, 2016).

As SCs consist of and span many boundaries, policy makers, practitioners, researchers, and other stakeholders need to better understand various SSCMP and their performance implications (Sarkis, 2012), but most of the prior studies only partially investigate these relationships by focusing on subsets of SSCMP and on the environmental and economic dimensions (Gorane & Kant, 2017; Muzaffar, Khurshid, Malik, & Azhar, 2019). Consequently, firm's social performance has received limited consideration (Mani, Gunasekaran, & Delgado, 2018). Likewise, a recent review by Carter and Washispack (2018) found that there is "white space" for examining relationships among specific SSCM constructs. Hence, this finding further strengthens the rationale for our meta-analysis to examine relationships between SSCMP and FP. Meta-analysis is a necessary element of scientific inquiry and theory building that allows reconciling contradictory numerical findings and conceptually comparable (Hunter & Schmidt, 2004). Furthermore, it has been argued that because of the relatively small sample size, a single study does not have enough power to explain the magnitude of a statistical relationship (Lipsey & Wilson, 2001). Thus, a meta-analysis study is the best available tool to make empirical generalizations by synthesizing extant findings for clarifying the ongoing debate whether SSCMP positively contribute to FP.

1.1 | Gap identification and problem statement

While few studies have tried to reconcile and consolidate numerical findings on the SSCMP—FP link, their scope is narrower compared with our study, and thus, their conclusions are limited in several ways. Golicic and Smith (2013) meta-analytically combined results from 31 studies and partially tested the relationship between green supply chain management (GSCM) practices and economic performance. The meta-analysis by Geng, Mansouri, and Aktas (2017) is based on 50 articles from Asian emerging economies and tested the impact of some GSCM on firm's social, economic, operational, and environmental performance. However, none of the above meta-analyses tested the link between social SC practices (Pullman, Maloni, & Carter, 2009; Shafiq, Johnson, Klassen, & Awaysheh, 2017; Wolf, 2014) and FP. Likewise, both previous meta-analyses use fixed-effects meta-analysis and assume that the population effect size is identical for all primary studies. Nevertheless, this is in contradiction with best-practice recommendations for conducting a meta-analysis in organizational sciences (Aguinis, Gottfredson, & Wright, 2011) since the fixed-effect model should rather not be used given that the samples are drawn from different geographical regions, industries, and have been analyzed using different conceptual frameworks.

Previous meta-analyses focus only on environmental and economic perspective and only partially have tested the SSCMP-FP links, by omitting other important practices such as sustainable production, sustainable distribution and packaging, as well as investment recover. Similarly, they do not check for outliers when performing their meta-analyses. Furthermore, either they are focused on a single industry and geographical region or they are drawn on a limited sample. In our study, we tried to bridge these gaps from previous meta-analyses and to improve the methodological rigor, thus we believe that the present study provides a more updated and comprehensive synthesis of SSCMP-FP link. Table 1 shows a comparison between previous meta-analyses and our study and highlights its contribution on SSCM literature.

In sum, in reviewing the literature, we find broad agreement among scholars that SSCMP carry a great theoretical and practical importance (Figure 1), but their consequences in various FP dimensions remain inconclusive and partially ambiguous. Likewise, the literature analysing SSCMP-FP is scattered and fragmented. Moreover, previous meta-analyses focus only on subsets of green supply practices, but a comprehensive and systematic study analyzing social supply practices along with all green supply practices on different firm's performance dimensions is missing. Hence, we seek to find more extensive evidence for such relationships by answering two questions: (a) What is the impact of SSCM practices on firm's environmental, social, operational, and economic performance? (b) Under what conditions SSCMP-FP link is stronger?

Answering these research questions, we apply natural resource-based theory (NRBT) (Hart, 1995) and the relational view (RV) (Dyer & Singh, 1998) to argue that SSCMP adaptation impact the performance and then test our hypotheses by conducting a random-effects meta-analysis of correlation using 145 independent samples composed of 33,886 firms. Additionally, we identify and test several moderators, including firm characteristics and methodological choices on the SSCMP–FP link. Our comprehensive meta-analysis broadens current understanding about the SSCMP–FP link in several ways. First, our study contributes to accomplishing empirical generalization and richer understating of the variables, constructs, and moderators to the SSCMP–FP link. Second, the proposed conceptual framework enables an in-depth examination of SSCMP and FP by operationalizing them in nine and four sub-constructs, respectively. This allowed us to provide greater clarity and nuanced views on whether different types of sustainable supply practices are positively correlated with various FP dimensions. Third, for the first time in SSCM literature, this study synthesizes the contribution of social supply practices to triple bottom line performance dimensions. Fourth, results from moderator analysis show under what conditions SSCMP yield higher sustainability payoffs. Finally, we contribute to resource-based theories in validating whether sustainable supply practices can be seen as a source of superior performance, as well as, detecting areas that require additional research.

Following the introduction, we continue our discussion by reviewing the SSCM literature and present our research framework from which we develop hypotheses and explain potential moderators. Next, we describe the methodology employed to analyze the data and present our findings. Finally, we discuss theoretical and practical implications and note the limitations of our analysis.

2 | THEORY AND HYPOTHESES

To underpin our research and structure the analysis, this section presents a brief literature review regarding independent

TABLE 1 Comparison of previous meta-analyses with the present study

						Theory		Methodology			SSCM Practices					Firm performance				Moderators						
Study	Period	No of papers	Sample size	Region	Sector	NRBV	RV	Model	Duplicates Check	Outlier Check	Other practices	Social supply practices	Sus. Manufact.	Sus. Distribu.	Inv Recovery	Environmental	Social	Operational	Economic	Firm size	Geogra. region	Industry type	ISO Certified	Eco conditions	Self-report	Evolution
Golicic and Smith (2013)	2000–2011	31	15,160	World	All	✓		Fixed	✓		✓							✓	✓	✓	✓	✓		✓		
Geng et al. (2017)	1996–2017	50	25,680	Asia	Manufacturing	Not Specified		Fixed			✓					✓	✓	✓	✓	✓		✓	✓			
Present study	1996–2019	143	33,886	World	All	✓	✓	Random	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note: NRBV, Natural Resource-based view; RV, Relational view; SSCMP, Sustainable supply chain management practices.

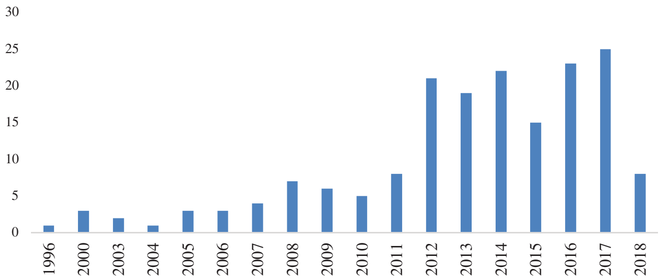

FIGURE 1 Number of empirical studies that test the relationship between sustainable supply chain management practices and firm performance [Colour figure can be viewed at wileyonlinelibrary.com]

variable— SSCMP and the dependent variable— FP as well as provides theoretical lenses that are used to ground the hypothesized relationships.

2.1 | Sustainable supply chain management practices

The reviewed literature shows that sustainable SC practices have generated much debate within the academic literature as well as among industry practitioners (Adebanjo, Teh, & Ahmed, 2016; Qorri, Mujkić, & Kraslawski, 2018) but scholars have used different terminologies to explain such practices (Dai, Cantor, & Montabon, 2017; Kassinis & Soteriou, 2003). For instance, Tachizawa, Gimenez, and Sierra (2015) classified GSCM into monitoring-based and collaboration-based practices, Rao and Holt (2005) operationalized GSCM into three broad constructs including inbound, production and outbound practices, while Eltayeb, Zailani, and Ramayah (2011) and Younis, Sundarakani, and Vel (2016) measured GSCM including eco-design, green purchasing, environmental cooperating with suppliers and customers, and reverse logistics. Similarly, social SC practices have primarily highlighted legislative and health and safety issues rather than cultural and ethical issues (Wang & Dai, 2018). However, as the SSCM literature started to mature, a growing number of researchers studied the link between social supply practices and FP. For example, Das (2017) classified such initiatives into practices for employees and practices for community while other researchers used only one construct that is mainly focused on internal issues such as employee welfare, participation, and training (Hollos, Blome, & Foerstl, 2012; Pullman et al., 2009).

While in the reviewed literature, authors have often GSCM and SSCM constructs interchangeably, in our study, we use only SSCM term for the following reason. By definition SSCM represents all inter-organizational practices for the purpose of improving firm's social, environmental, and economic performance (Carter & Rogers, 2008), whereas, GSCM represents practices that aim to improve firm's environmental, and economic performance (Miroshnychenko, Barontini, & Testa, 2017). Thus, SSCM is a broader construct and includes three sustainability aspects whereas GSCM focuses mainly on environmental and economic dimensions. Accordingly SSCMP are recognized as mechanisms or initiatives for achieving superior environmental, social, operational, and economic performance (Chiou, Chan, Lettice, & Chung, 2011; Kuei, Madu, Chow, & Chen, 2015). Moreover, Lee, Tae Kim, and Choi (2012) highlighted that GSCM practices should be considered from an integrated perspective because firms benefit more when such practices are managed cohesively in cross-functional and cross-company processes. In this context, two different but complementary forms of SSCMP exist within the extant literature: (a) internal practices that span within firm's direct control such as environmental management systems (Feng, Cai, Wang, & Zhang, 2015; Sroufe, 2003), sustainable product design (Khan & Qianli, 2017; Zhu & Sarkis, 2004), social and environmental certifications (González-Benito & González-Benito, 2005), and production processes (Hojnik & Ruzzier, 2016); (b) external practices including sustainable procurement (Carter, Kale, & Grimm, 2000; Woo, Kim, Chung, & Rho, 2016), collaboration with consumers (Rao & Holt, 2005), and sustainable distribution (Vachon & Klassen, 2006).

Given that SSCM practices consist of and span many boundaries (Sarkis, 2012) and have been operationalized using different constructs, we followed one of the most used frameworks developed by Zhu, Sarkis, and Lai (2007). They structure GSCM into five managerial practices including internal environmental management, environmental procurement, environmental product design, environmental customer collaboration, and investment recovery. Additionally, in line with recent recommendations (Das, 2017; Gualandris & Kalchschmidt, 2016), we extended this framework by including other practices such as environmental manufacturing (Jayaram, Vickery, & Droge, 2008), environmental distribution and packaging (Esfahbodi et al., 2017), reverse logistics (Huang, Wu, & Rahman, 2012; Ye, Zhao, Prahinski, & Li, 2013), and social practices (Das, 2017; Hollos et al., 2012). Thus, grounded on extant literature, we conceptualize SSCMP as a holistic and multidimensional construct that is measured using following practices: Internal Sustainable Management, Sustainable Purchasing (cooperation with suppliers is included), Sustainable Product Design, Sustainable Manufacturing, Sustainable Distribution and Packaging, Customer Sustainable Cooperation, Reverse Logistics, Employee Social Practices, and Investment Recovery. Table 2 shows measurement items and several references for each construct. Next, we continue our discussion by presenting the literature of the dependent variable-FP.

TABLE 2 Constructs and measurement items for sustainable supply chain management practices (SSCMP)

Practice	Definition	Items	References
Internal Sustainable Management	Refers to strategies, processes and procedures supporting intra-organizational environmental and social objectives.	• Written sustainability policy statement. • Environmental management system and regulatory compliance. • Top and middle management support and commitment to environmental and social programs. • ISO 9000, ISO 14001, SA8000 and/or ISO 26000 standards. • Cross-functional cooperation for sustainable improvements.	Green, Toms, & Clark, 2015; Kim & Rhee, 2012; Koo, Chung, & Ryoo, 2014; Wu, Melnyk, & Calantone, 2008; Yang, Lu, Haider, & Marlow, 2013
Sustainable Purchasing	Reflects the importance of cooperating with suppliers for the purpose of developing products that are environmentally and socially sustainable.	• Select suppliers who control hazardous substances and have or are obtaining standards such as ISO 14001, OHSAS 18000, ISO 9000, SA8000, and/or ISO 26000. • Environmental and social audit of suppliers' internal management practices. • Cooperation with suppliers for improving environmental and social practices to achieve sustainability goals.	Gimenez & Sierra, 2013; Graham & Potter, 2015; Khaksar, Abbasnejad, Esmaeili, & Tamošaitienė, 2016; Lee, Ooi, Chong, & Lin, 2013; Vijayvargy & Agarwal, 2014
Sustainable Product Design	The design of products with environmental and social objectives and impacts in mind during their entire life-cycle and focus more on recycling and reusing products.	• Design products for reuse, recycle, recovery of material and component parts. • Design products to reduce or eliminate the use of harmful/hazardous/toxic materials. • Design products to store at room temperature and to reduce storage area needed in transportation. • R&D for sustainable product innovation. • Provide design specifications to partners that include environmental and social requirements for purchased items.	Ar, 2012; Grekova, Bremmers, Trienekens, Kemp, & Omta, 2013; Huang & Wu, 2010; Khan, Dong, Zhang, & Khan, 2017; Küçükoğlu & Pınar, 2015; Li, 2014; Van den van den Berg, Labuschagne, & van den Berg, 2013; Wong, Lai, Shang, Lu, & Leung, 2012
Sustainable Production	All activities implemented to minimize environmental impacts in manufacturing processes.	• Use of pollution prevention and energy-efficient technologies. • Remanufacturing, raw material consumption, and waste reduction in equipment and processes. • R&D for sustainable production process innovation.	Aboelmaged, 2018; Sezen & Çankaya, 2013; Zeng, Meng, Yin, Tam, & Sun, 2010; Grekova, Calantone, Bremmers, Trienekens, & Omta, 2016
Sustainable Distribution and Packaging	Any means of transportation from suppliers to manufacturers to final customers with the purpose of having the minimal harmful impacts and packaging usage.	• Cooperate with vendors to standardize and downsize packaging and to use renewable energy in transportation. • Promote and adopt reusable and recycled packaging. • Use of alternative fuel vehicles and collaborative warehouses. • Combine modes of transportation and upgrade freight logistics to minimize negative environmental impacts. • Customer feedback regarding the use of green transportation.	Chung & Tsai, 2007; Kung, Huang, & Cheng, 2012; Petljak, Zulauf, Štulec, Seuring, & Wagner, 2018; Tang, Lai, & Cheng, 2016; Zailani, Jeyaraman, Vengadasan, & Premkumar, 2012
Customer Sustainable Cooperation	Working with customers to better understand sustainability related problems and issues from a downstream point-of-view.	• Cooperation with customers for sustainable purchasing. • Customer cooperation for sustainable design. • Cooperation with customers for cleaner production. • Customer cooperation for green distribution and packaging.	Chandra Shukla, Deshmukh, & Kanda, 2009; Jabbour, Jabbour, Latan, Teixeira, & de Oliveira, 2014; Kirchoff et al., 2016; Laari et al., 2016; Laari et al., 2016b

(Continues)

TABLE 2 (Continued)

Practice	Definition	Items	References
Reverse Logistics	Include activities that aim taking products back or materials from consumers to manufacturers for the purposes of reuse or recycling.	• Retrieve products and materials from the point of consumption for recycling, reusing, and safe disposal. • Waste collectors and remanufacturing policies • Reprocessing of the used products by the company.	Abdul-Rashid, Sakundarini, Raja Ghazilla, & Thurasamy, 2017; Agan, Acar, & Borodin, 2013; Khor, Udin, Ramayah, & Hazen, 2016
Employee Social Practices	Firm's efforts to induce socially responsible behavior in its own operations and the operations of its suppliers.	• Safe working conditions for employees. • Skills development and fair compensation to all employees. • Healthy and positive working environment for employees. • Supporting projects and social commitment to the external community.	Mani et al., 2018; Masa'deh et al., 2017; Pullman et al., 2009; Wolf, 2014
Investment Recovery	Reflects the importance of capturing value through resell and reuse of used materials.	• Sale of excessive capital equipment. • Sales of scrap and used materials. • Sale of excess inventories or materials.	Gorane & Kant, 2017; Ketikidis, Hayes, Lazuras, Gunasekaran, & Koh, 2013

2.2 | Types of firm performance

SSCM literature categorizes FP into four broad types: environmental, social, operational, and economic performance (Chien & Shih, 2007; Dubey, Gunasekaran, & Samar Ali, 2015). The SSCM research further highlights the existence of synergies and trade-offs between performance types but these have only partially been studied (Gimenez, Sierra, & Rodon, 2012). For example, Zhu and Sarkis (2004) considered environmental and economic aspects; Pullman et al. (2009) environmental, quality, and cost performance; De Giovanni (2012), Luzzini, Brandon-Jones, Brandon-Jones, and Spina (2015) and Sreekumar and Rajmohan (2019) considered environmental, social, and economic aspects; while Luthra, Garg, and Haleem (2014) operationalized FP into economic, environmental, social, and operational performance.

Following the guidelines of past research on SSCM (e.g., Christmann, 2000; Das, 2017; Simpson, 2012), we operationalize FP as a combination of environmental, social, economic, and operational dimensions. Additionally, operational performance is considered in our study because operations managers should monitor delivery and quality metrics, alongside specific aspects of environmental and social dimensions (Hollos et al., 2012). Environmental performance measures the reduction of environmental pollutants in air, land, water, and the decrease of harmful or hazardous or toxic materials released to the environment (Roberts & Gehrke, 1996). Social performance is measured using indicators related to improvements in overall stakeholder welfare, community health, and safety of workers (Paulraj et al., 2017; Peng & Lin, 2008). Operational performance includes indicators of product quality, delivery, flexibility, and more efficient resource utilization (Sambasivan, Bah, & Ho, 2013; Zhang & Yang, 2016; Zhu, Sarkis, & Lai, 2012). Economic performance represents indicators related to financial benefits, market share growth, and productivity improvement (Yang, 2018; Zailani, Govindan, Iranmanesh, Shaharudin, & Sia Chong, 2015). Table 3 shows measurement items and references for FP dimensions. Next, we present theoretical underpinnings used in this study.

2.3 | Theoretical foundations

To explain mechanisms that support SSCMP—FP links, researchers have grounded their studies in a variety of organizational theories (please refer to Sarkis, Zhu, and Lai (2011) and Touboulic and Walker (2015) for an overview). While institutional theory, stakeholder theory, and contingency theory are utilized to provide rationale for why firms implement SSCMP, resource-based view (RBV) (Barney, 1991) with the extensions of natural resource-based view (NRBV) and relational view (RV) of the firm are commonly used to underpin SSCMP-FP links in the reviewed literature and thus we develop our hypotheses grounded on these theories.

