Lean, Green Practices and Process Innovation: A Framework for Green Supply Chain Performance

Abstract

This paper investigates the relationship between lean, green and process innovation practices and green supply chain (GSC) performance. Data were collected from 374 manufacturing firms and results analyzed using Structural Equation Modeling (SEM). The findings revealed a synergetic effect between process innovations, green and lean practices, which play a crucial role towards the improvement of GSC performance. In particular, the results suggested that: (1) lean practices such as JIT, set-up time reduction, cellular manufacturing, and waste elimination can significantly contribute to improve GSC performance; (2) green practices including eco-design, life cycle assessment, green manufacturing, reverse logistics, and waste management significantly and positively affect GSC performance; (3) process innovation practices such as fast response to new processes introduced by other companies within the same sector, pioneering disposition to introduced new processes, and number of changes in the process introduced in one year, do not have a direct contribution to improving GSC performance; finally that (4) process innovation amplifies the effect which contributes for lean and green practices to offer a higher payoff rate in terms of GSC performance when these are coupled with process innovation activities. This paper presents an innovative approach since it studies simultaneously the three dimensions of sustainability (environmental, social and economic), the lean, the innovation process and green paradigms, which are considered strategic for supply chain competitiveness. Investigating the relationships between the four strategies is a contribution that the authors hope will become a forward step for promoting sustainability in manufacturing supply chains.

Keywords: Lean; Green; Process Innovation; Green Supply Chain Performance; SEM; Survey.

1. Introduction

In recent years, rapid industrial development has led to negative environmental impacts, including the over-use of resources, toxic pollutions and greenhouse gas (Peng and Lin, 2008). Global climate change has already had observable effects on the planet. It is recognized as the most significant environmental challenge facing humankind today (Dou, 2013). In this line, the effects of climate change pressures on organizations are growing every day (Lee, 2012). As a result, increasing concerns for the environment and social responsibility over the last few years, including pressure from customers, regulators, and other stakeholders, have led organizations to consider sustainability as part of their strategic management (Sprengel and Busch, 2011). For example, it has now become more common and accepted knowledge that for organizations to remain competitive, a proper balance of economic, environmental and social priorities needs to be managed in their global operations (Cherrafi et al., 2016b). Thus, determining how to promote sustainability is currently one of the most important issues being investigated in both theory and practice (Dou, 2013).

A successful transition to sustainability depends on many factors related to the economy, society, politics, law and culture (Dou, 2013) and requires radical changes in technology, institutions, business strategies and consumption practices. As a result, companies are likely to face new challenges, especially in terms of the management of their processes and operations. This scenario requires changes in innovation practices and the deployment of new methods and approaches to improve sustainability performance not only at a company's level but also across supply chains. Firms need to extend their focus beyond internal operations to external partners in their supply chains (Martínez-Jurado and Moyano-Fuentes, 2014). In this context, lean, green and process innovation practices have emerged as major parts of the sustainability answer to support organizations in becoming more competitive and sustainable in an ever more volatile and highly demanding market arena (Hojnik and Ruzzier, 2016; Garza-Reyes, 2015a).

Several studies have investigated the relationship between lean and green practices (Dües et al., 2013; Martinez-Jurado & Moyano-Fuentes, 2014; Tomelero et al., 2017; Cherrafi et al., 2017a; Colicchia et al., 2017). These studies have supported the synergetic effect between the two strategies. The integration of lean and green practices can have a more important, positive impact on organizational performance when implemented together (Carvalho et al., 2017; Ng et al., 2015). According to Cherrafi et al. (2017a), the organizations that have simultaneously implemented lean and green practices have achieved better results than those organizations that have only focused on either of the initiatives. The integration of lean and green will need a new approach for addressing economic and environmental issues. This will require process innovation for maximizing the impact of synergetic effects and help organization to be more competitive and environmentally sustainable (Maneesh and Vasco, 2018).

Several studies can be categorized under the label of "Green and Lean" (e.g. Garza-Reyes et al., 2018; Cherrafi et al., 2016a; Garza-Reyes, 2015a), "Lean and Green Supply Chain" (e.g. Carvalho et al., 2017; Martínez-Jurado et al., 2014; Hajmohammad et al., 2013), "Innovation and Supply Chain" (e.g. Jabbour et al., 2015; Zailani et al., 2015; Lii et al., 2016; Zimmermann et al., 2016) or "Innovation and Lean" (He et al., 2015). However, no research has explored the relationship between the practices of these three approaches (i.e. lean, green and process innovation) and their effect on different dimensions of Green Supply Chain (GSC) performance.