The RBV postulates that firms can achieve sustained competitive advantage from its owned or controlled strategic resources, which are valuable, rare, inimitable, and non-substitutable (VIRN) resources (Barney, 1991). The NRBV proposes that firms, through proper environmental management strategies such as pollution prevention and product stewardship, can develop capabilities that are valuable, rare and difficult to replicate by competitors (Hart, 1995). Whereas the theories mentioned above argue that discrepancy in FP can be attributed to heterogeneity in resources and capabilities within firm boundaries, the RV of competitive advantage (Dyer & Singh, 1998) posits that combining resources at inter-firm level to develop relationship-specific capabilities, performance gains are possible (Esfahbodi, Zhang, & Watson, 2016; Gualandris & Kalchschmidt, 2016). To sum up, despite their differences, these theoretical perspectives cohesively argue that firms can gain superior performance by leveraging firm-specific and/or relationship-specific resources and capabilities and together address the upstream and downstream as well as partnership aspects of the SSCMP.

SSCMP are considered as capabilities developed from a given set of resources (Esfahbodi et al., 2017; Gilley, Worrell, Davidson, & El-Jelly, 2000; Gimenez et al., 2012; Stefanelli, Jabbour, & Jabbour, 2014). Such capabilities can lead to a superior FP by facilitating the acquisition of strategic resources through increased cooperation and integration of specialized assets, skills, and information across firms (Vachon & Klassen, 2006). For instance, environmental collaboration with suppliers and consumers, as well as sustainable design and manufacturing can bring innovations to reduce waste, material, and energy usage and, in turn, can contribute to FP. Furthermore, Carter and Rogers (2008) argued that intangible resources, such as the learning that occurs between SC partners when they are working together to improve sustainable performance, can be considered as VIRN resources. Accordingly, using these theories, the extant research has debated whether and to what extent various SSCMP have the potential to drive FP in environmental, social, operational, and economic dimensions (Albino, Dangelico, & Pontrandolfo, 2012; Choi & Hwang, 2015; Christmann, 2000; Laari, Solakivi, et al., 2016; Mani et al., 2018; Peng & Lin, 2008; Richey et al., 2005). Subsequently, we present our conceptual model and develop hypotheses.

2.4 | Research framework

Building on the arguments raised in the previous sections, and guided by Das (2017) and Zhu et al. (2007), we develop a research framework by linking SSCMP and FP, to aggregate existing numerical results using meta-analytic procedures. The conceptual model is shown in Figure 2. Dimensions and measurement scales of both independent and dependent variables have been used repeatedly in reviewed literature (Abdullah & Yaakub, 2014; Ann, Zailani, & Wahid, 2006; Chan, He, Chan, & Wang, 2012; Chien & Shih, 2007; Dubey, Gunasekaran, & Chakrabarty, 2015; Lirn, Lin, & Shang, 2014; Simpson, 2012) and are included in our study because they capture all key practices of SSCM and FP and are in line with the SSCM definition provided by Carter and Rogers (2008). This framework allowed us to test SSCMP consequences in firm's environmental, social, operational, and economic performance. In this framework, there are also presented associated hypotheses and potential variables that moderate the focal/overall relationship.

2.5 | Hypotheses development

SSCMP as intra- and inter-organizational practices represent mechanisms that integrate environmental and social concerns along the

TABLE 3 Constructs and measurement items for types of firm performance (FP)

Dimensions	Description	Items	References
Environmental performance	Environmental outcomes represent consequences of SSCM practices on the natural environment inside and outside organizations.	• Reduction of air emission and wastewater • Reduction of solid waste and energy consumption • Reduction of used harmful and toxic materials • Firm's environmental accidents decline and biodiversity protection in the surrounding area.	Dong, Wang, Jin, Qiao, & Shi, 2014; Hung, Chen, & Chung, 2014; Laosirihongthong, Adebanjo, & Choon Tan, 2013; Rodríguez, 2009; Sancha, Wong, & Gimenez Thomsen, 2016; Yang, Hong, & Modi, 2011
Social performance	Social performance represents indicators covering improvements in overall stakeholder welfare, community health and safety of workers.	• Improvement of corporate image • Enhanced employee job satisfaction • Enhanced health and safety of employees • Improvement of awareness and protection of the claims and rights of people in community served	Abdul-Rashid et al., 2017; Amjad, Jamil, & Ehsan, 2017; Chen, Lai, & Wen, 2006; Gopal & Thakkar, 2016; Lai & Wong, 2012; Lim & Biswas, 2019
Operational performance	Operational outcomes measure improvements in operational activities to more efficiently produce and deliver products to customers.	• Reduction in delivery time and improvements in capacity utilization • Reduction in inventory levels and scrap rate • Improvement in the efficiency of inbound and outbound logistics. • Quality improvement of products and services.	Ali, Bentley, Cao, & Habib, 2017; Fraj-Andrés, Martinez-Salinas, & Matute-Vallejo, 2009; Kuei, Chow, Madu, & Wu, 2013; Mitra & Datta, 2014; Perramon, Alonso-Almeida, Llach, & Bagur-Femenías, 2014; Schoenherr, 2012; Yu, Chavez, Feng, & Wiengarten, 2014
Economic performance	Economic outcomes are expected financial benefits resulting from SSCM practices.	• Cost reduction for purchased materials, energy consumption, waste treatment and discharge. • Growth in market share and profitability • Increase on return on investment and sale growth	Cheng, Yang, & Sheu, 2014; Jiang, Hu, Yen, & Tsao, 2018; Li, Jayaraman, Paulraj, & Shang, 2016; Longoni, Luzzini, & Guerci, 2018; Wang & Sarkis, 2013; Wu, Jim Wu, Chen, & Goh, 2014

value chain (Ateş, Bloemhof, Van Raaij, & Wynstra, 2012; Singhal, 2013). Developing and implementing SSCMP require a considerable amount of time, expertise, and investments to be allocated by firms and among SC members. As suggested by RBV, NRBV, and RV theories, being valuable, intangible, and socially complex, the SSCMP can be considered strategic resources that directly improve FP in various dimensions. Building on this rationale, many empirical studies (e.g., Chang, 2011; Chen, Wu, & Wu, 2015; Kuei et al., 2015; Lee, 2016; Luzzini et al., 2015; Severo, de Guimarães, Dorion, & Nodari, 2015; Wang & Dai, 2018) have found that the adoption of internal sustainable practices coupled with sustainable product and process innovation lead to reduction in air emission, solid waste, energy and water consumption, and harmful and toxic materials used. Other authors by investigating the effect of sustainable collaboration with suppliers and consumers argue that such practices can be beneficial because firms create socially complex and unique relationship-specific capabilities (Hajmohammad, Vachon, Klassen, & Gavronski, 2013; Paulraj, 2011). On the contrary, another set of studies (e.g., Abdullah & Yaakub, 2014; Mitra & Datta, 2014; Younis et al., 2016) found insignificant or negative links. Similarly, the findings related to the impact of social SC practices on environmental performance are mixed as some authors report insignificant, negative and significantly positive relationships (e.g., Das, 2017; Pullman et al., 2009; Wolf, 2014). However, based on the tenets of NRBV and RV we postulate that SSCMP (as strategic capabilities) will lead to superior environmental performance because of reductions in consumption of materials, waste and energy, environmental accidents, and excessive inventory.

Hypothesis H1 Sustainable supply chain management practices are positively correlated with firm's environmental performance.

Although most research looking at sustainable supply practices was concentrated on economic and environmental outcomes (Jawaad & Zafar, 2020), recently, the social dimension of sustainability is increasingly being studied but the results are mixed (Paulraj et al., 2017) and less convincing (Mani et al., 2018). The implementation of sustainable design and manufacturing practices can improve social performance employees and the community's quality of life (Gimenez et al., 2012), which in turn, might improve the firm's reputation (Wang & Dai, 2018). This is consistent with the results of Sezen and Çankaya (2013) who analyzed the data from 53 Turkish companies and found that sustainable manufacturing has a positive effect on social and environmental performance. Likewise, the adaptation of social supply practices such as employee safety and supporting projects for the external communities are found to improve firm social reputation and social performance (Gimenez & Sierra, 2013; Wang & Dai, 2018). On the contrary, negative or insignificant relationships between sustainable product design, sustainable distribution, and reverse logistics and social performance are reported by Abdul-Rashid

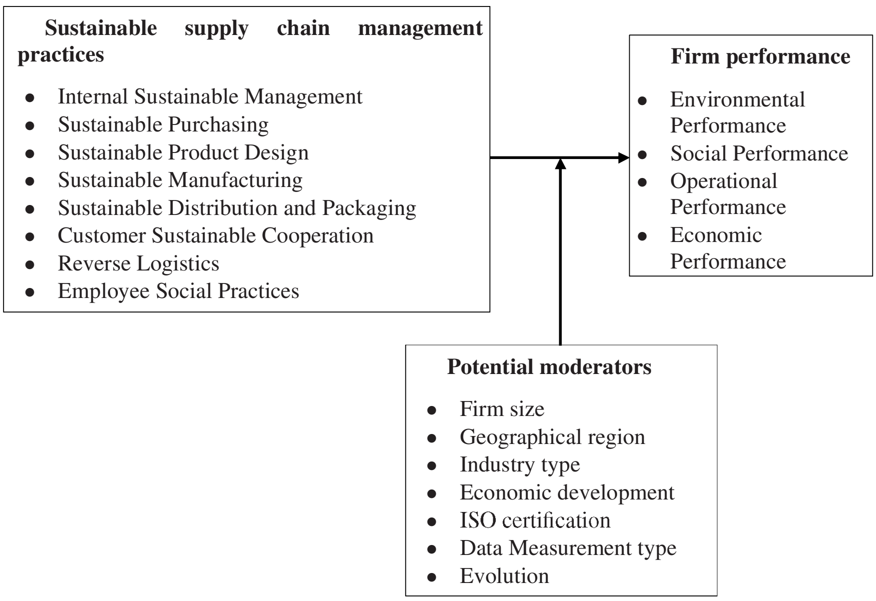

FIGURE 2 Research framework

et al. (2017) and Eltayeb et al. (2011). Similar negative or insignificant links between sustainable supply practices and social performance are reported also in other studies (e.g., De Giovanni, 2012; Luthra et al., 2014; Younis et al., 2016). Thus, among fragmented streams of literature, there is a strong need to meta-analytically synthesize the extant evidence.

The RV theory postulates that performance benefits can be gained not only by resources owned or controlled by the firm but also from inter-firm collaboration. Thus, to improve social sustainability at the SC level, firms should select and collaborate with partners (i.e., suppliers) who possess social standards such as SA 8000 or ISO 26000 or are compliant with the rules of safety and working time limits (Das, 2017). Building on the above arguments, we expect SSCMP to improve firm's social performance because by implementing a safe and healthy work environment, collaborating with SC partners on social and environmental initiatives, and promoting the return of end-of-life recyclable products, firms can reduce waste, improve working conditions and strengthen people's health.

Hypothesis H2 Sustainable supply chain management practices are positively correlated with firm's social performance.

Another dimension of performance that has often been studied in the reviewed literature is operational performance. The operational performance consists of indicators that assess firm's capabilities to optimize production process, improve product quality, flexibility, and delivery speed (Chien & Shih, 2007; Christmann, 2000). Efficiencies gained from SSCMP implementation include reduced material inputs and delivery time, less inventory and improved product quality (Carter & Rogers, 2008; Zhang & Yang, 2016). Furthermore, the adaptation of sustainable design and manufacturing practices may identify inefficiencies in production processes that were not previously recognized and can accelerate product innovation through more careful use of resources and design for recycling (Christmann, 2000; Masa'deh et al., 2017). Likewise, Hollos et al. (2012) and Carter and Rogers (2008) argued that better working conditions (i.e., balanced working hours and fair compensation) should enhance workers' motivation, which in turn may improve product quality, and reduce health and safety costs. However, similar to environmental and social performance, findings between SSCMP and firm's operational performance are mixed. For example, Zhang and Yang (2016) and Hollos et al. (2012) report positive, negative and insignificant correlations while Sroufe (2003) reports only positive ones. Vachon and Klassen (2006) and Carter et al. (2000) found that by implementing sustainable procurement and working together with consumers can improve operational performance by increasing firm flexibility. Zhu et al. (2007) suggested that speed and delivery reliability of products can be increased by implementing SSCMP. Thus, building on the above arguments, we postulate that by decreasing virgin material use, eliminating hazardous product parts as well as collaborating with their SC partners, firms develop unique, valuable, and rare capabilities that eventually will encourage innovation and technological advancement in processes and practices, leading to superior operational performance.

Hypothesis H3 Sustainable supply chain management practices are positively correlated with firm's operational performance.

SSCMP enhance firm's capabilities to fulfill environmental and social expectations but are accompanied by high initial investments and direct operating costs (Schmidt, Foerstl, & Schaltenbrand, 2017; Zhu et al., 2007). In this direction, a stream of research argues that financial benefits from SSCMP are uncertain (Hollos et al., 2012; Kassinis & Soteriou, 2003). In contrast, another stream of literature proposes a positive influence of SSCMP on economic performance (Golicic & Smith, 2013; Longoni et al., 2018; Zhu et al., 2012). However, firms should strive to achieve “win-win” situation between environmental, social, operational, and economic performance to rationalize the investment in sustainable practices (Balasubramanian & Shukla, 2017). Such “win-win” situations are doable because, on the one hand, by implementing sustainable design and manufacturing practices, firms cut costs from reducing resources and improving efficiency (Chan, Yee, Dai, & Lim, 2016; Longoni et al., 2018; Rao & Holt, 2005), on the other hand, by collaborating with their SC partners firms can generate less waste in their production and distribution processes, resulting in reduced costs, greater production efficiency, and increased earnings (Gimenez et al., 2012). Furthermore, the recovery of valuable components during product reconditioning and remanufacturing activities contributes to enhanced environmental and economic performance (Huang et al., 2012; Khor et al., 2016; Kung et al., 2012). In contrast, Green, Zelbst, Meacham, and Bhadauria (2012) found that sustainable collaboration with consumers and investment recovery are positively associated with environmental performance but not with economic performance. Esfahbodi et al. (2017) reported insignificant or negative relationships between sustainable design, investment recovery, and sustainable distribution and economic performance. However, in accordance with NRBV theory, internal sustainable practices, can be considered as sources of competitive advantages (Laari, Solakivi, et al., 2016; Zhu et al., 2007) as firms reap benefits including an improved reputation, increased market penetration, and increased profitability (Youn, Yang, Hong, & Park, 2013). Likewise, based on RV theory, inter-firm practices such as sustainable cooperation with suppliers and consumers lead to creation of tacit knowledge and efficient management routines (Blome, Hollos, & Paulraj, 2014). Thus, we argue that the adaptation of SSCMP could improve production efficiency and reduce the use of resources, reduce production costs, increase market share and profitability, thereby lead to superior economic performance.

Hypothesis H4 Sustainable supply chain management practices are positively correlated with firm's economic performance.

While previous hypotheses test the relationships between SSCMP and firm's environmental, social, operational, and economic performance separately, in line with other meta-analyses (e.g., Geng et al., 2017; Golicic & Smith, 2013), we also analyze the link between SSCMP and overall/aggregated firm performance. In our study, FP is defined as a combination of environmental, social, operational, and economic performance. An aggregated view for performance is important because it allows us to group relevant evidence of SSCMP-FP, which has been operationalized in different constructs by researchers in our sample. As mentioned earlier, the implementation of sustainable supply practices among firms in SC is complex and requires unique capabilities that are costly and difficult to imitate (Hart, 1995; Zhu et al., 2007) and thus eventually they will enable firms to achieve superior performance (Paulraj, 2011). Furthermore, among many other outcomes, by implementing SSCMP firms can improve the corporate image in the eyes of consumers and other stakeholders, resulting in added turnover and profitability (Bag, 2014; Kuei et al., 2013; Zhu & Sarkis, 2004). Thus, building on the above arguments, we suggest the following hypothesis:

Hypothesis H5 Sustainable supply chain management practices are positively correlated with overall firm's sustainability performance.

In addition, to summarize similar results reported in other studies (e.g., Aan, Kuzey, Acar, & Açikgöz, 2016; Chung & Tsai, 2007; Li, 2014; Youn et al., 2013) and to provide richer information along with the focal relationship, we conducted a post-hoc analysis by testing nine other sub-propositions (H5a, H5b,…, H5j) which hypothesize one by one constructs of SSCMP presented in Table 2 with aggregated FP.

2.6 | Moderating variables

In a meta-analysis the researcher can examine theoretically relevant variables that can explain the variability in effect sizes (Hunter & Schmidt, 2004). These contingency variables are coded from the primary studies but should have some theoretical justification for consideration as moderators (Aguinis et al., 2011). Thus, we first provided the rationale behind moderators and then assess the impact of such moderators on SSCMP-FP link, by dividing studies into mutually exclusive subgroups based on the underlying moderator.

In our sample of studies, firm size, industry type, geographical region, and ISO certification have been usually used as control variables, and hence we use them as moderators. Other variables including drivers and barriers, institutional and other stakeholder pressures are not considered as they are not consistently reported in the reviewed studies. This is in line with the recommendation of Lipsey and Wilson (2001) who state that a moderating variable to be considered in a meta-analysis should be reported consistently in primary studies.

Firm size can affect the implementation of sustainable supply practices since large firms have more resource availability, are under intense scrutiny from their stakeholders, and serve to many customers (González-Benito & González-Benito, 2005; Schmidt et al., 2017). Likewise, given that large firms offer more products and services and have complex SC, they can benefit from many efficiencies including a reduction in wastes, effluents, material inputs, and energy consumption as well as through recycling and remanufacturing, production costs will decrease resulting in added turnover and profitability. In contrast, it is argued that small and medium enterprises (SMEs) are in short supply of knowledge, technologies, expertise, financial, and human resources to adopt SSCMP (Huang et al., 2012; Zhu & Sarkis, 2007). Furthermore, due to the scarcity of resources, it is essential for SMEs to develop strategic partnerships with their SC partners for adopting external sustainable supply practices in order to minimize risks and to improve their performance. The literature also suggests that managers are quite aware that the adoption of SSCMP is more than a technical process (Pullman et al., 2009) and complex sustainability strategies (Baumgartner & Ebner, 2010) should be avoided when their firms lack the capabilities to manage them (Hart, 1995). Conversely, operations managers in large firms with greater capabilities adopt more easily SSCMP (González-Benito & González-Benito, 2005). Hence, large firms often find SSCMP adaptation beneficial because they reduce wastes, warehousing costs, minimize defects, and indirectly improve corporate image and profitability following recycling, reusing, refurbishing and reverse logistics programs (Lee et al., 2012). Consequently, we expect that large firms to benefit more than SMEs from SSCMP adoption.

SSCMP may not be equally beneficial to all sectors as some manufacturing sectors are higher polluters and have stricter regulations than others (Christmann, 2000; Fraj-Andrés et al., 2009). For instance, while sustainable packaging is critical in retail and transportation, in the oil industry, it is not relevant. Similarly, regulatory requirements for firms operating in high polluting industries (i.e., mining, heavy manufacturing, oil and gas, chemicals) are much more demanding than in other industries. Given that, firms operating in manufacturing sectors are highly regulated and are under intense stakeholder pressure, they should invest more in sustainable supply practices than firms in service industries (i.e., banking, hospitability, transportation, and retail) (Dai et al., 2017). Hence, we expect higher SSCMP-FP correlation in manufacturing sectors than in service industries.

Firms are exposed to different laws, regulations, and public scrutiny (Schmidt et al., 2017). They should implement diverse sustainable supply practices to operate in developed vs developing economies, institutional settings, geographical regions, and cultural backgrounds. Likewise, Sarkis (2012) and Vanalle, Ganga, Godinho Filho, and Lucato (2017) argued that political and cultural factors are important boundaries that can be used for policymakers, organizations, and managers to understand the relationship between SSCMP and FP better. Therefore, we seek to examine whether country economic development and its geographical region moderates the SSCMP-FP link.

Firms certified with standards such as ISO 14001 or ISO 26000 are more prone to adopt sustainable supply practices (Choi & Hwang, 2015) than companies that are not certified. In this direction, some studies reported higher correlations for firms that possess such standards (Laosirihongthong et al., 2013; Rao & Holt, 2005). Other researchers have further suggested that stakeholders' involvement in a firm's ISO 14001 can become a unique and valuable capability (Miroshnychenko et al., 2017). Likewise, firms reduce environmental and social risks related to their activities by requiring ISO 14001 and ISO 26000 certifications from their suppliers (Agan et al., 2013). Furthermore, the literature suggests that firms with such certifications are more prone to integrate sustainable practices with supply chain partners (Khor et al., 2016). Thus, we expect a stronger SSCMP-FP link for companies that are ISO certified.

In addition to potential moderators that come from firm characteristics, we have identified another potential moderating variable self-report vs archival measures that comes from methodological choice employed in the primary studies. Specifically, it has been highlighted that there might be potential inherent bias when managers provide self-reported metrics (Dixon-Fowler, Slater, Johnson, Ellstrand, & Romi, 2013). In other words, the objectivity of self-reported questionnaires depends on the perception of managers who may report better sustainability performance than it actually is. Thus, we have included this moderator to investigate whether performance differences exist based on the source of the data used in primary studies. Finally, we include the publication year as a moderator in order to examine the evolution of sustainable supply practices adaptation. By including this variable, we aim to clarify the ongoing debate whether SSCMP may increase, decrease, or stabilize performance over time as there are contradictory arguments (Hollos et al., 2012). However, none of the studies in our database explore the evolution of SSCMP using longitudinal data. Thus, we use the publication year of the study as a proxy measure to explore the evolution of SSCMP-FP link.

3 | METHODOLOGY

3.1 | Search for relevant studies

To identify relevant empirical studies, we used several search methods based on the guidelines provided by Aguinis et al. (2011) and Geyskens, Krishnan, Steenkamp, and Cunha (2009). First, we conducted computerized keyword searches in main databases: SCOPUS, ISI Web of Knowledge, EBSCO Business Source Complete, and Google Scholar. The last time that we queried these databases was the end of February 2018. Our search string was:

(Green OR environment OR sustain OR ethic* OR soci*) AND ("supply chain" OR "value chain" OR GSCM OR SSCM OR logistics) AND (practice* OR activit* OR operation* OR initiative*) AND (performance OR outcome OR advantage OR consequence OR benefit) AND (empiric* OR statistic* OR test OR analy* OR survey OR sampl* OR quantitative)*

Second, we examined the reference sections of retrieved studies to collect more articles that are relevant. Finally, the study samples in both prior meta-analyses (Geng et al., 2017; Golicic & Smith, 2013), were searched for any unidentified article.

3.2 | Study selection criteria

After the initial examination of abstracts and having skimmed through the content of each study, we adopted several inclusion criteria. First, studies had to empirically test the relationship between SSMCP and FP. Second, studies had to report correlation coefficients (r) or other statistics (i.e., $p - value$, t, F, β, $\chi 2$) that can be converted to r. Finally, studies had to be written in English and published in peer-reviewed academic sources. Following the above-mentioned criteria, we were able to identify 178 usable studies. The studies' search and selection processes are given in Figure 3.

After dropping studies that do not fulfill criteria for statistical independence and outliers (explained below), the final sample consists of 143 papers. Figure 4 presents the distribution of studies by journal where four or more articles are published, which shows the quality of the data our study is drawn. In Appendix S1, we provide details of articles used in the analysis.

3.3 | Statistical independence

When more than one effect size (e.g., correlation) relevant to a given association is derived from the same sample, the statistical independence of each effect size is violated (Geyskens et al., 2009). We tried to ensure an acceptable level of independence among correlations in our database as follows. On the one hand, using detection heuristics provided by Wood (2008), we dropped 26 studies from our database because they use the same or partially overlapping sample(s) with other studies kept in the database and similar constructs were used in both remaining and dropped studies. Whenever studies used the same sample but operationalized different constructs, which are following our definition of constructs shown in Tables 2 and 3, we recorded the sample only once and extracted relevant data from each study. On the other hand, for a few studies (Esfahbodi et al., 2016; López-Gamero, Molina-Azorín, & Claver-Cortés, 2009) that used multiple independent samples, correlations and all other relevant data were coded for each sample independently. Furthermore, whenever a study reported more than one performance dimension, we average respective correlations to obtain a single value for aggregated FP ensuring statistical independence.

3.4 | Coding procedure

A coding form was developed in a spreadsheet based on the research framework, potential moderators, and coding practices suggested by (Lipsey & Wilson, 2001). Initially, using the coding form, the authors and a research assistant coded a random sample of 15 studies to identify data that should be extracted from primary studies and validate the coding protocol. Following this step, the remaining studies were coded by the first author and a research assistant independently from one other. Besides, the coders compared their codes after a batch of 20 studies to ensure consistency throughout the process. Discrepancies in coded studies and complicated cases were marked and later resolved in a discussion between coders and authors. To ensure that the items of each construct in primary studies belong to respective constructs in our study presented in Tables 2 and 3, 75% of the items should closely match our definition (Hunter & Schmidt, 2004). Using

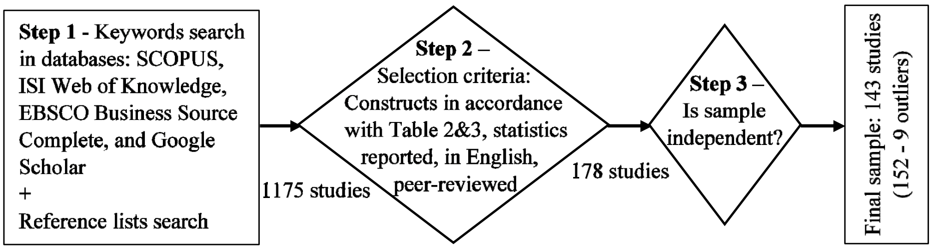

FIGURE 3 Literature search and selection process for studies included in the meta-analysis

FIGURE 4 Distribution of reviewed studies by journal where four or more articles are published [Colour figure can be viewed at wileyonlinelibrary.com]

this rule and the coding protocol, we recorded data from each study for the variables of our interest, including the sample size, reliability estimates, correlations or other statists that can be converted to *r*, and moderators. Specifically, to create mutually exclusive subgroups, the moderating variables are coded as follows. The firm size in each sample is coded as either large enterprises (more than 500 employees) or SMEs. We excluded studies that draw their samples from mixed or unknown firm size. For industry type, each study is coded in one industry (i.e., automotive, electronics, etc.) based on the sample used in the article. Studies that draw their samples from more than one industry settings are excluded from moderator analysis. We also coded the samples as either ISO certified or the ISO not specified, whenever the information about certification is not explicitly stated in the study. Likewise, we coded samples based on the country they were drawn and the source of data (self-reported in surveys vs. obtain archival data from a database) employed by primary studies. Finally, we recorded the publication year to test whether there is a tendency in SSCMP-FP link. This process of coding and discussion between coders yielded inter-coder reliability of 93%. Formulas developed by Hunter and Schmidt (2004, pp. 435–437) for calculating inter-construct correlation are used when item level correlations were reported. Otherwise, we calculated the mean of inter-construct correlations reported (Geyskens et al., 2009). Likewise, reliabilities for these composite correlations were estimated with the Mosier formula (Hunter & Schmidt, 2004). Similar to other meta-analyses, mean reliability reported across all studies was substituted whenever reliability was not reported, or ranges were not provided. If only reliability ranges were given, we recorded the lowest value (usually 0.70).

3.5 | Meta-analytic approach

In this study, we used the meta-analytic procedures by Hedges and Olkin (1985) and recommendations by Aguinis et al. (2011) and Geyskens et al. (2009). For our analysis, we relied on Pearson product–moment correlation coefficient (*r*) as a bivariate linear measure between constructs. Because of variation in population parameters in our research (i.e., firm size, country, industry) and based on suggestions from previous studies (e.g., Aguinis et al., 2011) for organizational research, we used the random-effects meta-analysis. The sequence of calculations conducted in this meta-analysis is outlined in the following steps.

Step 1: We corrected recorded effect sizes for measurement error by dividing the correlation coefficient by the product of the square root of the reliabilities (attenuation factor) of the dependent and independent constructs. This step aims to correct for imperfections of research methods used in the primary studies (Hunter & Schmidt, 2004) and is appropriate in our case because the goal is to understand construct-level relationships (Aguinis et al., 2011).

Step 2: The reliability adjusted correlations were transformed into Fisher's *z*-coefficients in an effort to make them approximately normally distributed (Geyskens et al., 2009). After the calculations are completed, we back-transformed Fisher's *z*-coefficients to *r*.

Step 3: Based on the guidelines provided by Aguinis, Gottfredson, and Joo (2013) and on the method for the detection of outliers developed by Viechtbauer and Cheung (2010), we identified, analyzed and finally dropped 9 studies from our database. After dropping the outliers, the final number of studies included in our database is 143 articles (145 independent samples).

Step 4: We computed corrected mean correlation (*r*) by averaging and weighting *z*-coefficients by their inverse variance.

Step 5: We calculated standard error (*SE*) and 95% confidence interval (*C.I*) for *r*.

Step 6: To examine the existence of moderators, we calculated the *Q* statistic (Lipsey & Wilson, 2001). A significant *Q* is a sign of potential presence of moderators.

Step 7: We performed moderator analysis using analog to analysis of variance (ANOVA) technique (Lipsey & Wilson, 2001). This approach is suitable for categorical moderating variables (Aguinis et al., 2011). For each variable, we split the total sample into subgroups and then separate meta-analyses were conducted. The analysis involved partitioning the *Q* statistic into a within-subgroups homogeneity statistic (Q_w) and a between-subgroup statistic (Q_b)—an index of the variability that tests whether the difference between mean Q_w correlations is zero. A statistically significant Q_b, which has an approximate $\chi 2$ distribution with $p-1$ degrees (*p* is the number of subgroups), suggests that mean correlation across subgroups differs by more than the sampling error or, in other words, the subgrouping variable is indeed a moderator.

Step 8: Finally, we used the following methods to check potential publication bias (Rosenthal, 1979). We estimated the Orwin's (1983) fail-safe number (N_{fs}) of missing studies averaging null results that would be required to reduce the mean effect size to a specified level. As a trivial value for mean correlation in our study, we set the criterion value to 0.05 and calculated N_{fs} for all relationships.

More advanced methods for detecting publication bias including Trim and fill, Rank correlation tests, Regression-based models (e.g., Egger's regression test) were not used because they can produce misleading results in the presence of between study heterogeneity (Peters et al., 2010). However, following in footsteps of Ioannidis and Trikalinos (2007), we also observed the issue of continuing inappropriate use of publication bias tests. As an additional investigation of publication bias, we visually inspected funnel plots for symmetry and examined the forest plot for evidence of drifts of correlations in the cumulative meta-analysis (Borenstein, Hedges, Higgins, & Rothstein, 2009). This process included performing a cumulative meta-analysis with one study, then with two studies, and so on, until all studies have been added. We did not notice any significant shift of the correlation in the forest plot where effect sizes were sorted by precision (i.e., sample size). Thus, in sum, we can claim that publication bias is not a major concern in our study.

4 | RESULTS

The results for hypotheses H1 to H4 are presented in Table 4. First, we tested the associations between SSCMP and firm's environmental, social, operational, and economic performance, and then we tested the relationship between SSCMP and FP. In our database, there are 87 studies that test the link between SSCMP and firm's environmental performance. The results show a positive and significant effect, with a mean correlation of 0.54 ($p < .01$), and thus, we conclude there is support for H1. Likewise, the correlations between SSCMP and firm's social, operational, and economic performance are significant and positive, thereby providing support for H2, H3, and H4. While all the correlations are positive, findings further indicate that firms from adopting SSCMP can expect more significant improvements in terms of environmental and operational performance.

Additionally, the results of individual sustainable supply practices and overall FP are shown in Table 5. The correlations are significant and positive, and thus we conclude that there is support for H5 and for all other sub-hypotheses. While the findings indicate that it pays off to invest in greening and behaving socially responsible in SC, firms would expect higher payoffs in terms of overall FP from implementing internal sustainable management programs coupled with sustainable product design and social practices. These results show that initially firms can implement sustainable practices that fit with their existing capabilities and knowledge. Next, they should leverage their resources and capabilities to identify and develop strategic partnerships with their supply partners. Thus, even firms that lack capabilities or knowledge for developing sustainable strategies can learn and benefit from complementary assets resulting from collaborative practices with suppliers, distributors and consumers, leading to improvements in performance. Following the results of the main associations, this section continues with evaluating whether the mean correlation between SSCMP and FP is affected by potential moderators including firm size, industry type, and country.

4.1 | Moderator analysis

Given that primary studies in our sample examined a diverse range of firms in terms of industry, economic development, geography, data measurement source, ISO-certification, and company size, we will test whether such contingencies affect the strength of SSCMP-FP link. The *Q* statistic (3,274.78; $p < .01$) for the overall relationship is quite large and significant, indicating the existence of moderators. To create mutually exclusive groups for moderator analysis, we had to exclude many samples that are drawn on various firm sizes (n = 97), industries (n = 96), and countries (n = 16). Following this criterion, we then run

TABLE 4 Results between sustainable supply chain management practices (SSCMP) and firm's performance types

Hypotheses				*k*	*N*	*r*	*SE*	95% CI		*Q*	N_{fs}
H1:	SSCMP	→	EnP	87	16,752	0.5393	0.033	0.49	0.58	1,505.93	963
H2:	SSCMP	→	ScP	28	6,900	0.4279	0.059	0.33	0.52	597.08	229
H3:	SSCMP	→	OpP	59	13,104	0.4574	0.047	0.38	0.53	1,557.92	524
H4:	SSCMP	→	EcP	96	22,257	0.4230	0.034	0.37	0.48	2,327.25	771

Note: k, number of independent samples; *N*, total number of firms; *r*, corrected mean correlation; *SE*, standard error; *CI*, confidence interval; *Q*, chi square statistic; N_{fs}, Orwin's fail safe number; *EnP*, Environmental Performance; *ScP*, Social Performance; *OpP*, Operational Performance; *EcP*, Economic Performance. *p*-value <.01.

TABLE 5 Bivariate meta-analytical results between sustainable supply chain management practices (SSCMP) and firm performance

Hypotheses				*k*	*N*	*r*	*SE*	95% CI		*Q*	N_{fs}
H5:	**SSCMP**	→	**FP**	**145**	**33,886**	**0.4571**	**0.027**	**0.42**	**0.50**	**3,274.78**	**1,287**
H5a:	ISM	→	FP	61	14,496	0.4844	0.041	0.42	0.54	1,379.24	585
H5b:	SP	→	FP	76	18,609	0.4587	0.039	0.40	0.52	1941.21	678
H5c:	SD	→	FP	63	11,361	0.5015	0.041	0.44	0.56	1,094.61	632
H5d:	SM	→	FP	47	14,680	0.4231	0.045	0.35	0.49	1,206.20	378
H5e:	SDP	→	FP	17	2,737	0.5096	0.118	0.32	0.66	581.58	175
H5f:	CSC	→	FP	32	5,305	0.4372	0.050	0.35	0.51	395.16	269
H5g:	RL	→	FP	15	3,545	0.2986	0.051	0.20	0.39	109.09	78
H5h:	ESP	→	FP	13	4,282	0.4928	0.106	0.32	0.63	494.40	128
H5j:	IR	→	FP	15	2,384	0.5035	0.078	0.38	0.61	185.64	152

Note: k, number of independent samples; *N*, total number of firms; *r*, corrected mean correlation; *SE*, standard error; *CI*, confidence interval; *Q*, chi square statistic; N_{fs}, Orwin's fail safe number. *ISM*, Internal Sustainable Management; *SP*, Sustainable Purchasing; *SD*, Sustainable Product Design; *SM*, Sustainable Manufacturing; *SDP*, Sustainable Distribution and Packaging; *CSC*, Customer Sustainable Cooperation; *RL*, Reverse Logistics; *ESP*, Employee Social Practices; *IR*, Investment Recovery; *FP*, Firm Performance. *p*-value <.01.

subgroup analysis and results are presented in Table 6. Although, in contrast to our expectation, the findings indicate nonsignificant differences regarding firm size, industry type, country economic development, and ISO certification, there are several important implications which will be highlighted in the discussion section. Next, we examined whether there is a difference between surveying managers (self-reporting) and using secondary (archival) data (i.e., COMPUSTAT, Sustainalytics) for measuring FP. The findings reveal a statistically significant difference (Q_b = 9.54, p < .01), suggesting that managers tend to be biased when reporting performance measures of the firm they work for. The results also show a significant difference regarding the study publication year, and thus we conclude that there is evidence for a positive evolution of SSCMP influence on FP. We further categorized samples based on the specific country and continent because we have argued earlier that, the political, social, cultural, and economic factors play an important role in SSCMP adaptation. The results show that such factors moderate the relationship between SSCMP and FP among various countries and continents significantly. For instance, samples from US show weaker correlations (*r* = 0.29) than samples from Taiwan (*r* = 0.51), China (*r* = 0.46), and India (*r* = 0.47).