It is clear that process innovation, green lean and supply chain sustainability have been extensively investigated, but mainly treated as separated research streams, which has resulted in these subject fields being separately and independently researched from each other. This suggests the existence of a gap in our current understanding of the relationship of supply chain sustainability, lean, green and process innovation. Putting all these subjects together is a challenge and the originality of this research. In addition, the lack of a clear relationship between these practices and GSC performance is an obstacle for companies seeking to justify the implementation of GSCs. Given this situation, this study aims at proposing a conceptual framework to analyze the effect of process innovation, green, and lean practices on the performance of GSCs. In addition, this paper aims to study how these practices differ in diverse regions of the world. Green supply chain, lean manufacturing and process innovation are mostly associated with large firms from developed countries. Increasingly, small and medium enterprises (SMEs) in both developed and developing countries participate in the efforts to adopt green supply chain management practices. Thus, international comparative studies should include both small and large firms from both developed and developing countries.

This study has significant theoretical and practical contributions. At the theoretical front, it develops a theoretical framework to study the relationship between different elements of interest for this research, namely: process innovation, lean, green and GSC performance. Such relationship has not been assessed in the scholarly literature and is important in clarifying the role of the three constructs regarding their effect on GSCs. At the managerial front, this research can help managers in understanding the role of different constructs on GSC performance and consequently to formulate appropriate strategies for effectively developing and/or adopting GSC practices within their organization. Considering this, the main research question addressed by this research is:

- Is there any relationship between lean, green and process innovation practices and a synergetic-combined effect of these on the performance of GSCs?
- What is the quantified individual and combined effects of lean, green and process innovation on GSC performance, and how can it be explained?

The rest of the paper is structured as follows: in the following section, a literature review related to lean, process innovation, green practices and their linkage to GSC performance is presented. From the literature review, hypotheses are formulated and a research framework to establish the theoretical and casual relationships between lean, process innovation, green practices and GSC performance is proposed. Then, the research methodology is described, and data analysis and results presented. Lastly, considerations, implications, and conclusions derived from the present research are included.

2. Literature review and hypotheses formulation

The objective of this literature review is to reflect on and analyze the current body of research exploring the relationship between lean, green and process innovation practices, and their effects on GSC performance. First, literature exploring the individual effects of these practices on GSC performance is reviewed, followed by similarities between them to analyze their combined effect on GSC performance. Based on this, hypotheses are formulated and a research framework for GSC performance that establishes its casual relationships with lean, green and process innovation practices is proposed. These are subsequently tested in the following sections. Figure 1 illustrates the sequence of activities carried out during the literature review stage of the present research.