It is important to note that we could not perform meta-analytic regression analysis (MARA), as an alternative technique to complement the subgroup analysis, since we did not have enough studies covering all moderating variables. For example, we grouped studies by firm size in SMEs and large firms. However, most samples (97 out of 145) are drawn on mixed firm sizes and hence cannot be assigned a binary value. Consequently, after we excluded these studies, our database consists of 48 samples covering all variables. Likewise, after dropping samples drawn from more than one industry and country from the above database, we are left with a small sample size (*n* = 17). According to Borenstein et al. (2009, p. 188), the use of MARA with multiple covariates, is not a recommended option when the number of studies is small. They further suggest a ratio of ten studies for each covariate (moderator). Hence, due to the restrictions on sample size, we were not able to construct a MARA with at least two moderators. Thus, the only option left to test moderators was by performing subgroup analysis explained above.

5 | DISCUSSION

The aims of this study were twofold: (a) to examine empirical research on the association between SSCMP and firm performance; (b) to explore which factors moderate SSCMP-FP relationship. By

TABLE 6 Results of moderators' effect on the sustainable supply chain management practices (SSCMP) and firm performance (FP) link

	k	r	95% CI		Q_b	Z	p
Company size							
Large	35	0.420	0.34	0.50		8.88	0.000
SMEs	13	0.537	0.41	0.64		7.04	0.000
					2.37		0.124
Single industry							
Automotive	9	0.455	0.31	0.58		5.70	0.000
Construction	4	0.521	0.23	0.72		3.33	0.001
Electronics	16	0.513	0.40	0.61		7.57	0.000
Food	7	0.426	0.27	0.56		5.12	0.000
Shipping and logistics	4	0.371	0.12	0.58		4.93	0.000
Other	9	0.436	0.29	0.56		5.49	0.000
					1.90		0.863
Industry							
Manufacturing	41	0.474	0.40	0.54		11.49	0.000
Services	8	0.463	0.25	0.63		4.07	0.000
					0.01		0.913
ISO Certification							
ISONo	123	0.463	0.42	0.51		16.88	0.000
ISOYes	22	0.443	0.35	0.52		8.70	0.000
					0.18		0.674
Measurement							
Archival data	12	0.221	0.04	0.39		2.41	0.016
Self-report	133	0.481	0.44	0.52		19.80	0.000
					9.54		0.002
Evolution							
1996–2009	26	0.348	0.27	0.42		8.37	0.000
2010–2018	119	0.481	0.43	0.53		17.31	0.000
					9.36		0.002
Economic conditions							
Developed countries	78	0.455	0.40	0.51		14.12	0.000
Developing countries	54	0.493	0.43	0.55		12.69	0.000
					0.80		0.371
Country							
China	20	0.464	0.37	0.55		8.29	0.000
India	12	0.470	0.31	0.60		5.29	0.000
Malaysia	9	0.402	0.30	0.49		7.47	0.000
South Korea	6	0.661	0.49	0.78		6.09	0.000
Spain	7	0.411	0.25	0.55		4.66	0.000
Taiwan	19	0.513	0.42	0.60		9.01	0.000
Turkey	6	0.553	0.41	0.67		6.40	0.000
US	17	0.287	0.18	0.39		5.24	0.000
Other	33	0.512	0.42	0.59		9.35	0.000
					23.85		0.002
Continent							
Africa	2	0.754	0.32	0.93		2.95	0.003
America	23	0.324	0.24	0.41		6.93	0.000

(Continues)

TABLE 6 (Continued)

	k	r	95% CI		Q_b	Z	p
Asia	86	0.494	0.45	0.54		17.25	0.000
Europe	27	0.463	0.38	0.54		9.91	0.000
					14.95		0.002

Note: k, number of samples, *r*, mean corrected correlation, *CI*, confidence interval, Q_b, between group statistic. Indicates samples that are drawn from a single industry or country and are not shown in the respective category but are grouped as *other*.

synthesizing empirical findings, we have provided a more accurate estimation of SSCMP-FP link and have identified important moderators regarding this link. While a few meta-analyses are conducted in the SSCM literature, our study provides clarity and extends further their findings by investigating the relationship between sustainable supply practices and various types of FP, which are not studied in earlier meta-analyses (see Table 1). Specifically, our results show strong and significantly positive relationship between individual SSCMP and FP (see Table 5). In addition to the focal relationship, we tested the impact of SSCMP on firm's environmental, social, operational, and economic dimensions separately (see Table 4). Again, the results show that all associations are strong and significantly positive and thus supporting our hypotheses which are consistent with a stream of previous research (e.g., Choi & Hwang, 2015; Sancha et al., 2016; Wu et al., 2014; Yang et al., 2011). Such results provide further evidence that by adopting sustainable supply practices, firms and their SC partners, enhance their reputation in front of consumers and other stakeholders regarding social concerns, as well as they acquire access to new resources/capabilities, knowledge, experiences, and have more control of and lower risks in their SCs. Accordingly, knowledge and capabilities of SC partners can be leveraged to create unique value in sustainable strategies, which would allow firms to not only differentiate their services/products but also increase their sustainable performance from triple bottom line perspective, thereby generating positive spillover effects (Christmann, 2000; Pullman et al., 2009). In sum, our study provides strong evidence that SSCMP are positively correlated with FP sustainability dimensions and contradicts the view of trade-offs between environmental and social, and economic performance (Adebanjo et al., 2016; Esfahbodi et al., 2016).

5.1 | Theoretical implications

By combining empirical findings that are conceptually comparable (Lipsey & Wilson, 2001), this meta-analysis study makes significant contributions to the SSCM literature. First, leveraging insights from NRBV and RV theories, we were able to determine whether SSCMP should be viewed as a source of competitive advantage. Carter and Rogers (2008) argue that combining existing frameworks into one comprehensive framework helps define the boundaries of the field more rigorously. Our comprehensive research framework grounded on NRBV and RV theories operationalizes SSCMP and FP in nine and four constructs respectively and can serve as a foundation for future research to investigate such associations more consistently. Then yielding results can be grouped and accumulated easier in a future meta-analysis. However, given that social SC practices—as opposed to GSCM practices are relatively newly deployed in many firms and have been less researched (Wichaisri & Sopadang, 2018), we were restricted to synthesize extant research in a single construct. Thus, we believe that our framework can help authors in scoping new research and enable them to focus more on other contingencies that affect SSCMP-FP link.

Second, although prior research on SSCMP-FP dimensions shows mixed evidence (Esfahbodi et al., 2017; Green et al., 2012; Zhu & Sarkis, 2007), the results from our study provide an empirical generalization of positive and significant relationships between SSCMP and FP dimensions. The findings from hypotheses provide strong evidence that SSCMP are important strategic capabilities and are linked with firm's environmental (H1; r = 0.54), social (H2; r = 0.43), operational (H3; r = 0.46), economic (H4; r = 0.42), and aggregated (H5; r = 0.46) performance. These findings support the complementarity of the NRBV and RV theories and show that both intra- and inter-firm practices such as eco-design, sustainable purchasing, and reverse logistics can be considered as bundles of strategic resources that lead to superior performance. On the one hand, firms directly improve their performance, for example, through reduced energy and material usage, waste reduction, and enhanced health and safety of employees. On the other hand, SSCMP improve FP by combining resources and knowledge in collaborative practices across SC (Schmidt et al., 2017).

Third, the positive links between individual SSCMP and FP (*H5a-H5j*) suggest that firms should implement diverse social and environmental supply practices to enhance their performance. Our results are in line with Tachizawa et al. (2015) who stressed that a firm benefits more from SSCMP adoption than the mere reconciliation of environmental practices with stakeholder expectations. Moreover, such findings imply that additional FP is gained when there is joint implementation and collaboration between SC partners. This highlight further the relevance of resource-based theories (NRBV and RV) used in our study by indicating that competitive advantages may emerge also from exploiting resources/capabilities beyond firm boundaries.

Fourth, for the first time in SSCM literature, we meta-analytically synthesized quantitative research on the relationship between social SC practices and FP dimensions. Results suggest that these links are significantly positive for both overall firm performance (*H5h:* r = 0.49) and for individual performance dimensions. This helps to clarify mixed evidence reported in extant research (e.g., Das, 2017; Esfahbodi et al., 2017; Gimenez et al., 2012; Rao & Holt, 2005), and, thus our findings extend and complement recent research related to the SSCMP-FP link and advance the understanding of the importance of social and environmental supply practices. Furthermore, while previous studies focused on subsets of SSCMP and single types of performance such as environmental and economic dimensions, our study simultaneously considers SSCMP from end-to-end perspective and all four types of performance studied in the reviewed literature.

Fifth, a comparison of our results with Golicic and Smith (2013) and Geng et al. (2017) yields mostly similar outcomes but there are some significant differences that need to be highlighted. The correlations between SSCMP and firm's environmental, operational, and financial dimensions are usually stronger than the respective correlations from previous meta-analyses. Perhaps this is because we aggregated results from 145 independent samples, which is 3 to 5 times higher than the total samples of prior meta-analyses. Another element that may contribute to these discrepancies is that we have used random-effect meta-analysis model while they used the fixed-effect meta-analysis.

Sixth, in moderator analysis (see Table 6), we examined potential variables that might affect the focal relationship between SSCMP and FP. Surprisingly, and contrary to our argumentation that large firms and ISO certified companies are expected to gain more benefits, we found nonsignificant differences regarding firm size and ISO certification. Due to the flexible nature and structure of SMEs, it seems that implementation of practices such as sustainable design and manufacturing coupled with improved working conditions for employees pays off more for SMEs than large firms. However, given that the majority of the primary studies utilized various firm sizes operating in more than one industry, such findings should be taken with more caution. The results also show that firms benefit from SSCMP adaptation regardless if they are ISO certified or not. This finding is consistent with Geng et al. (2017). Moreover, because of certifications such as ISO 14001 are costly (Vanalle et al., 2017), firms try to adopt their environmental practices consistent with such certifications without formally acquiring them (Zhu et al., 2012). This might explain the reason behind stronger correlations for firms that are not ISO certified (r = 0.46) versus those that are ISO certified (r = 0.44). Again, given the small number of samples in ISO certified category, this finding should be taken with caution. Next, the results also indicate that the firms in manufacturing industries (i.e., automotive, electronics; r = 0.47) with high rates of scrapping and dumping waste, earn more than firms in service industries (i.e., transportation, retail; r = 0.46) from implementing SSCMP. Although the difference between manufacturing and service industries, is not statistically significant (p = .91), it shows that firms improve significantly their sustainability performance regardless of their industry and is in line with previous studies (Yang, Lin, Chan, & Sheu, 2010; Zailani et al., 2015).

Interestingly, in contrast to our expectation, the findings show that SSCMP lead to better performance in developing (r = 0.49) than in developed countries (r = 0.45). Such results can be explained from the resource-based view perspective. While in industrialized and developed countries, SSCMP are fairly developed and implemented to some degree, they may not be considered (anymore) as a valuable, rare, inimitable, and nonsustainable (VRIN) resources because many firms in the industry likely have adopted such practices, leading to weak competitive advantage (Schoenherr, 2012). In contrast, in emerging and developing economies SSCMP can be viewed as VIRN resources, leading to competitive advantage, because firms may earn benefits of "low hanging fruits" associated with the reduction in materials, energy, emissions, and waste as well as market performance gains from intra- and inter-process inefficiencies (Li et al., 2016; Schmidt et al., 2017). Likewise, firms benefit from social supply practices by enhancing skills, compensation, and quality of life of workers, leading to increased employee retention and productivity (Pullman et al., 2009). Moreover, our results indicate that firm's geographic location, source of performance data used in primary studies, and publication year make a difference in the SSCMP-FP link. Our findings indicate that sustainable supply practices yield greater performance benefits in collectivist Asian cultures (r = 0.49) than in the individualistic Western cultures such as in Europe (r = 0.46) or in America (r = 0.32). One explanation includes differences in cultures and regulatory requirements in individual countries among these regions. In Asian countries, environmental and social regulatory requirements have been implemented later than in European and North American countries. Thus, there is more room for improvement because of adopting SSCMP, which has led to higher performance. We also find that using archival data yields a lower correlation (r = 0.22) than using self-report measures (r = 0.48). As a result, this finding diverges from Dixon-Fowler et al. (2013) and implies that studies drawn on self-reported performance data can be biased compared to studies that use archival data. However, both correlations are significant and positive and thus providing strong empirical evidence that SSCMP are valuable and important sources for improving FP. Our results also help to clarify the debate on whether SSCMP improve performance over time as there is a significant difference in the publication year of the studies. In other words, this indicates that studies published after 2010 show a stronger correlation (r = 0.48) than the correlation (r = 0.35) stemming from the studies published before 2010. Thus, we can conclude that sustainable supply practices strengthen performance over time.

Finally, as we have emphasized earlier, samples used in the meta-analysis must be statistically independent. Wood (2008) developed an algorithm based on detection heuristics (study characteristics) that should be checked to ensure an acceptable level of statistical independence. However, previous meta-analyses (Geng et al., 2017; Golicic & Smith, 2013) violated this criterion and coded duplicate samples as unique by which they artificially increased the sample size. Likewise, when testing the effect of moderators, both prior meta-analyses fail to build mutually exclusive subgroups and did not test at all for statistical differences between such groups. In contrast, we provide a detailed discussion of the methodology applied in conducting this study and we believe that might be helpful to other researchers who may follow it when preparing similar studies.

5.2 | Managerial and policy implications

This meta-analysis can help practitioners and policy makers to understand the importance of sustainable supply practices to improve environmental, social, operational, and economic performance by providing relatively large empirical evidence. First, the positive and significant SSCMP-FP correlations with overall firm performance and with each sub-dimension of sustainability performance, indicate that sustainable supply practices not only improve firm's environmental and social reputation but also increase firm's operational and economic benefits. That includes gains in financial performance, more efficient processes and quality improvement of products/services, and reduced pollution, water and energy consumption, as well as enhanced company image and job satisfaction. Thus, a firm can realize many sustainable development objectives through SSCMP implementation, leading to enhanced value for all stakeholders involved.

Second, individual outcomes of SSCMP-FP links (*H5a-H5j*) can help managers in choosing sustainable practices that fit with their firm's capabilities and knowledge and which would lead to the desired performance. Moreover, such results also suggest that to gain the highest performance from SSCMP adoption, firms should work at least at two levels. Internally, as a strategic imperative to develop companywide sustainable practices and to modify information systems to monitor and process performance outcomes of such practices. Externally, to enhance collaboration and cooperation with supply and demand sides for providing and encouraging consumption of more sustainable products/services. This implies that SC managers must develop various managerial skills, structures, and sustainability practices in intra- and inter-firm levels, to work together with suppliers and consumers for taking advantage of complementarity effects resulting from distributing costs and benefits and the combination of resources and knowledge.

Third, the positive and significant link between social supply practices and performance provides further evidence for practitioners that social practices along with environmental initiatives are important and should be integrated for realizing competitive advantages over their competitors. Accordingly, by offering healthy and safe working environment for employees and more career development opportunities, along with increased good social welfare, firms can not only reduce risks, but they may enhance their sustainable performance and competitiveness.

Finally, regarding SSCMP-FP links under different conditions, our results show that such links are significant and positive regardless of firm characteristics and market condition. Managers should also be informed that firms gain additional benefits from SSCMP adoption when they operate in manufacturing industries vs. service industries, in developing countries vs. developed countries, SMEs vs. large firms, and ISO not certified vs. ISO certified firms. However, such findings should be taken with caution resulting from analyzing small number of studies in several respective categories.

From a policy perspective, this study provides important implications. Our results can help policy makers to identify and prioritize factors for devising and adjusting policies for adopting environmental and social supply practices. On the one hand, governments and regulators should develop mechanisms that control and regulate issues relating to environmental and social sustainability dimensions. On the other hand, governmental bodies should provide financial and technical assistance and invest in appropriate infrastructures that promote and develop social and environmental capabilities and expertise among firms. Thus, governments and local municipalities should have a complimentary approach by requiring firms to be in line with green and social standards and policies and to provide measures such as subsidies or other public grants and tax exemptions for firms that adopt sustainable business practices. Our meta-analytic results show that environmental and social supply practices improve sustainable performance and in turn may lead to economic growth, as well as findings from moderators analysis may help policymakers and managers to deploy resources more appropriately.

5.3 | Limitations and future research

A meta-analysis study has some inherit limitations. First, the quality of the meta-analytic findings depends on data obtained from available studies. To ensure the quality of the data our study is drawn, we decided to restrict our search to peer-reviewed published documents. We believe that this limitation does not weaken the validity of our results as we employed several searching techniques to identify suitable studies (145 independent samples) and found very high fail-safe numbers shown in Tables 4 and 5. Thus, we are confident that the inclusion of additional (existing) studies in the meta-analysis would be unlikely to significantly change our results. Furthermore, our database of samples is significantly larger (3 to 5 times) than the number of studies in previous meta-analyses (Geng et al., 2017; Golicic & Smith, 2013). Second, due to the small sample size for the correlation between SSCMP and firm's social performance, it is evident that additional studies are needed. Third, in several studies reported information is not enough to estimate the Pearson correlation coefficient, which forced us to dismiss the records for a few constructs. Hence, in future empirical SSCMP-FP studies, we encourage authors, at least, to report correlations between latent variables and the reliabilities between constructs. Fourth, given that we aggregated samples from different contexts (i.e., countries, time period) with cross-sectional design, this study does not allow inferring causality from results of meta-analysis. Similarly, Pullman et al. (2009) and Wong et al. (2012) highlighted that defining causality and relationships between sustainable SC practices and performance outcomes is difficult. Thus, a longitudinal study is worth pursuing as it can advance understanding of the causal relationships amongst sustainable supply practices and performance over time. Fifth, findings from moderator analysis on the SSCMP-FP link indicate that additional research is needed to examine other contextual factors. This will help researchers and managers to better understand contingencies that lead to the best performance when adopting SSCMP. Likewise, future studies should address areas that are not sufficiently researched by drawing their samples from specific countries, single industry settings, and archival data. Finally, in a meta-analysis study, the researcher sometimes is required to mix and compare results that look like apples and oranges. Thus, the aggregation across different types of sustainable supply practices and types of performance may be a potential limitation, despite rigorous methodology followed.

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CONFLICT OF INTEREST

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ORCID

Ardian Qorri https://orcid.org/0000-0003-1206-9964

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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Publication IV

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A practical method to measure sustainability performance of supply chains with incomplete information

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A practical method to measure sustainability performance of supply chains with incomplete information

Ardian Qorri[a], Saranda Gashi[a], Andrzej Kraslawski[a]

[a]*School of Engineering Science, Industrial Engineering and Management, Lappeenranta University of Technology, P.O. Box 20, FI-53581 Lappeenranta, Finland*

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Abstract

Measuring and managing supply chain sustainability is essential for achieving sustainable development goals. Existing methods fail to assess all three sustainability aspects across supply chain partners when measuring sustainability performance. Hence, this paper aims to develop a new method that evaluates environmental, social, and economic sustainability aspects across the entire supply chain, from raw material providers to consumers to reverse logistics providers. By combining content analysis, expert's evaluation, fuzzy Shannon's Entropy, and fuzzy TOPSIS, we develop a novel approach to measure the end-to-end supply chain sustainability performance. Utilizing data from six sustainability reports published by large pharmaceutical companies we demonstrate the practicality and ease of application of the proposed solution. Results show that the developed method can be used by managers and policymakers to benchmark supply chains and evaluate the effectiveness of adopted sustainable supply chain initiatives. Additionally, the sensitivity analysis indicates that the results obtained from the proposed method are promising and robust. Researchers and practitioners can use the proposed approach to measure sustainability, increase their value chain transparency, and identify potential environmental and social issues across their supply chains, leading to more informed decision-making about the implementation of sustainability practices across inter-organizational processes.

Keywords: Performance Measurement, Pharmaceutical industry, SSCM, Sustainable Environmental Performance, Fuzzy TOPSIS, Fuzzy Entropy

1. Introduction

Supply chains (SCs) are the backbone of each company. Improving sustainability management and transparency of interdependent activities and processes throughout a value chain is difficult and often impossible without a successful adoption of a performance measurement system at SC level (Beske-Janssen et al., 2015). Consequently, many large and small companies (e.g., Apple, BMW, Xerox) have started to integrate sustainability practices throughout their SCs (Li et al., 2019) and to report their sustainability performance (Papoutsi and Sodhi, 2020). Understanding how to turn a SC into sustainable ecosystems requires a holistic approach where each member firm should set environmental, social, and economic goals (Rao and Holt, 2005) and adopt appropriate green/sustainable supply chain management (GSCM/SSCM) practices to attain such goals (Linton et al., 2007). Despite investment, SSCM practices demand cooperation and involvement of many stakeholders including suppliers, manufacturers, distributors, and consumers to reduce environmental impacts (Zhu and Sarkis, 2007) and to act socially responsible throughout the lifecycle of a product or a service (Mani et al., 2016).

Besides, helping companies to cope with increasing pressure from the community and governments for reducing or eliminating negative environmental (e.g., waste, GHG emissions) and social (e.g., poor working conditions) impacts (Esfahbodi et al., 2017) through their production processes and value chain activities, SSCM practices can potentially create new revenue streams (Qorri et al., 2021; Tajbakhsh and Hassini, 2015). However, due to the lack of comprehensive performance measurement methods and frameworks that evaluate sustainability of SCs (Qorri et al., 2018; Schöggl et al., 2016), the potential of SSCM practices cannot be fully understood and utilized (Ahi and Searcy, 2015; Hassini et al., 2012).

Measuring performance across firms is complex for many reasons including non-standardized metrics (Ahi and Searcy, 2015), cultural and geographical differences, poor understanding of measures (Hervani et al., 2005), and lack of cooperation and data sharing across SC firms (Qorri et al., 2018). Likewise, the complexity of sustainability performance measurement is increased by numerous tiers within a SC (Sloan, 2010). While overcoming these barriers is not a trivial issue, the firm's sustainability performance and competitiveness might rely on the successful implementation of the performance measurement system that evaluates all three sustainability aspects (Hervani et al., 2005). Moreover, performance measurement enables managers and policymakers to evaluate and trace the sustainability of products and companies (Schöggl et al., 2016) and is crucial for both internal control and external reporting (Piotrowicz and Cuthbertson, 2015).

The importance of sustainability assessment spans beyond academia as several initiatives are proposed and implemented by international organizations (e.g., United Nations, Dow Jones Sustainability Indices) (Allen, Cameron and Clouth, 2012; Tajbakhsh and Hassini, 2015). However, despite numerous contributions (Ahi and Searcy, 2015; Govindan et al., 2013; Hervani et al., 2005; Piotrowicz and Cuthbertson, 2015; Tajbakhsh and Hassini, 2015), the literature on measuring sustainability performance of SCs is fragmented and incomplete (Qorri et al., 2018). Most of the research is focused on assessing performance of individual firms or between suppliers and manufacturers (Yakovleva et al., 2012) and the evaluation is mainly focused on environmental performance (Hassini et al., 2012). Furthermore, the performance measurement frameworks that evaluate environmental, social, and economic dimensions across each SC member are not well-developed (Beske-Janssen et al., 2015; Qorri et al., 2018). Thus, there is a significant need to develop a method to assess sustainability on three dimensions across all SC partners. To bridge this gap, this study aims to develop a novel method that helps to assess the SC sustainability performance based on all three sustainability dimensions across each member of the value chain.

The contribution of this study in SSCM literature and practice is as follows. *First*, by combining methods such as content analysis, expert's evaluation, fuzzy Entropy, and fuzzy TOPSIS, we develop a novel and practical approach to measuring SC sustainability performance. The proposed method helps in integrating sustainability practices into operational and strategic levels and enables tracking their performance across SC partners. *Second*, given the enormous impact of pharmaceutical industry on people's lives (Milanesi et al., 2020), and responding to the call for development of a holistic framework for assessing performance across the pharmaceutical SC (Chaturvedi et al., 2017; Ding, 2018; Singh et al., 2016), we applied the proposed approach based on data collected from pharmaceutical companies. *Third*, utilizing the proposed method, practitioners can benchmark and gain more granular understating for their overall SC sustainability performance and for each SC tier. This allows managers to focus their attention on developing strategic plans and implementing initiatives for improving SC sustainability. *Finally*, because we use SSCM practices as performance criteria, we believe that the proposed method can be easily applied in other industries and contexts.

Following the introduction, we review the SSCM literature in pharmaceutical sector and identify relevant sustainability practices. Next, we describe the research methodology, starting with sample selection, data collection and a step-by-step explanation of methods used, followed by a presentation of the findings. Finally, we discuss implications of our results and note the limitations of our analysis as well as provide recommendations for future research.

2. Literature Review

In this section, the research relating to sustainability performance measurement and SSCM practices in pharmaceutical industry are reviewed and discussed. Sustainability reporting practices are also discussed at the end of this section.

2.1. Measuring supply chain sustainability performance

Measuring SC sustainability performance is necessary to manage and guide sustainability improvements across partnering firms as it provides useful information for decision-making at strategic, tactical, and operational levels (Hervani et al., 2005). Given that sustainability performance measurement should assess social, environmental, and economic dimensions across all partners in a SC, it becomes a challenging and inherently complex process (Sloan, 2010).

Sustainability performance is complex, nonlinear, integrated, and difficult to be assessed (Pavláková Dočekalová et al., 2017). Consequently, a sustainability measuring system should be apt to use and process multidimensional, partial, subjective, and vague data in an integrated manner (Ahi and Searcy, 2015). Likewise, sustainability performance is assessed by both qualitative and quantitative criteria (Govindan et al., 2013), and SC performance is evaluated using both tangible and intangible performance measures (Chan et al., 2003) as well as striving to improve socio-economic benefits while reducing negative environmental impacts, often results in conflicting criteria/objectives in decision making (Erol et al., 2011). Thus, measuring SC sustainability performance is a multi-criteria decision making (MCDM) problem (Diaz-Balteiro et al., 2017) and fuzzy logic is a suitable approach for integrating uncertainty, intangibility and vagueness (Kannan et al., 2014; Uygun and Dede, 2016).

In a recent review, Qorri et al. (2018) found that the application of MCDM techniques for measuring SC sustainability performance is increasing and argued that to increase the accuracy of the assessment, such methods should be combined with fuzzy logic. Other reasons that justify the use of fuzzy logic in sustainability assessment include (1) multifaceted nature of sustainability, (2) partial or vague quantitative data, (3) for many (social) criteria only linguistic description is available (qualitative data), and (4) sustainability assessment often involves consulting experts with varying experience across many fields whose opinions cannot be modeled using traditional mathematics of crisp numbers. (Pavláková Dočekalová et al., 2017; Phillis et al., 2010). More info about fuzzy logic is provided in the section of Preliminaries.

In SSCM literature, several performance management systems have been proposed (for a review see Qorri et al. (2018), Schöggl et al. (2016), and Beske-Janssen et al. (2015)) to help in addressing the complexity of evaluating sustainability performance. For example, a social lifecycle assessment framework for wine industry is proposed by Arcese et al. (2017), whereas a modified Balanced Scorecard is suggested by Shafiee et al. (2014). Tajbakhsh and Hassini (2015) developed a method based on Data Envelopment Analysis. While several studies proposed conceptual frameworks (Hassini et al., 2012; Hervani et al., 2005; Qorri et al., 2018; Sloan, 2010), only few papers used MCDM techniques and fuzzy set theory (Agrawal et al., 2016; Erol et al., 2011; Uygun and Dede, 2016) to develop models for measuring sustainability. However, most of the proposed approaches assess sustainability performance solely among suppliers and manufacturers, omitting other SC members such as distributors, consumers, and reverse logistics providers (Qorri et al., 2018). Likewise, except conceptual frameworks, other proposed approaches are developed by focusing solely on aggregating metrics or measures and not on inter-organizational practices (e.g., supplier selection, eco-design) and interdependent and collaborative processes. But previous research has shown that standardized sustainability metrics are missing (Ahi and Searcy, 2015) and in many companies such metrics are kept disaggregated, leading to useless results (Wicher et al., 2019). Furthermore, most of the existing sustainability assessment frameworks lack to consider social sustainability (Hassini et al., 2012) and fail to "talk to each other" (Büyüközkan and Karabulut, 2018), resulting in sparse application of the proposed methods (Qorri et al., 2018).

However, among proposed analytical sustainability assessment approaches, in terms of usefulness and practicality, the most promising solution seems to be the one that combines MCDM techniques with fuzzy logic. To our knowledge, only three studies attempted to build an overall SC sustainability assessment framework based on this solution. Erol et al. (2011) proposed a framework for retail industry that follows the logic of composite indicators based on fuzzy entropy and fuzzy multi-attribute utility. A simple fuzzy rule-based system to evaluate performance of a closed-looped SC is developed by Olugu and Wong (2012). Combining fuzzy ANP and fuzzy TOPSIS, Uygun and Dede (2016) proposed a framework for evaluating GSCM performance. While these studies present important contributions in developing an overall sustainability measurement system, their applicability and comprehensiveness is limited because they are developed based on either limited number of metrics, which are not standardized among firms and industries (Ahi and Searcy, 2015; Qorri et al., 2018) or are not designed for scalability and flexibility as well as fail to consider multi-dimensional aspects of sustainability. In GSCM/SSCM literature, there are other studies (e.g., Govindan et al., 2013; Kannan et al., 2014) that combine MCDM techniques and fuzzy logic but their scope is much narrower (e.g., supplier selection) compared with our study, and thus will not be reviewed.

In line with the recommendations of many authors in the SSCM literature (Hassini et al., 2012; Hervani et al., 2005; Linton et al., 2007; Qorri et al., 2018; Tajbakhsh and Hassini, 2015), we conceptualize the SC sustainability performance measurement as a system that integrates the performance of each individual partnering firm of the chain. Therefore, to overcome the above limitations, we aim to develop a usable and practical method for measuring sustainability of SCs based on SSCM practices, by integrating all partners and sustainability dimensions in the assessment process. Since our proposal for measuring sustainability performance utilizes SSCM practices as criteria, they are discussed subsequently.

2.2. Sustainable supply chain management practices

To explain better GSCM or SSCM practices discussed in extant literature, we initially present the most prominent definitions. Srivastava (2007) defined GSCM as "*integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life*". Based on a comparative analysis of 22 definitions for GSCM and 12 definitions for SSCM, Ahi and Searcy (2013) defined SSCM as: "*The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, in- formation, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term.*" Further clarity was added by Mani et al. (2016) who defined social sustainability practices as "*the way companies interact with the people spanning across all three tiers of the supply chain, in terms of addressing their safety, health, hygiene, wages, labor rights, etc., leading to the sustainability of the firm*". Therefore, based on these definitions it is evident that sustainable supply practices and initiatives consist of and span across many firms and business functions, from suppliers to manufacturers to reverse logistic providers, resulting in diverse initiatives that should integrate environmental, social, and economic dimensions throughout value chain to meet stakeholder requirements over the short- and long-term.

Many authors highlighted the importance of SSCM in achieving sustainable development goals described by the United Nations (Eltayeb et al., 2011; Tachizawa et al., 2015; Vanalle et al., 2017; Zhu and Sarkis, 2004), but a holistic framework for categorizing SSCM practices does not exist (Laosirihongthong et al., 2013). Constructing a general and comprehensive framework is difficult because SSCM practices are diverse and have a wide area of application across various industries and firm sizes (Qorri et al., 2021). However, most authors used the framework proposed by Zhu and Sarkis (2007), who categorized SSCM practices into Internal Environmental Management, Eco Design, Cooperation with Customers, Green Purchasing, and Investment Recovery. Moreover, following recent suggestions, we complement this framework with other practices including Sustainable Manufacturing (Abdul-Rashid et al., 2017), Sustainable Distribution and Packaging (Esfahbodi et al., 2017), Reverse Logistics (Sroufe, 2003), Socially Inclusive Practices for Community, and Socially Inclusive Practices for Employees (Das, 2017). Thus, grounded on extant literature, we propose to categorize SSCM into ten practices as shown in Table 1. This categorization can be considered comprehensive as it includes other frameworks which have divided SSCM initiatives into internal (inbound) and external (outbound) practices (De Giovanni, 2012; Rao and Holt, 2005), or monitoring-based and collaboration-based practices (Tachizawa et al., 2015). Furthermore, such categorization is also supported by a recent comprehensive meta-analysis (Qorri et al., 2021), which found that SSCM practices are positively correlated with firm's performance regardless of firm size and industry type, as well as firms profit more when such environmental and social supply practices are integrated and managed cohesively with internal functions and inter-organizational processes. In the following section, we discuss SSCM practices adopted by pharmaceutical companies.

2.3. Sustainable pharmaceutical supply chain practices

The pharmaceutical sector is highly regulated and complex with many processes, interactions, stakeholders, and companies involved in the discovery, development, production, distribution and marketing of drugs (Halabi and Gostin, 2015; Viegas et al., 2019). Although pharma SC is fragmented and complex, Singh et al. (2016) showed that SSCM practices are strategic issues in the pharmaceutical industry and emphasized that for improving overall performance, pharma companies need to integrate their resources and processes with performance measures from social, environmental, and economic aspects.

Before starting the production of pharmaceuticals, manufacturers should buy their raw material ingredients and other material inputs from suppliers that comply with environmental and social standards (Xie and Breen, 2012). To select sustainable suppliers in the pharma industry, a few solutions are proposed. For example, Low et al. (2016) recommended utilizing analytic hierarchy process (AHP) and Roschangar et al. (2017) proposed a simple "Green Scorecard" based on ISO1400 standard. These methods are limited as either depend on subjective weights or do not consider enough metrics to measure all three sustainability dimensions.

Although the focus in the design stage of pharmaceuticals is on safety and quality, drugs can still be designed to be more sustainable (Ding, 2018). For example, by substituting toxic and hazardous chemicals, reducing or eliminating harmful ingredients, and employing green chemistry principles to promote substitutions and the inclusion of lifecycle analysis in the research and development process of medicines (Koenig and Dillon, 2017; Xie and Breen, 2012). A framework that incorporates environmental criteria into the design of a pharmaceutical SC network is proposed by Low et al. (2016) but lacks practical application.

The manufacturing of pharmaceutical products requires water, energy, active pharmaceutical ingredients, and other inputs, which also generates waste and pollution in different forms (Li and Hamblin, 2016). As such, emerging Industry 4.0 technologies can be used for cleaner pharmaceutical production and to upgrade batch-based mass manufacturing with sustainable, efficient, smart, patient-centered and continuous production (Ding, 2018). Furthermore, other technologies and initiatives aiming to improve eco-efficiency and reduction of input resources are essential to be implemented by manufacturers for improving their environmental footprint (Gernaey et al., 2012).

After pharmaceuticals are manufactured, they should be packaged, distributed to hospitals or retailers (e.g., pharmacies) via forward flow, whereas returned and recalled medicines should be collected via reverse flows. In this context, packaging should be designed and produced in close collaboration with all parties involved, from logistic providers to patients, to convey the details of the product (medicine) in an appealing way, and to protect the product as well as to be easily handled in the transportation (Kumar et al., 2008). Besides, packaging materials should be recyclable, lightweight, reusable (Meherishi et al., 2019), and package sizes and shapes should encourage patients to use the drug completely, reducing waste generation and facilitating reverse logistics (Ding, 2018; Xie and Breen, 2014).

Packaged pharmaceuticals are distributed via a complicated network of logistics. Possible approaches to minimize harmful impacts and emissions in distribution include a combination of modes of transportation that use alternative fuels, more energy efficient warehouses and better optimization of their locations, as well as utilizing emerging technologies in inventory control and storage (Esfahbodi et al., 2017). Using interpretive structural modelling Gardas et al. (2019) identified several environmental and social criteria for the selection of third-party logistics service providers in the pharmaceutical industry.

The need and importance of coordination and collaboration in pharmaceutical SC among suppliers, producers, distributors, consumers, and other stakeholders to improve sustainability performance is discussed by Nematollahi et al. (2018) and Veleva et al. (2018). Regarding social sustainability, the drug availability, quality, accessibility, and community involvement and development are considered as main social responsibilities in the pharmaceutical SC (Nematollahi et al., 2018; Zahiri et al., 2017). Apart from social practices focused on community, pharmaceutical companies should provide good working conditions, respect human and labor rights, as well as offer a healthy and safe workplace to their workers (Milanesi et al., 2020).

For more information about the evolution and adoption of sustainable procurement, design, manufacturing, and distribution practices in the pharmaceutical industry see two recent reviews (Chaturvedi et al., 2017; Ding, 2018). A more general review of sustainability aspects including social practices in the pharmaceutical industry is done by Milanesi et al. (2020). While sustainable packaging practices are reviewed by Meherishi et al. (2019), reverse flows including investment recovery practices were reviewed by Viegas et al., (2019). Additionally, Xie and Breen (2012) proposed a green pharmaceutical SC that can prevent pharmaceutical waste. In line with the literature discussed above, we adopted the SSCM practices for the pharmaceutical industry as shown in Table 1.