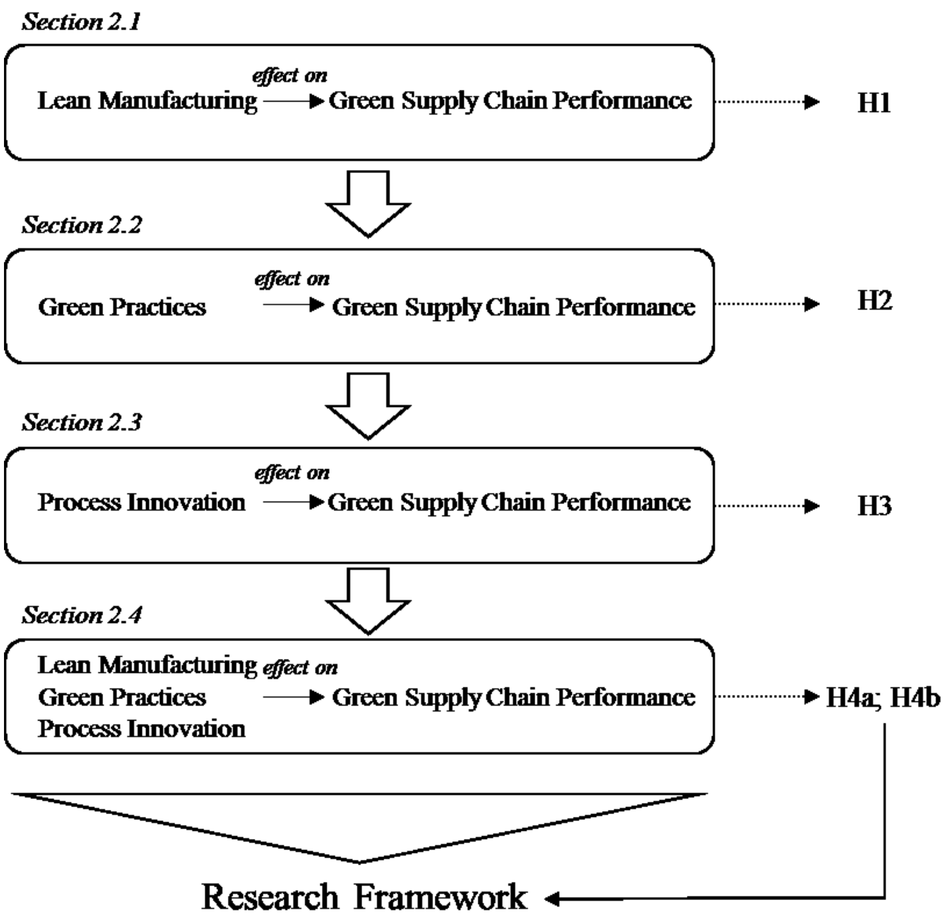

Fig.1. Structured approach to the literature review of the present research

2.1. The impact of Lean Management on Green Supply Chain Performance

The main goal of a lean system is to produce products or services of higher quality at the lowest cost and in the least time by eliminating wastes (Dennis, 2007). Within the lean context, waste is defined as "anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product" (Russell and Taylor, 2000). Seven forms of waste are identified: transport, inventory, motion, waiting, overprocessing, overproduction, and defects. All of these wastes have a direct impact on performance, quality and costs, and these are all non–value–adding operations for which customers do not want to pay. In recent decades, organizations in different economic sectors have implemented lean management (LM) and in many cases this has helped them to improve their competitiveness (Belekoukias et al., 2014). In this context, it is important for lean practices and principles to be spread throughout the supply chain to derive the potential benefits of LM (Hajmohammad et al., 2013). There is evidence in the literature regarding the positive impact of LM on the economic and social sustainability of supply chains. According to Fliedner and Majeske (2010), sustainability is the next evolutionary stage of LM as it goes beyond the internal waste elimination of Ohno's seven lean principles, encouraging external waste reduction across the supply chain and leading to the improvement of social conditions globally (Govindan et al., 2014a). LM can be implemented right across the whole supply chain, from placing the order with suppliers to product distribution and delivery to the customer, with the aim of reducing wastes, improving quality, increasing flexibility and customer service and reducing costs at all stages of the supply chain (Marodin et al., 2017).

The LM strategy has a positive impact on economic performance in the following way: a positive impact of the level of internal LM implementation on both suppliers and customers (So and Sun, 2010), improvements in results to be achieved in the chain as a whole (Pérez et al., 2010), business risk reduction through joint investments in R&D and technology, improved product quality, reduced inventories, increased knowledge through collaborative product design or an overall reduction in wastage throughout the supply chain (Marodin et al., 2017). In the same way, LM is important for achieving environmental sustainability across the supply chain and, ultimately, all the potential benefits of the Green Supply Chain strategy (Campos et al., 2016; Mollenkopf et al., 2010). Thus, LM impacts on environmental sustainability in the following way: close and long-term relationships trigger the adoption of environmental management practices (Florida, 1996), some practices and tools, such as lean supplier development and value stream mapping, could be useful for adopting environmental management practices (Mason et al., 2008), collaborative design from the very first stages of product development impacts on environmental design to reduce environmental pollution throughout all stages of a product's life cycle (e.g. closed-loop supply chain) (Carvalho et al. 2017; Carvalho et al., 2011). Garza-Reyes et al. (2018) found that lean approaches such as Total Productive Maintenance and Just-in-Time have a positive effect on environmental performance, whereas continuous improvement can also help to reduce the use of materials and release of pollutants. Other positive results that come out of the synergy between the LM and GSC management strategies are reductions in inventory levels, excess capacity, transport and production times, and increased levels of integration and frequency of information sharing throughout the supply chain (Carvalho et al. 2017; Carvalho et al., 2011). From this perspective, the following hypothesis is formulated:

H_1: LM has a positive effect on Green Supply Chain performance

2.2. The impact of Green practices on Green Supply Chain Performance

In recent times, changes in the business environment, including increasing environmental awareness, pressure from customers, legal requirements, the need for waste management, product recovery, reuse of materials and packaging, and changes in product projects, have influenced supply chain management (de Oliveira et al., 2018). Thus, organizations have been forced to make their operations greener and more sustainable by adopting initiatives that take into consideration the environmental impacts of their processes, services and products (Vinodh et al. 2016; Garza-Reyes, 2015a). In this line, green practices have emerged as a new philosophy to help organizations to improve their environmental performance while still achieving their economic objectives (Cherrafi et al., 2016a; Garza-Reyes, 2016b).