2.4. Sustainability reporting in supply chain research

Among several reporting guidelines proposed by numerous agencies, the Global Reporting Initiative (GRI) is the most used across all industrial sectors (Chaturvedi et al., 2017; Papoutsi and

Sodhi, 2020). Following GRI guidelines, companies are increasingly disclosing sustainability performance of their initiatives undertaken to minimize impacts on the environment and society (Aras et al., 2018). As such, the sustainability report is becoming a common and credible mean of communication to stakeholders (Azim and Azam, 2013). Although, usually sustainability reports are not audited like annual reports, Papoutsi and Sodhi (2020) concluded that sustainability reports indicate actual sustainability performance of companies. Their finding is derived from analyzing 331 sustainability reports across many industries and geographical regions.

Managing, measuring, and reporting SC sustainability practices assist companies to add business value to their processes (Qorri et al., 2018). By reviewing 11 corporate sustainability reports in the pharmaceutical sector, Schneider et al. (2010) found that pharma companies are increasingly implementing more programs to improve their sustainability performance. Such programs include initiatives for climate change, air emissions, water, waste, product stewardship, wastewater, supplier management, and labor practices. Likewise, Min et al. (2017) found that pharmaceutical companies are increasingly reporting on environmental, social, and economic aspects. The authors also conclude that corporate sustainability reporting should be viewed as a long-term investment because it improves reputation and profitability as well as helps in stakeholder management by creating positive relationships.

Table 1. Description and measurement items of sustainable supply chain management (SSCM) practices (*Modified from* Qorri et al. (2021)).

Practice	Description	Exemplary items	References
Internal Sustainable Management (C1)	Refers to strategies, processes and procedures supporting intra-organizational environmental and social objectives.	• Written sustainability policy promoting transparency and ethics • Environmental management system adopted, ISO 9000, ISO 14001, SA8000 and/or ISO 26000 standards, and regulatory compliance. • Top and middle management support and commitment to environmental and social programs. • Cross-functional cooperation for sustainable improvements.	(Abdul-Rashid et al., 2017; Eltayeb et al., 2011; Milanesi et al., 2020; Vanalle et al., 2017; Zhu and Sarkis, 2007)
Sustainable Purchasing (C2)	Reflects the importance of cooperating with suppliers for the purpose of developing products that are environmentally and socially sustainable.	• Select suppliers who control hazardous substances and have or are obtaining standards such as ISO 14001, OHSAS 18000, ISO 9000, SA8000, and/or ISO 26000. • Environmental and social audit of suppliers' internal management practices. • Cooperation with suppliers for improving environmental and social practices to achieve sustainability goals.	(Govindan et al., 2013; Kannan et al., 2014; Mujkic et al., 2019; Tachizawa et al., 2015; Vanalle et al., 2017)
Sustainable Product Design (C3)	The design of products/drugs with environmental and social objectives and impacts in mind during their entire lifecycle.	• Design products for reuse, recycle, recovery of material and component parts. • Design products to reduce or eliminate the use of harmful/hazardous and toxic materials. • Design products/drugs to store at room temperature and to reduce storage area needed in transportation. • R&D of products following green chemistry principles. • Provide design specifications to partners that include environmental and social requirements for purchased items.	(Abdul-Rashid et al., 2017; Chaturvedi et al., 2017; Ding, 2018; Eltayeb et al., 2011; Esfahbodi et al., 2017; Zhu and Sarkis, 2007, 2004)
Sustainable Production (C4)	All activities implemented that require less energy and resource use and minimize environmental impacts in manufacturing processes.	• Use of pollution prevention and energy-efficient technologies • Use of Industry 4.0 manufacturing technologies and practices that reduce raw material consumption, land, water, pollution, waste, and effluents • R&D for sustainable and continuous production innovation.	(Abdul-Rashid et al., 2017; Esfahbodi et al., 2017; Li and Hamblin, 2016)

Sustainable Packaging and Distribution (C5)	Any means of transportation from suppliers to manufacturers to final customers with the purpose of having the minimal harmful impacts and packaging usage.	• Cooperate with vendors to standardize and downsize packaging and to use renewable energy in transportation. • Promote ecological materials and adopt reusable and recycled packaging. • Use of alternative fuel vehicles and collaborative warehouses. • Combine modes of transportation and upgrade freight logistics to minimize negative environmental impacts. • Customer feedback regarding the use of green transportation.	(Çankaya and Sezen, 2019; Eltayeb et al., 2011; Gardas et al., 2019; Meherishi et al., 2019; Nematollahi et al., 2018)
Customer Sustainable Cooperation (C6)	Working with customers (wholesalers, pharmacies, and patients) to better understand and integrate their sustainability perspectives and assuring high-quality medicines.	• Cooperation with customers for sustainable purchasing. • Customer cooperation for sustainable design and production • Customer cooperation for green distribution and packaging. • Customer cooperation for reverse logistics. • Cooperation with customers for improving quality of products	(Çankaya and Sezen, 2019; Esfahbodi et al., 2017; Zahiri et al., 2017; Zhu and Sarkis, 2007)
Reverse Logistics (C7)	Include activities that aim at taking products back or materials from consumers to manufacturers for the purposes of reuse or recycling.	• Retrieve returned and recalled drugs and materials for recycling, reusing, and safe disposal. • Waste management policies and waste collectors • Reprocessing of the used products by the company.	(Eltayeb et al., 2011; Rao and Holt, 2005; Sroufe, 2003; Viegas et al., 2019)
Investment Recovery (C8)	Reflects the importance of capturing value through resell and reuse of used materials.	• Sale of excessive capital equipment. • Sale of scrap and used materials • Sale of excessive inventories or materials	(De Giovanni, 2012; Viegas et al., 2019; Zhu and Sarkis, 2004)
Social Practices for Employees (C9)	Firm's efforts to induce socially responsible behavior in its own operations and the operations of its partners.	• Respect human rights and create non-discrimination workplace • Provide training, education, and fair compensation for all workers • Embrace gender equality, justice, and diversity inclusion • Provide safe and healthy working conditions	(Aras et al., 2018; Chaturvedi et al., 2017; Das, 2017; Mani et al., 2016; Milanesi et al., 2020)
Social practices for community (C10)	Firm's investments in surrounding community in terms of generation of employment and business opportunities, providing education, training, healthcare facilities etc.	• Supporting projects facilitating local communities' development • In compliance with anti-corruption and anti-bribery laws • Enhancement of well-being and rights of people in community • Expanding affordability and accessibility of drugs • Improving safety and quality of medicines produced and served	(Das, 2017; Mani et al., 2016; Milanesi et al., 2020; Viegas et al., 2019; Xie and Breen, 2012)

Utilizing data from sustainability reports, several studies have analyzed sustainability practices, metrics, trends, and performance outcomes. For example, utilizing data collected from 12 sustainability reports, Aras et al. (2018) proposed a sustainability performance evaluation model for Turkish banks. Environmental indicators reported by pharmaceutical companies are reviewed by Veleva et al. (2003). In their study, Demir and Min (2019) showed that sustainability reporting in the pharmaceutical sector outperforms other industries, but certain discrepancies exist among companies in the content of their disclosures.

Since sustainability assessment is complex, and this study aims to develop a new method which considers qualitative, quantitative, and partial data for each SC partner, we employ fuzzy logic concepts, which will be discussed subsequently.

3. Preliminaries

In the SC context, decision-making is a complex process due to imprecise data, incomplete information and uncertainties of human thinking and reasoning (Kumar et al., 2019). The natural language used by experts to express judgments and perceptions is uncertain, subjective, vague, or all three (Govindan et al., 2013). To deal with the subjectivity and vagueness of human judgment, Zadeh (1965) proposed fuzzy set theory. Decision-makers or experts express their preferences in the fuzzy set theory using linguistic terms. An expert using linguistic terms such as high, medium, low etc., can provide evaluation for different problems (e.g., sunny weather). Likewise, in many other situations, crisp numbers are insufficient to model real world systems as for example in supplier selection problem where performance weights cannot be assigned precisely (Kannan et al., 2014). Thus, there is a need to apply fuzzy set theory concepts to solve such problems. In our study, a triangular fuzzy number is used as membership function, because it captures the vagueness of the linguistic assessments, it is intuitively easy for the decision makers to use and calculate (Erol et al., 2011) as well as it is very commonly used in practical applications. In the following we present some definitions of fuzzy numbers (dos Santos et al., 2019; Govindan et al., 2013; Kannan et al., 2014; Şengül et al., 2015) used in our study.

Definition 1. A fuzzy set is defined as a set of ordered pairs (X, f) where X is a nonempty set and $f: X \to [0,1]$ is a membership function. The X is called universe of discourse and for each element x in X, the value $f(x)$ is called the grade/degree membership of x in (X, f). The function $f = \mu_{\tilde{A}}(x)$ is called the membership function of the fuzzy set $\tilde{A} = (X, \mu_{\tilde{A}}(x) | x \in X)$.

Definition 2. The $\alpha -$ cut ($\alpha -$ level set) of a fuzzy number $\tilde{a}$ is defined as

$$\tilde{a}^{\alpha} = \{x \in X \mid \mu_{\tilde{a}}(x) \geq \alpha\}, \text{where } \alpha \in [0,1] \quad (1)$$

Definition 3. A triangular fuzzy number can be represented by a triplet $\tilde{a} = (a_1, a_2, a_3)$ where $a_1, a_2,$ and a_3 are real numbers and $a_1 \leq a_2 \leq a_3$ as illustrated in Figure 1. The degree of membership function $\mu_{\tilde{a}}(x)$ of a triangular fuzzy number $\tilde{a}$ is defined as:

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x - a_1}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \frac{a_3 - x}{a_3 - a_2}, & a_2 \leq x \leq a_3 \\ 0, & x < a_1, x > a_3 \end{cases} \quad (2)$$

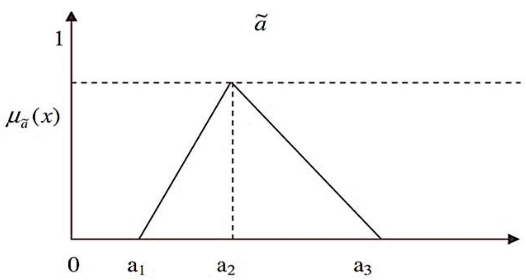

Figure 1. Membership function $\mu_{\tilde{a}}(x)$ of triangular fuzzy number $\tilde{a} = (a_1, a_2, a_3)$.

Definition 4. Given any positive real number k and two positive fuzzy triangular numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$, the main operations are expressed as follows:

$$\tilde{a} + \tilde{b} = (a_1 + b_1,\ a_2 + b_2, a_3 + b_3) \tag{3}$$

$$\tilde{a} - \tilde{b} = (a_1 - b_1,\ a_2 - b_2, a_3 - b_3) \tag{4}$$

$$\tilde{a} * \tilde{b} = (a_1 * b_1,\ a_2 * b_2, a_3 * b_3) \tag{5}$$

$$\tilde{a}/\tilde{b} = (a_1/b_1,\ a_2/b_2, a_3/b_3) \tag{6}$$

$$\tilde{a}^{-1} = \left(\frac{1}{a_1}, \frac{1}{a_2}, \frac{1}{a_3}\right) \tag{7}$$

$$k *\ \tilde{a} = (k * a_1, k * a_2, k * a_3) \tag{8}$$

$$-\ \tilde{a} = (-a_1, -a_2, -a_3) \tag{9}$$

Definition 5. The distance between two fuzzy triangular numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ using the vertex method is calculated as:

$$d(\tilde{a}, \widetilde{b}) = \sqrt{1/3[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \tag{10}$$

Definition 6. Assume that a decision group consist of k members $(D_1, D_2, .., D_k)$, and the fuzzy rating of each decision maker can be represented as a positive triangular fuzzy number $\tilde{R}_s = (a_s, b_s, c_s), (s = 1,2, \dots k)$ with membership function $\mu_{\tilde{R}}(x)$. Then the aggregated fuzzy rating can be defined as:

$$\tilde{R} = (a, b, c), \text{where} \quad a = \min_s a_s\, , b = \frac{1}{k}\sum_{s=1}^{k} b_s, \text{and} \quad c = \max_s c_s\,, \qquad s = 1,2, \dots k \tag{11}$$

A linguistic variable is expressed with words or sentences in natural or artificial language. As such, it is useful for providing approximate characterization of phenomena that are too complex or ill-defined to be described in conventional quantitative terms (Zadeh, 1965). In the fuzzy set theory, conversion scales are applied to transform the linguistic terms into fuzzy numbers. In this study, we will use a scale of 1–9 to rate the criteria (SSCM practices) as shown in Table 2.

Table 2. Linguistic terms for the alternative ratings.

Linguistic expression	**Fuzzy numbers**	**Description**
Very Poor (VP)	(1, 1, 3)	Very little and sparse information provided.
Poor (P)	(1, 3, 5)	Brief statements and some information provided.
Fair (F)	(3, 5, 7)	More substantial information with some detail provided.
Good (G)	(5, 7, 9)	Good coverage provided with some detail missing.
Very Good (VG)	(7, 9, 9)	Extensive information with lots of detail provided.

4. Methodology

The methodology section of this paper includes both qualitative and quantitative data analysis techniques including Content Analysis, Experts Evaluations, fuzzy Entropy and fuzzy TOPSIS. For the sake of clarity, the analysis procedure is divided into five phases shown in Figure 2. While the first phase—criteria identification (SSCM practices) is presented in the Literature review section, other phases are discussed in detail in the following sub-sections.

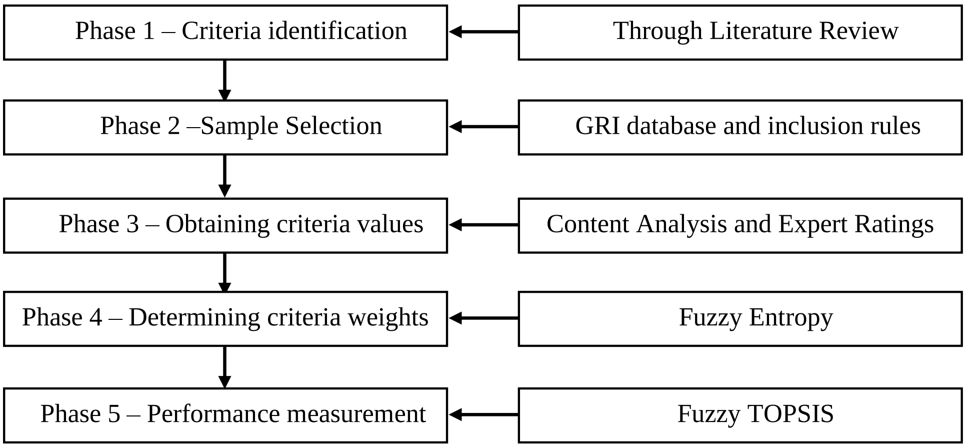

Figure 2. Five-phase research methodology.

4.1. Sample selection and data collection

Since pharmaceutical firms are seen as the leader in SC sustainability initiatives (Demir and Min, 2019) and managing, measuring, and reporting sustainability performance is essential for pharmaceutical companies (Qorri et al., 2018; Schneider et al., 2010), as well as sustainability reports can be considered to indicate the actual (accurate) sustainability performance (Papoutsi and Sodhi, 2020) of the company, we have chosen to analyze data collected from such reports.

In this study, sustainability reports were retrieved from GRI Database (https://database.globalreporting.org/search/) using following inclusion criteria:

- The sustainability report is categorized in the sector of healthcare products
- The sustainability report is prepared in accordance with the latest GRI Standards
- The sustainability report is published by a European pharma firm
- The sustainability report is published from a large or multi-national enterprise (MNE)
- The sustainability report discloses information for 2017, 2018, or 2019

The last search for reports was conducted in the end of 2020 and returned 25 sustainability reports. Whenever, more than one report was available for a specific company, we selected the newest published sustainability report. Next, we skimmed and partly read the content of downloaded reports, after which, eight reports were dropped because they were not written in English. Likewise, to ensure some comparability between companies in terms of revenues, number of employees etc., we were forced to further filter downloaded reports. Therefore, we decided to retain only reports from companies that fall in range of net sales between one to five billion dollars and employ between 3000 and 9500 workers. This process yielded a final number of six sustainability reports shown in Table 3.

Table 3. A summary of sustainability reports used in the study.

Company	Country	Reporting Year	Number of pages	Number of employees	Net sales in millions $
Chiesi Group	Italy	2019	156	5854	1993
ConvaTec	Great Britain	2019	54	9197	1827
LEK Sandoz	Slovenia	2018	94	4084	1061
Orion	Finland	2019	59	3265	1051
Richter Gedeon	Hungary	2017	43	7036	1437
UCB	Belgium	2019	241	7606	4784

In the next phase, these reports are analyzed and assessed independently by three scholars who have been actively publishing in environmental and sustainable operations and SC management literature for more than 20 years. After explaining and discussing the aim and the methodology of this study through several meetings, we asked these experts to read and evaluate each sustainability report according to linguistic terms shown in Table 2 for each SSCM practices presented in Table 1. In addition, to increase the reliability of evaluations obtained from experts, we cleaned each report from data that can be used to identify the company. Likewise, to increase the reproducibility and consistency of ratings, we asked experts to evaluate sustainability reports twice with two weeks gap between evaluations. No significant differences were noted between two independent assessments. Hence, we believe that the assessment of criteria (SSCM practices) is as objective as possible.

However, since information disclosed in sustainability reports vary in format and content, as well as human judgments and preferences are often complex and vague, we guided our experts to use linguistic ratings during their evaluation. Consequently, to analyze the retrieved data, we employ fuzzy Entropy to calculate criteria weight and fuzzy TOPSIS to rank companies based on their sustainability disclosure.

4.2. Fuzzy Shannon's Entropy based on $\alpha - sets$

There are several methods for determining criteria weights in multi attribute decision making (MADM) literature. However, no single method can guarantee an accurate result and determine what the true weight is (Erol et al., 2011). While subjective weighting methods (e.g., Delphi method, AHP, expert survey) take decision makers' experiences and opinions into the account in criteria weighting process, in objective weighting methods (e.g., entropy, multiple objective programming), criteria weights are estimated from mathematical models and algorithms without any consideration of the decision maker's preferences.