In a literature review conducted by Srivastava (2007) about GSCs, green practices were classified into four groups: green design (eco-design and life cycle assessment), green operations (green manufacturing and remanufacturing), reverse logistics and waste management. This classification was selected to delimit the present study because the first was a compilation of the most often described practices in the literature. According to Jayal et al. (2010), efforts to make manufacturing more sustainable must take into consideration product, process and systems perspectives. At process level, occupational hazards, resource and energy consumption, and toxic wastes need to be minimized. At system level, all aspects of the entire supply chain need to be considered, taking into account all of the major life cycle stages—pre-manufacturing, manufacturing, use and post-use—over multiple life cycles.

The impact of green practices on supply management performance has been the topic of several studies (Vanalle et al., 2017). This impact includes economic, environmental and social performance. Various researchers have provided empirical evidence to support the linkage between the adoption of green practices within a firm, or across its supply chain, and its environmental and social performances. Vinodh et al. (2011) argue that the adoption of green practices in supply chains can have a positive impact on sustainability; one example is related to Ford, where this company had implemented recyclable plastic containers for shipping their car parts as opposed to cardboard, reducing CO2 emissions during transportation, improving process efficiency since new containers were handled more easily by plant workers, and reducing transportation cost by over 25%. According to Scur and Barbosa (2017), leading manufacturers generally implement green practices and have high levels of environmental and social performance including improved environment; better compliance with environmental regulations; more cohesive working environment for laborers and; better public image of the organization (Halme et al., 2002). Moreover, the implementation of green practices offers many significant economic benefits (Dubey et al., 2015; Govindan et al., 2014b), which present a "win-win" situation for firms and the environment (Beckmann et al., 2014). Green practices can reduce material and production costs, reduce transportation and logistics cost, increase product quality, reduce warehouse cost, and even increase innovativeness (Pagell and Gobeli, 2009; Svensson, 2007). These practices enhance resource efficiency which relates directly to economic performance (Zhang et al., 2012). Rao and Holt (2005) demonstrated a positive relationship between green practices and the economic performance of supply chains. They also found that GSCM practices led to competitiveness and better economic performance. Also, Fang and Zhang (2017) found that, internal and external GSCM practices are positively related, and they are both positively related to firm performance. They found out that both operational and economic performance are positively correlated with environmental performance of GSCM practices, and that there is also a significantly positive relationship between operational and economic performance.

However, there is a need for more research in this area to ascertain how green practices interact with different performances of GSCs. Consequently, the following hypothesis is formulated:

H_2: Green practices have a positive effect on Green Supply Chain performance

2.3. The impact of Process Innovation on Green Supply Chain Performance

Over the past few decades, rapid changes in the business arena and globalization have forced organizations, regardless of their size; to adopt innovation to face the dynamic uncertainty and intense competition posed by such business environment (Pan and Li, 2016). Innovation has thus become vital to organizations' growth and survival (Hojnik and Ruzzier, 2016). The literature on innovation distinguishes between different types of innovation, for example, process innovation and product innovation. The present study pertains to process innovation, which refers to new elements (e.g. new production methods, management approaches and new technologies) introduced into organizations' management and production operations (Brem et al., 2016; Salerno et al., 2015). It involves the use of new knowledge, tools and devices inputs that can help organizations to reconfigure, exploit and maximize resources and capabilities in order to reduce costs and enhances production efficiency (Salerno et al., 2015). Process innovation may possibly be translated into investment in new technology embodied in equipment and machinery, new software for supply-chain management, new software for designing products and training of staff to offer new services to customers, etc. (Pan and Li, 2016).