In this study, to overcome the shortage of subjective weighting methods, the entropy method is used to calculate objectively the weights of SSCM practices. The entropy concept is proposed by Shannon (1948) and has wide applications in physics, mathematics, social sciences (Şengül et al., 2015), and recently in operations management literature (dos Santos et al., 2019). Lotfi and Fallahnejad (2010) extended the Shannon's entropy for the interval and fuzzy data cases. Steps to determine criteria weights using fuzzy Shannon's Entropy are as follows:

Step 1: **Arrange the initial decision matrix:** Suppose there are m alternatives (rows) to evaluate and n evaluation criteria (columns) structured in a matrix $D = (x_{ij})_{mxn}$, where each x_{ij} is a fuzzy triangular number.

Step 2: **Transform fuzzy data into interval data using the α-level sets:** To find the α −cut of a fuzzy triangular number $\tilde{a} = (a_1, a_2, a_3)$, we use Equation (1). First, we set α equal to the left and right membership function of $\tilde{a}$ using Equation (2) and solve for *x*, then we can write the fuzzy interval in terms of α −set interval as:

$$\tilde{a}_\alpha = [\ \alpha * (a_2 - a_1) + a_1, \alpha * (a_2 - a_3) + a_3] \quad (12)$$

Step 3: **Normalization of decision matrix:** Criteria of decision matrix should be normalized due to unit differences with the following equations:

$$p_{ij}^l = \frac{x_{ij}^l}{\sum_{i=1}^m x_{ij}^u}, \qquad p_{ij}^u = \frac{x_{ij}^u}{\sum_{i=1}^m x_{ij}^u}, i = 1, \dots, m;\ \mathrm{j} = 1, \dots, \mathrm{n} \quad (13)$$

Step 4: **Calculate the lower bound (h_j^l) and upper bound** (h_j^u) **of interval entropy** with the following equations:

$$h_j^l = min\left\{-h_0 \sum_{i=1}^{m} p_{ij}^l ln\, p_{ij}^l, -h_0 \sum_{i=1}^{m} p_{ij}^u ln\, p_{ij}^u\right\}, \qquad \text{j} = 1, \dots, \text{n}$$

$$h_j^u = max\left\{-h_0 \sum_{i=1}^{m} p_{ij}^l ln\, p_{ij}^l, -h_0 \sum_{i=1}^{m} p_{ij}^u ln\, p_{ij}^u\right\}, \qquad \text{j} = 1, \dots, \text{n} \qquad (14)$$

where is $h_0 = 1/\ln m$, and $p_{ij}^l ln\, p_{ij}^l$ or $p_{ij}^u ln\, p_{ij}^u$ is defined as 0 if $p_{ij}^l = 0$ or $p_{ij}^u = 0$

Step 5: **Calculate the lower bound** (d_j^l) **and upper bound** (d_j^u) **of degree of diversification** as follows:

$$d_j^l = 1 - h_j^u,\ d_j^u = 1 - h_j^l,\ \ j = 1, \dots, n \qquad (15)$$

Step 6: **Calculate the lower bound** (w_j^l) **and upper bound** (w_j^u) **of interval weight** with the following equations:

$$w_j^l = \frac{d_j^l}{\sum_{s=1}^{n} d_s^u}, \qquad w_j^l = \frac{d_j^u}{\sum_{s=1}^{n} d_s^l}, \qquad \text{j} = 1, \dots, \text{n} \qquad (16)$$

The averages between w_j^l and w_j^u for each criteria generates the final weight that will be used in the TOPSIS to rank the alternatives. It is worthy to note that the higher the entropy weight is, the more important the criteria is considered.

4.3. Fuzzy TOPSIS

The technique for order preference by similarity to ideal solution (TOPSIS) is proposed by Hwang and Yoon (1981). This method aims to choose the shortest distance from the positive ideal solution that maximizes the benefit and the longest distance from the negative-ideal solution that maximizes cost. Govindan et al. (2013) lists several advantages of TOPSIS compared with other techniques (e.g., AHP/ANP) including the avoidance of pairwise comparison and a relatively simple computation process. To deal with incomplete and inaccurate information TOPSIS is combined with the fuzzy set theory by many researchers and applied in many real word problems such as supplier selection (Kannan et al., 2014; J. Li et al., 2019), assessing renewable energy systems (Şengül et al., 2015), evaluating sustainable transportation systems (Awasthi et al., 2011) and measuring corporate sustainability performance (Aras et al., 2018). Hence, we use fuzzy TOPSIS in our study to measure sustainability performance of pharmaceutical SC by assessing SSCM practices reported in sustainability reports. Steps involved in calculating fuzzy TOPSIS are as follows:

Step 1: **Construct the fuzzy decision matrix** $\widetilde{D}$ composed of m alternatives and n criteria, where fuzzy values $\tilde{x}_{ij} = (a, b, c)$ denote the rating of alternative A_i with respect to criterion C_j.

$$\widetilde{D} = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \qquad i = 1, \dots, m;\ \mathrm{j} = 1, \dots, \mathrm{n} \tag{17}$$

Step 2: **Normalize the fuzzy decision matrix** denoted by $\tilde{R}$ using the following formulas:

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}, \qquad i = 1, \dots, m;\ \mathrm{j} = 1, \dots, \mathrm{n} \tag{18}$$

where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right), \qquad c_j^+ = \max_i c_{ij} \text{ and } j \text{ belongs to benefit criteria} \tag{19}$$

and

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), \qquad a_j^- = \min_i a_{ij} \text{ and } j \text{ belongs to cost criteria} \tag{20}$$

Step 3: **Calculate the weighted normalized decision matrix** denoted by $\tilde{V}$ using the following formulas:

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn}, \qquad i = 1, \dots, m;\ \mathrm{j} = 1, \dots, \mathrm{n} \tag{21}$$

where elements of this matrix are calculated using $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}j$, and $\tilde{w}j$ represents the weight of criterion C_j.

Step 4: **Determine the fuzzy positive ideal solution (FPIS, A^+) and fuzzy negative ideal solution (FNIS, A^-)** using the following formulas:

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+) \tag{22}$$

$$A^- = (v_1^-, v_2^-, \dots, v_n^-) \tag{23}$$

where $v_j^+ = \max_{i=1,..,m} \tilde{v}_{ij}$ and $v_j^- = \min_{i=1,..,m} \tilde{v}_{ij}$, j = 1,2, …, n.

Step 5: **Calculate the distance of each alternative from FPIS and FNIS** using the following formulas:

$$d_i^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, v_1^+\right), \qquad i = 1,2, \dots, m \tag{24}$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, v_1^-\right), \qquad i = 1,2, \dots, m \tag{25}$$

where $d\left(\tilde{v}_{ij}, v_1^+\right)$ *and* $d\left(\tilde{v}_{ij}, v_1^-\right)$ are distances between two fuzzy numbers and are calculated using Equation (10).

Step 6: **Compute the closeness coefficient (CC_i)** of each alternative using the following equation:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \qquad i = 1, \dots, \mathrm{m} \tag{26}$$

Step 7: **Rank the alternatives** After the closeness coefficients are determined, alternatives are ranked in descending order based on CC_i values. Clearly, the closer the value of CC_i is to 1 (approaches FPIS), the respective alternative A_i is more feasible (better) for the decision-maker to select it.

5. Application of the proposed methodology

In the SC context, measuring sustainability performance is complex as each firm in a chain should be assessed (Qorri et al., 2018). To address this complexity, in the following we examine the practicality and the effectiveness of the proposed approach to assess the sustainability performance of the pharmaceutical SCs. Initially, three experts evaluated independently the degree of information disclosed in sustainability reports for each criteria (SSCM practices) presented in Table 1 using linguistic terms given in Table 2. These ratings by experts for the alternatives (sustainability reports) are given in Tables 4a, 4b, and 4c.

Table 4a. Evaluation of sustainability reports by the first expert.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Chiesi Group (A1)	VG	VG	VG	G	F	G	G	VP	VG	VG
ConvaTec (A2)	VG	G	VG	VG	G	F	F	P	VG	VG
LEK Sandoz (A3)	VG	G	G	F	G	F	F	P	G	G
Orion (A4)	VG	VG	VG	VG	G	G	G	VP	VG	G
Richter Gedeon (A5)	G	F	F	G	G	P	P	P	G	F
UCB (A6)	VG	G	G	G	F	G	G	F	VG	VG

Table 4b. Evaluation of sustainability reports by the second expert.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Chiesi Group (A1)	G	VG	G	VG	F	G	F	P	VG	G
ConvaTec (A2)	VG	VG	G	VG	G	G	G	P	VG	VG
LEK Sandoz (A3)	G	G	G	G	G	F	F	VP	VG	G
Orion (A4)	VG	VG	G	VG	G	F	G	F	VG	G
Richter Gedeon (A5)	G	G	F	G	F	P	F	P	G	G
UCB (A6)	VG	G	G	VG	F	G	F	P	VG	VG

Table 4c. Evaluation of sustainability reports by the third expert.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Chiesi Group (A1)	G	VG	VG	G	F	G	F	P	VG	G
ConvaTec (A2)	VG	VG	G	VG	G	F	G	P	VG	VG
LEK Sandoz (A3)	VG	G	F	F	G	F	F	P	G	G
Orion (A4)	VG	VG	G	VG	VG	G	VG	P	VG	G
Richter Gedeon (A5)	G	F	F	G	G	P	P	P	G	F
UCB (A6)	VG	G	VG	G	F	G	G	F	VG	VG

Next, we converted linguistic terms into triangular fuzzy numbers according to conversion scales given in Table 2, and then using Equation (11) we calculated aggregated fuzzy ratings, which are shown in Table 5.

Table 5. Aggregated evaluation of sustainability reports.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(*5, 7.67,* 9)	(9, 9, 9)	(5, 8.33, 9)	(5, 7.67, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5.67, 9)	(1, 2.33, 5)	(9, 9, 9)	(5, 7.67, 9)
A2	(9, 9, 9)	(5, 8.33, 9)	(5, 7.67, 9)	(9, 9, 9)	(5, 7, 9)	(3, 5.67, 9)	(3, 6.33, 9)	(1, 3, 5)	(9, 9, 9)	(9, 9, 9)
A3	(5, 8.33, 9)	(5, 7, 9)	(3, 6.33, 9)	(3, 5.67, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(1, 2.33, 5)	(5, 7.67, 9)	(5, 7, 9)
A4	(9, 9, 9)	(9, 9, 9)	(5, 7.67, 9)	(9, 9, 9)	(5, 7.67, 9)	(3, 6.33, 9)	(5, 7.67, 9)	(1, 3, 7)	(9, 9, 9)	(5, 7, 9)
A5	(5, 7, 9)	(3, 5.67, 9)	(3, 5, 7)	(5, 7, 9)	(3, 6.33, 9)	(1, 3, 5)	(1, 3.67, 7)	(1, 3, 5)	(5, 7, 9)	(3, 5.67, 9)
A6	(9, 9, 9)	(5, 7, 9)	(5, 7.67, 9)	(5, 7.67, 9)	(3, 5, 7)	(5, 7, 9)	(3, 6.33, 9)	(1, 4.33, 7)	(9, 9, 9)	(9, 9, 9)

Once we obtained the aggregated fuzzy evaluations of alternatives, we used the interval Shannon's Entropy method to determine weights of ten criteria (SSCM practices). In the subsequent sections, the calculations were done using MS Excel 2019.

5.1. Weight determination of SSCM practices

The fuzzy data in Table 5 are transformed into interval data using Equation (12) by setting $\alpha = 0.9$. Next, using Equation (13) the normalized interval decision matrix is determined and shown in Table 6.

Table 6. The normalized interval decision matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	[0.15, 0.15]	[0.19, 0.19]	[0.18, 0.19]	[0.16, 0.17]	[0.12, 0.13]	[0.19, 0.20]	[0.15, 0.17]	[0.11, 0.13]	[0.18, 0.18]	[0.16, 0.17]
A2	[0.18, 0.18]	[0.17, 0.18]	[0.17, 0.18]	[0.19, 0.19]	[0.17, 0.18]	[0.15, 0.17]	[0.17, 0.18]	[0.14, 0.16]	[0.18, 0.18]	[0.19, 0.19]
A3	[0.16, 0.17]	[0.15, 0.15]	[0.14, 0.15]	[0.12, 0.13]	[0.17, 0.18]	[0.14, 0.15]	[0.13, 0.14]	[0.11, 0.13]	[0.15, 0.15]	[0.15, 0.16]
A4	[0.18, 0.18]	[0.19, 0.19]	[0.17, 0.18]	[0.19, 0.19]	[0.19, 0.20]	[0.17, 0.19]	[0.20, 0.22]	[0.14, 0.17]	[0.18, 0.18]	[0.15, 0.16]
A5	[0.13, 0.14]	[0.12, 0.13]	[0.11, 0.12]	[0.15, 0.15]	[0.15, 0.17]	[0.08, 0.09]	[0.09, 0.11]	[0.14, 0.16]	[0.13, 0.14]	[0.12, 0.13]
A6	[0.18, 0.18]	[0.15, 0.15]	[0.17, 0.18]	[0.16, 0.17]	[0.12, 0.13]	[0.19, 0.20]	[0.17, 0.18]	[0.20, 0.23]	[0.18, 0.18]	[0.19, 0.19]

Finally, interval entropy values $\left(h_j^l, h_j^u\right)$, interval diversification values $\left(d_j^l, d_j^u\right)$, and interval weight boundaries $\left(w_j^l, w_j^u\right)$ are computed using Equations (14) – (16) and shown in Table 7.

Table 7. Interval entropy, diversification, and boundaries.

			$\alpha = 0.9$		$\alpha = 0.5$		$\alpha = 0.1$	
	$[h^l, h^u]$	$[d^l, d^u]$	$[w^l, w^u]$	w_j	$[w^l, w^u]$	w_j	$[w^l, w^u]$	w_j
C1	[0.986, 0.998]	[0.002, 0.014]	[0.005, 0.189]	**0.0973**	[0.000, 1.486]	**0.7432**	[0.000, 3.966]	**1.9832**
C2	[0.974, 0.994]	[0.006, 0.026]	[0.016, 0.351]	**0.1834**	[0.001, 2.453]	**1.2268**	[0.000, 6.339]	**3.1695**
C3	[0.966, 0.994]	[0.006, 0.034]	[0.018, 0.472]	**0.2447**	[0.003, 3.595]	**1.7985**	[0.001, 9.511]	**4.7559**
C4	[0.975, 0.995]	[0.005, 0.025]	[0.014, 0.343]	**0.1787**	[0.001, 2.448]	**1.2244**	[0.000, 6.339]	**3.1694**
C5	[0.962, 0.993]	[0.007, 0.038]	[0.019, 0.517]	**0.2680**	[0.003, 3.917]	**1.9602**	[0.001, 10.126]	**5.0640**
C6	[0.945, 0.983]	[0.017, 0.055]	[0.048, 0.754]	**0.4008**	[0.009, 4.907]	**2.4578**	[0.004, 12.319]	**6.1615**
C7	[0.946, 0.989]	[0.011, 0.054]	[0.031, 0.745]	**0.3885**	[0.004, 5.376]	**2.6899**	[0.001, 13.774]	**6.8878**
C8	[0.920, 0.989]	[0.011, 0.080]	[0.031, 1.089]	**0.5598**	[0.005, 8.143]	**4.0740**	[0.003, 20.108]	**10.055**
C9	[0.990, 0.998]	[0.002, 0.010]	[0.006, 0.142]	**0.0739**	[0.000, 1.020]	**0.5100**	[0.000, 2.657]	**1.3284**
C10	[0.974, 0.995]	[0.005, 0.026]	[0.015, 0.353]	**0.1838**	[0.001, 2.475]	**1.2379**	[0.000, 6.352]	**3.1760**

In the following step, these criteria weights obtained from interval Shannon's Entropy are used in the proposed fuzzy TOPSIS to rank sustainability performance scores.

5.2. Ranking firms based on Fuzzy TOPSIS

For the TOPSIS method, the criteria should be classified in Cost or Benefit Criteria. According to the definition of SSCM practices given in Table 1, all criteria (C1-C10) fall under the benefit category. Hence, using data from Table 5 as decision matrix and applying Equation (19), the normalized fuzzy decision matrix is obtained and shown in Table 8.

Table 8. Normalized fuzzy decision matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(0.556, 0.852, 1)	(1, 1, 1)	(0.556, 0.926, 1)	(0.556, 0.852, 1)	(0.333, 0.556, 0.778)	(0.556, 0.778, 1)	(0.333, 0.630, 1)	(0.143, 0.333, 0.714)	(1, 1, 1)	(0.556, 0.852, 1)
A2	(1, 1, 1)	(0.556, 0.926, 1)	(0.556, 0.852, 1)	(1, 1, 1)	(0.556, 0.778, 1)	(0.333, 0.630, 1)	(0.333, 0.704, 1)	(0.143, 0.429, 0.714)	(1, 1, 1)	(1, 1, 1)
A3	(0.556, 0.926, 1)	(0.556, 0.778, 1)	(0.333, 0.704, 1)	(0.333, 0.630, 1)	(0.556, 0.778, 1)	(0.333, 0.556, 0.778)	(0.333, 0.556, 0.778)	(0.143, 0.333, 0.714)	(0.556, 0.852, 1)	(0.556, 0.778, 1)
A4	(1, 1, 1)	(1, 1, 1)	(0.556, 0.852, 1)	(1, 1, 1)	(0.556, 0.852, 1)	(0.333, 0.704, 1)	(0.556, 0.852, 1)	(0.143, 0.429, 1)	(1, 1, 1)	(0.556, 0.778, 1)
A5	(0.556, 0.778, 1)	(0.333, 0.630, 1)	(0.333, 0.556, 0.778)	(0.556, 0.778, 1)	(0.333, 0.704, 1)	(0.111, 0.333, 0.556)	(0.111, 0.407, 0.778)	(0.143, 0.429, 0.714)	(0.556, 0.778, 1)	(0.333, 0.630, 1)
A6	(1, 1, 1)	(0.556, 0.778, 1)	(0.556, 0.852, 1)	(0.556, 0.852, 1)	(0.333, 0.556, 0.778)	(0.556, 0.778, 1)	(0.333, 0.704, 1)	(0.143, 0.619, 1)	(1, 1, 1)	(1, 1, 1)

Next, using Equation (21) and criteria weights from interval Shannon's Entropy, the weighted normalized decision matrix is obtained and shown in Table 9.