With increasing environmental concerns, a new field of process innovation called green process innovation has emerged. It aims at modifying manufacturing systems and processes in order to reduce environmental impacts, pollution, and other negative effects on the use of resources (Xie et al., 2016). Saunila et al. (2017) found that green innovation is driven by economic and institutional pressures, and that such innovation can create value in terms of social sustainability. Previous empirical research suggests that process innovation improves various aspects of firms' performance (Lau et al., 2010; Lambertini and Mantovani, 2009). Specifically, it can improve customer satisfaction, operational performance, and also financial performance. Chen et al. (2006) found that the implementation of process innovation delivered positive outcomes – the more the firms invested in process innovation, the stronger was their competitive advantage. Similarly, Chiou et al. (2011) concluded that process innovation is positively related to a firm's competitive advantage. Companies implement process innovation in manufacturing processes to shorten production time and reduce costs (Tariq, 2017). More recently, Hojnik and Ruzzier (2016) determined that process innovation is worthwhile in terms of company profitability, growth, and competitive benefits. According to Kleindorfer et al. (2005), process innovation can assist organizations in increasing the economic and social performance of a company through waste and cost reduction. In this context, Doran and Ryan (2012) found that organizations that implement process innovation enjoy higher levels of revenue per employee than organizations that do not introduce process innovation. Moreover, firms that apply process innovation do not only improve market position, resolve difficulties and increase competitive advantages, but also improve corporate image, leapfrogs competition and creates breakthroughs (Presley et al., 2007; Mu et al., 2009).

With increasing environmental concerns, organization could also adopt green process innovation to reduce environmental risks, pollution, and other negative effects on resources use throughout its life cycle (Zhao and Sun, 2016). According to Peng and Liu (2016), green process innovation can make a substantial contribution to improve the environmental performance of organizations (Berrone et al., 2013; Qi et al., 2010). Therefore, three performance types (i.e., economic, environmental, and social) are considered within the benefits and outcomes of process innovation. Researchers have also considered the specific impact of process innovation within a supply chain context. For example, in a survey of 153 firms in the Malaysian automotive supply chain industry, Zailani et al. (2015) found a positive effect of process innovation on simultaneous firms' economic, social, and environmental performances. In general, researchers agree that improved innovation performance cannot be achieved by the firm on its own and there is an increased need for supply-chain collaboration (Kibbelling et al., 2013; Soosay et al., 2008). In addition, according to de Vargas Mores et al. (2017), supply chain collaboration is an important element to reduce the social and environmental impact along the supply chain. However, only few studies have analyzed the relationship between process innovation and green supply chain performance. For this reason, Gao et al. (2017) called for more research under the supply chain context. Since competition has moved beyond the single firm to the supply chain, and given the importance that process innovation has for the survival of organizations in the current market, the study of the impact of process innovation on green supply chain performance is of great importance. We have consequently proposed the following hypothesis:

H_3: Process innovation has a positive effect on Green Supply Chain performance

2.4. Lean, Green, Process Innovation and Green Supply Chain performance relationship

In the supply chain context, it is important to integrate management practices that do not only improve organizational and overall supply chain performance, but also that take into consideration the economic, environmental, and social dimensions (Beske, 2012). According to Govindan et al. (2014a), supply chain management should be concerned with its sustainability. Lean, green, and process innovation are referred to as SCM paradigms which can help organizations to become more sustainable and competitive in a high and volatile market. However, no researches have simultaneously explored the practices of these three approaches and their impact on green supply chain performance. The existing literature has only focused on two of these SCM paradigms (green and lean) and supply chain performance.

According to Azevedo et al. (2012), the implementation of lean and green practices along the supply chain enables an enhanced economic, environmental, and social performance. The benefits of integrating lean and green principles include reduced lead time and costs, improved process flow, better relationships with suppliers, customers and other stakeholders, improvement of environmental quality, as well as employee morale, and commitment (Cherrafi et al., 2016a; Hajmohammad et al., 2013). Integration of process innovation with these practices might be of greater value not only to a company's operation, but also to its supply chain. The performance of green lean supply chain can be supported and enhanced through the adoption of process innovation.

The proposed synergetic relationship between lean, green, process innovation and GSC performance can be supported by the resource-based view (RBV). The RBV aims to describe, explain and predict how organizations can achieve a sustainable competitive advantage by acquiring and controlling valuable, rare, inimitable and non-substitutable resources (Peteraf, 1993). Operation management systems such as lean and green viewed from a RBV perspective might not satisfy the requirements to be a source of sustainable competitive advantage. They can be substitutable and transferable across organizations and supply chains. The integration of process innovation with these practices will be of greater value not only for an organization's operation but also to its supply chain. Based on the RBV and previous literature, we believe that the impact of green and lean on GSC performance might be complemented by process innovation, resulting in a complementary performance enhancing relationship. According to Teece (1986), complementarity refers to how one resource might influence another, and how this relationship affects a firm's competitive position or performance. Consequently, we propose the following hypothesis:

H_4: The adoption of green practices and lean management has a stronger positive impact on green supply chain performance when combined with process innovation

Based on the conclusions and propositions derived from the literature, the following conceptual research framework is suggested to investigate the relationships between lean, green, process innovation and GSC performance, see Figure 2. Green and lean are the independent variables that are suggested to improve green supply chain performance (H_1 and H_2). Process innovation is also expected to improve green supply chain performance (H_3) and also moderate the impact of green and lean practices on performance (H_{4a} and H_{4b}). Organization size and industry were used as control variables. The effects of firm size are represented by the dotted lines. The subsequent sections report the empirical results of the testing of this framework with its associated hypotheses.

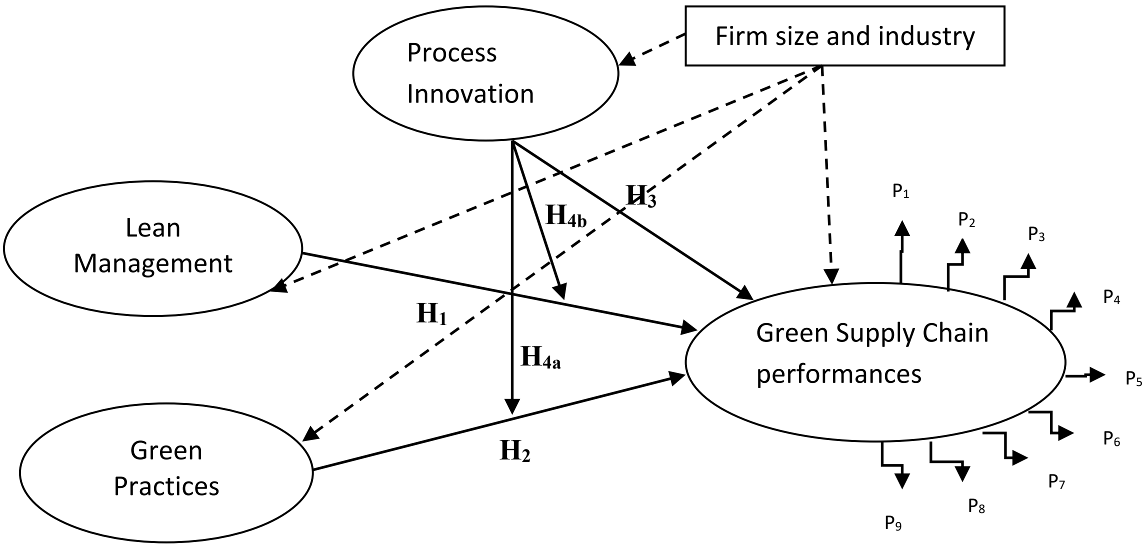

Fig.2. Research framework

3. Research methodology

This research used a quantitative survey with a structured questionnaire to collect data to study the impacts of lean, green and process innovation on GSC performance. The collected data was analyzed using SPSS Software Version 19. Details are addressed in following sub-sections.

3.1. Instrument development and data collection

A structured questionnaire was designed to obtain quantitative data for the statistical testing of the hypotheses. The questionnaire consisted of five sections with a total of 59 items. The first section was designed to capture basic profile information and demographic details about the respondents and their organizations. The rest of the sections consisted of questions to evaluate the impact of green, lean, and process innovation on GSC performance. To avoid social desirability bias, respondents could either choose to give their email addresses and the name of the company or remain anonymous.

The survey was prepared in English. National translators handled the translation of the survey as needed. The translators were identified through the most relevant professional groups existing on LinkedIn. During the translation process, we ensured to maintain the intended meaning and the measurement properties of the source questionnaire.