Table 9. Weighted normalized fuzzy decision matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	(0.054, 0.083, 0.097)	(0.183, 0.183, 0.183)	(0.136, 0.227, 0.245)	(0.099, 0.152, 0.179)	(0.089, 0.149, 0.208)	(0.223, 0.312, 0.401)	(0.129, 0.245, 0.388)	(0.080, 0.187, 0.400)	(0.074, 0.074, 0.074)	(0.102, 0.157, 0.184)
A2	(0.097, 0.097, 0.097)	(0.102, 0.170, 0.183)	(0.136, 0.208, 0.245)	(0.179, 0.179, 0.179)	(0.149, 0.208, 0.268)	(0.134, 0.252, 0.401)	(0.129, 0.273, 0.388)	(0.080, 0.240, 0.400)	(0.074, 0.074, 0.074)	(0.184, 0.184, 0.184)
A3	(0.054, 0.090, 0.097)	(0.102, 0.143, 0.183)	(0.082, 0.172, 0.245)	(0.060, 0.113, 0.179)	(0.149, 0.208, 0.268)	(0.134, 0.223, 0.312)	(0.129, 0.216, 0.302)	(0.080, 0.187, 0.400)	(0.041, 0.063, 0.074)	(0.102, 0.143, 0.184)
A4	(0.097, 0.097, 0.097)	(0.183, 0.183, 0.183)	(0.136, 0.208, 0.245)	(0.179, 0.179, 0.179)	(0.149, 0.228, 0.268)	(0.134, 0.282, 0.401)	(0.216, 0.331, 0.388)	(0.080, 0.240, 0.560)	(0.074, 0.074, 0.074)	(0.102, 0.143, 0.184)
A5	(0.054, 0.076, 0.097)	(0.061, 0.116, 0.183)	(0.082, 0.136, 0.190)	(0.099, 0.139, 0.179)	(0.089, 0.189, 0.268)	(0.045, 0.134, 0.223)	(0.043, 0.158, 0.302)	(0.080, 0.240, 0.400)	(0.041, 0.058, 0.074)	(0.061, 0.116, 0.184)
A6	(0.097, 0.097, 0.097)	(0.102, 0.143, 0.183)	(0.136, 0.208, 0.245)	(0.099, 0.152, 0.179)	(0.089, 0.149, 0.208)	(0.223, 0.312, 0.401)	(0.129, 0.273, 0.388)	(0.080, 0.347, 0.560)	(0.074, 0.074, 0.074)	(0.184, 0.184, 0.184)

Finally, distance of each company to FPIS and FNIS, closeness coefficient and ranks are obtained, using Equations (22) – (26) and shown in Table 10.

Table 10.TOPSIS ranking of sustainability performance scores.

	$\alpha = 0.9$				$\alpha = 0.5$				$\alpha = 0.1$			
	d^+	d^-	CC_i	Rank	d^+	d^-	CC_i	Rank	d^+	d^-	CC_i	Rank
A1	0.966	1.282	0.570	**4**	6.806	8.782	0.563	**4**	17.240	22.432	0.565	**4**
A2	0.876	1.362	0.608	**3**	6.098	9.389	0.606	**3**	15.384	24.006	0.609	**3**
A3	1.151	1.117	0.492	**5**	8.010	7.725	0.491	**5**	20.330	19.739	0.493	**5**
A4	0.798	1.487	0.651	**1**	5.558	10.279	0.649	**1**	14.006	26.230	0.652	**1**
A5	1.360	0.963	0.415	**6**	9.392	6.705	0.417	**6**	23.872	17.116	0.418	**6**
A6	0.878	1.416	0.617	**2**	6.155	9.757	0.613	**2**	15.598	24.848	0.614	**2**

According to the results obtained from Table 10, the pharmaceutical company with the most sustainable SC is Orion Pharma (A4), followed by UCB corporation (A6), CovaTec (A2), Chiesi Group (A1), LEK-Sandoz (A3), and Richter Gedeon (A5). To examine robustness of the results from the proposed method, in the following section we perform a sensitivity analysis.

5.3. Sensitivity analysis

To consider the impact of the criteria weights in assessing sustainability performance of pharma SCs for analyzed companies, a sensitivity analysis is performed. The sensitivity is checked by using different alpha cutting levels ($\alpha = 0.9$; $\alpha = 0.5$; $and\ \alpha = 0.1$), which generates various criteria weights as shown in Table 7. These weights are used to investigate ranking of companies obtained in fuzzy TOPSIS method. According to the results shown in Table 10, changing alpha cutting levels generates different criteria weights but the sustainability performance scores did not vary significantly.

To further investigate the ranking of companies when different criteria and/or different decision-makers are selected, we have considered 12 additional cases. The details and results of these cases are shown in Table 11 and Figure 3. Although such results show the ranking of companies is slightly changed, it is evident that the fourth company (A4) is generally selected with the most sustainable SC. Therefore, the sensitivity analysis indicates that the proposed fuzzy Entropy and fuzzy TOPSIS methodology is promising and produces consistent results.

Table 11. Details and results of cases generated for sensitivity analysis.

Case	Decision criteria	Decision makers	Firm ranking (respectively)
Initial Case	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM1, DM2, DM3	A4, A6, A2, A1, A3, A5
Case 1	C1, C2, C3	DM1, DM2, DM3	A4, A1, A2, A6, A3, A5
Case 2	C4, C5, C6	DM1, DM2, DM3	A4, A2, A1, A6, A3, A5
Case 3	C7, C8, C9, C10	DM1, DM2, DM3	A6, A4, A2, A1, A3, A5
Case 4	C9, C10	DM1, DM2, DM3	A2, A6, A1, A4, A3, A5
Case 5	C1, C2, C3, C4, C5, C6	DM1, DM2, DM3	A4, A2, A1, A6, A3, A5
Case 6	C1, C2, C3, C7, C8, C9, C10	DM1, DM2, DM3	A4, A6, A2, A1, A3, A5
Case 7	C1, C2, C3, C9, C10	DM1, DM2, DM3	A2, A6, A4, A1, A3, A5
Case 8	C4, C5, C6, C9, C10	DM1, DM2, DM3	A2, A4, A6, A1, A3, A5
Case 9	C1, C2, C3, C4, C5, C6, C7, C8	DM1, DM2, DM3	A4, A6, A2, A1, A3, A5
Case 10	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM1	A6, A2, A4, A1, A3, A5
Case 11	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM2	A4, A2, A6, A1, A3, A5
Case 12	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM3	A4, A6, A2, A1, A3, A5

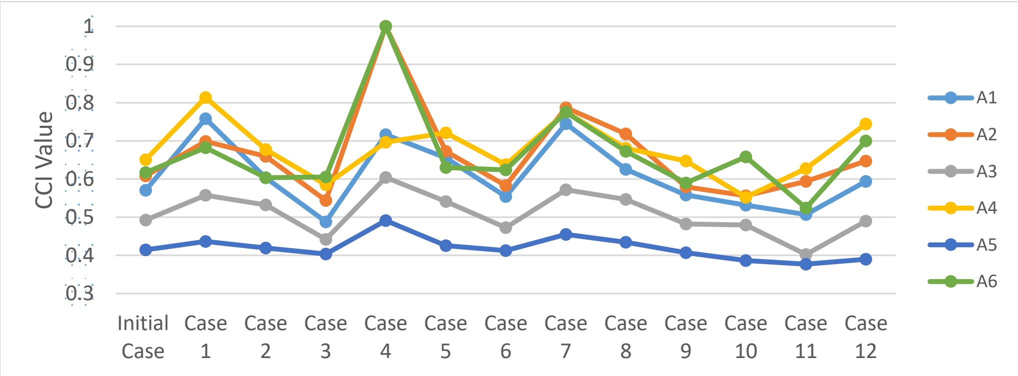

Figure 3. Results of sensitivity analysis.

6. Discussion

Since SSCM practices play a significant role in achieving sustainable development (Govindan et al., 2013), the measurement and assessment of SCs sustainability is attracting more attention, but the evaluation of sustainability performance is difficult (Aras et al., 2018). Existing measurement approaches lack to consider all three sustainability aspects or are focused on measuring sustainability performance only between suppliers and manufacturers, but not across all SC echelons (Qorri et al., 2018; Schöggl et al., 2016). In this context, the aim of this study was to propose a method to assess the performance of a supply chain by considering all member firms and sustainability dimensions. By combining Content Analysis, Expert ratings, fuzzy Entropy, and fuzzy TOPSIS, we developed a novel approach to measure sustainability performance of a SC from suppliers to consumers to reverse logistics providers.

While fuzzy logic allows the integration of vague, qualitative, interval values, and subjective data (Pavláková Dočekalová et al., 2017), MCDM techniques allow the ranking of alternatives by considering together multiple criteria (e.g., environmental, social, and economic aspects) (Govindan et al., 2013) and thus they are combined in our study. This is in line with current literature, where it has been argued that sustainability assessment is a MCDM problem (Diaz-Balteiro et al., 2017). Therefore, the accuracy and quality of results obtained by the proposed solution can be seen as more robust because the model considers the inherent subjectivity and uncertainty of data collected in assessing sustainability.

The proposed approach is demonstrated and validated utilizing data collected from six sustainability reports published by pharmaceutical companies. Initially, three experts evaluated the extent of sustainability disclosure for each SC practice given in Table 1 using fuzzy terms shown in Table 2. The retrieved evaluations were aggregated and used as inputs in fuzzy interval Shannon's Entropy to determine criteria weight (SSCM practices), which are then used in fuzzy TOPSIS to obtain sustainability performance scores for each company. Thus, the obtained findings allow to determine the most sustainable company and can be used to compare and benchmark sustainability performance of SCs. Furthermore, the proposed method can be used to better understand the complexities involved in assessing sustainability of a SC.

In SSCM literature the combination of fuzzy logic with MCDM methods is used frequently to study problems related to sustainability assessment including green supplier selection (dos Santos et al., 2019; Govindan et al., 2013), sustainable transportation systems (Awasthi et al., 2011), materiality assessment in sustainability reporting (Calabrese et al., 2016), and corporate sustainability performance assessment (Wicher et al., 2019). However, the scope of such studies is narrower compared with our study, as they examine few subsets of the SC sustainability performance. In contrast, we consider the end-to-end SC, and thus we believe that the results of our study extend SSCM literature and respond to research and practical needs (Beske-Janssen et al., 2015; Büyüközkan and Karabulut, 2018; Qorri et al., 2018) for developing a practical and usable methodology for assessing sustainability performance of SCs.

Additionally, to the best of our knowledge, only three studies (Erol et al., 2011; Olugu and Wong, 2012; Uygun and Dede, 2016) attempted to build an overall SC sustainability assessment framework based on fuzzy logic. However, the proposed solutions fall short in terms of applicability and comprehensiveness because they are based on either limited number of metrics that are not (and cannot be) standardized among firms and industries (Ahi and Searcy, 2015; Qorri et al., 2018) or are not designed for scalability and flexibility as well as fail to consider multi-dimensional aspects of sustainability. Given that our proposed methodology is based on SSCM practices and not on specific indicators or metrics as sustainability measurement criteria and it incorporates vague and subjective data stemming from environmental, social, and economic aspects, it has a significant advantage over existing measurement approaches. Thus, the proposed solution enables the sustainability performance assessment in an integrated and multidimensional manner, providing flexibility and comprehensiveness. Such features are useful for decision-makers and scholars alike.

Sensitivity analysis was performed to measure the influence of criteria weights and experts on the final ranking, using different alpha-cutting levels of fuzzy data in the Entropy method. From the definition of Equation (1), the α value ranges between 0 and 1. In this paper, we used alpha values ($\alpha = 0.1, 0.5, 0.9$) that are mostly adopted in literature (Lotfi and Fallahnejad, 2010; Şengül et al., 2015). Utilizing these values in the fuzzy interval Shannon's Entropy, various criteria weights are obtained, which are used to investigate the ranking of companies in fuzzy TOPSIS. A MCDM model is said to be robust if the final ranking remains stable or variations are in an acceptable range, after changing weights of some criteria (Govindan et al., 2013; Yazdani et al., 2019). In our study, since changes in the sustainability performance rankings in Table 10 and in Table 11 are minimal, we can say that the proposed method is robust and generates consistent results. Similar findings are reported by other scholars who used fuzzy Entropy and Fuzzy TOPSIS to address problems such as green supplier selection (dos Santos et al., 2019; Govindan et al., 2013) and ranking renewable energy supply systems (Şengül et al., 2015). It is also important to note that we used only objective criteria weights (obtained from fuzzy Entropy). The reason to not use subjective weighting methods (e.g., asking experts to rate the importance of each criteria) was to avoid vagueness, impreciseness, and other subjective factors (e.g., knowledge, background, experience) involved with human judgment.

Clearly, the proposed method in our study depends also on the number of SC echelons. For instance, if we assume that the downstream SC practices (e.g., C6-Customer Sustainable Cooperation, C7-Reverse Logistics, and C8-Investment Recovery) for examined firms are not relevant or there is no data available, the final ranking would have been changed to A2>A4>A6>A1>A3>A5 from initial ranking A4>A6>A2>A1>A3>A5. Therefore, although, we developed the proposed method from the perspective of the extended SC, and which was suitable for large pharmaceutical companies, other firms in different sectors may have different SC configurations that could consist of fewer (or more) echelons. However, the proposed methodology can be easily applied by simply adopting SSCM practices (Table 1) accordingly to the context, whereas the overall procedure and calculation steps remain untouched. This feature of modularity makes the proposed methodology unique in SSCM literature and helps in overcoming several issues of previous sustainability assessment frameworks that are sparsely used in practical applications (Qorri et al., 2018), and are hard to be adopted and fail to "talk to each other" (Büyüközkan and Karabulut, 2018).

Based on the results obtained from fuzzy TOPSIS method, sustainability performance scores of each company can be used to identify problems with SSCM practices and to implement necessary corrective actions for sustainability improvements. Likewise, these scores can be used to monitor and compare sustainability performance of SCs between companies and to provide insights about the extent of sustainability disclosure by each company in their sustainability report. Hence, we can claim that the proposed method is theoretically sound and practically applicable for the assessment of sustainability performance and presents a significant contribution to the literature.

6.1. Managerial and policy implications

The results of this study have some implications for managers and policymakers. First, by providing a list of evaluation criteria (SSCM practices), managers can better understand the concept of sustainability and focus their resources on measuring and managing sustainability performance than on developing new assessment methods. Second, the sustainability scores obtained are helpful for managers to discover which criteria are the most important for their SC, and to identify which SC partner(s) is(are) well or poorly aligned with the company's environmental and social objectives. Third, the proposed multi-criteria assessment method produces comparable results, which can be complemented with managers' intuition for more informed and justifiable decisions. Such scores can also be used to benchmark SCs. Similarly, these results can serve investors that consider acquisitions in the industry and other stakeholders to better understand the sustainability performance of a company and its SC as well as its progress towards sustainable development. Although assisting managers to identify opportunities and problems both within their company and across SC is essential to improve the sustainability performance, we acknowledge the fact that sustainability scores obtained from the proposed method should not be seen as the final answer, but as part of the overall learning and improvement process.

Finally, the findings have some policy implications as well. Using the proposed method to assess environmental, social, economic performance of a SC might provide guidance for policymakers on evaluating the impact of their policies. Specifically, governments might further tailor their policy measures, incentives, environmental policies, and regulations to promote the adoption of sustainable initiatives by rewarding top performers or imposing higher green taxes on companies that are hesitant to adopt social and environmental initiatives into their SCs. Likewise, the proposed method can be used by regulators to develop systematic sustainability disclosure guidelines.

7. Conclusion

Existing sustainability assessment methods lack effective ways of dealing with incomplete and qualitative information (Büyüközkan and Karabulut, 2018; Qorri et al., 2018) and traditional mathematical tools of crisp data are insufficient for capturing the vague nature of sustainability (Pavláková Dočekalová et al., 2017). Hence, there is a strong need to develop new performance measurement approaches that incorporate all sustainability aspects and integrate quantitative and qualitative data including vague and subjective evaluations by managers/experts. Benefiting from the combination of (1) fuzzy logic which allows the integration of vague data (e.g., some social measures cannot be expressed by numeric values) into the model through linguistic variables, and (2) MCDM techniques that deal with decision problems characterized with many decision criteria such as sustainability assessment (Diaz-Balteiro et al., 2017), we proposed a practical solution. Specifically, by combining Content Analysis, Expert ratings, fuzzy Shannon's Entropy, and fuzzy TOPSIS, we developed a novel approach to measure sustainability performance of a SC from suppliers to consumers to reverse logistics providers. The proposed solution enables a comprehensive assessment of SC sustainability performance and provides high-level modularity for utilizing in different SC configurations. Indeed, the outcomes from the proposed method can support decision-makers to signal and identify early potential sustainability performance problems across the entire SC.

7.1. Limitations and Future Research

As in any other study, the findings of this paper should be considered in the light of its limitations. First, although, we tried to identify the most relevant criteria through extensive literature review, there could be other criteria that we have omitted. Second, we have determined only objective criteria weights using fuzzy Entropy method and did not consider subjective weights because experts have different opinions, work experience and knowledge. However, Joshi and Kumar (2018) developed a method which combines both subjective and objective weights to rank alternatives following the VIKOR technique. Finally, due to the lack of availability of data needed for application of the proposed method, we used data derived from sustainability reports. But this does not imply that the proposed method is depended on data obtained from sustainability reports. On the contrary, one can apply the proposed method in any context as long required data for SSCM practices are available. Furthermore, we did not cross-check whether the data disclosed in sustainability reports represent the actual sustainable performance, but rather we assumed that the data provided in these reports are accurate and asked experts to assess such information and employed fuzzy Entropy and fuzzy TOPSIS to deal with incomplete preferences of experts.

The recognition of these limitations constitutes the basis for the development of future work. Other possible techniques including ANP/AHP, VIKOR, MULTIMOORA, and DEMATEL can be used in the future research. The results obtained from such methods could be compared with findings presented in this study. Furthermore, we are planning to use the Fuzzy VIKOR method in another study to measure sustainability performance of SCs. Future research could also examine what kind of information should be disclosed by companies (e.g., in sustainability reports) for easier application of the proposed method. Likewise, future research can study other approaches to determine the extent of sustainability disclosure in sustainability reports or to ask managers to evaluate criteria used to measure sustainability performance. Finally, in future studies it is also important to extend the proposed approach with other more advanced Pythagorean Fuzzy developments including Pythagorean fuzzy interactive Hamacher power aggregation operators

(Wang et al., 2021), Pythagorean fuzzy TOPSIS (Rani et al., 2020), and Entropy Measure for Linguistic Pythagorean Fuzzy Sets (N. Li et al., 2019). The results obtained from such methods could be compared with findings of this study.

Authors' contribution

Ardian Qorri – Conceptualization, Funding acquisition, Writing - original draft, Methodology, Writing - review and editing; **Saranda Gashi** – Data curation, Validation, Visualization, Funding acquisition, Writing - review and editing; **Andrzej Kraslawski** – Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced reported results in this study.

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