The items, see Appendix A1, were measured by using a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Data was collected from executive directors, engineers, manufacturing managers, production managers, operation managers, quality managers, and managing directors employed in various organizations in thirteen countries. This category of respondents was directly involved and had experienced on the supply chain operations and activities of their respective organizations. Before the questionnaire was mailed, it was pretested by taking feedback from three supply chain managers and two academic experts in the subject. Pretesting contributed in verifying the appropriateness and clarity of the questions in order to improve the survey and to ensure content validity. After pretesting the questionnaire, a pilot study was conducted to test the reliability of the study instrument. The questionnaire was then sent to the organizations. The targeted firms were selected based on a frame of population originated from a supply chain professional mailing list acquired from a reputable professional survey list development organization. This organization provided a random selection of 8,500 organizations from different manufacturing sectors and countries. Among them, 2,000 organizations were randomly selected by means of a systematic sampling to reflect different sizes, regions and manufacturing sectors. The systematic sampling is a method recommended by Forza (2002) for probabilistic sampling. In addition and according to Black (2004), systematic sampling is a type of probability sampling alternative in which sample items from a larger population are designated from a random starting point followed by items chosen at a fixed periodic interval.

This makes systematic sampling functionally similar to simple random sampling (Vanalle, 2017).

According to Luthra et al. (2016), the selection of the sample, and its size, are of paramount importance for achieving adequate/reliable data from the questionnaire survey. In the present study, data was collected from 374 units from thirteen countries. This provided enough data for the evaluation of their practices and an important source of information related to the impact of green, lean, and process innovation on GSC performance within an international context. Consequently, this sample frame can contribute in generalizing the results throughout these countries, which can be viewed as an advantage in comparison to single country studies (Onofrei et al., 2016).

Table 1 shows the characteristics of the organizations that participated in the study survey in terms of country, industry, and company size. After a number of email reminders, a total of 374 usable responses were collected to test the previously formulated hypotheses and research framework.

Table1. Characteristics of the sample

Country	**Frequency**	**Industry**	**Frequency**	**Size***	**Frequency**
Morocco	13	Chemical and plastics	22	< 50	42
South of Africa	15	Advanced manufacturing	13	51-100	89
Germany	59	Automotive	114	101-500	147
France	48	Biotechnology	7	501-1000	30
Italy	13	Building and construction	42	>1000	18
Spain	29	Food and agribusiness industry	61		
Sweden	18	Textile, clothing and footwear	58		
Finland	27	Pharmaceutical and health technologies	19		
USA	45	Metal and mining	19		
Austria	31	Other industries	5		
Brazil	37	Wood products and associate manufacturing	14		
Malaysia	23				
India	16				
Total	**374**	**Total**	**374**	**Total**	**374**

*Number of employees

In the present study, organization size and industry were used as control variables in order to make our results more conclusive and increase its generalizability. These variables were chosen because they have significant effects and may affect the results of the study. First, we included organization size as a control variable as it has been reported by various researchers as a significant factor that influences the adoption of green, lean and process innovation (Maneesh and Vasco, 2018; Wu, 2013; Wiengarten et al., 2013; Shah and Ward, 2003; Singh et al., 2014; Teles et al., 2015). The larger companies are most likely to implement green, lean, process innovation and green supply chain practices (Cainelli et al., 2015, Kesidou and Demirel, 2012; Jayaram and Avittathur, 2015). In addition, small and medium enterprises may encounter more challenges in implementing these practices due to small resource bases (Cherrafi et al., 2016a; Bose and Pal, 2012; Lee and Klassen, 2008). Second, we used industry sector as an additional control variable. Several studies have suggested that industries differ in terms of processes, pressures, barriers and opportunities to implement green, lean, process innovation and green supply chain management practices (Cherrafi et al., 2017; Jakobsen and Clausen, 2016). Organizations in some industries are more likely to obtain better performance from the implementation of these practices (Maneesh and Vasco, 2018). Therefore, we concluded that there is a need to include the firm size and industry as a control variable in the present study.

3.2. Measurement framework validation

To check the internal reliability of the collected data, the Cronbach's alpha reliability test was performed for the questionnaire constructs. In this study, the Cronbach's alpha of all constructs was well above the recommended value of 0.7 (Nunnally, 1978), with a minimum of 0.834, see Table 2. These results indicated that the study questionnaire was in compliance with internal consistency reliability requirements. Next, a confirmatory factor analysis (CFA) was conducted to examine the validity of the measurement framework, see Appendix A2 for the CFA input data, i.e. the variance / covariance matrix of the observed variables. Table 2 provides an overview of the CFA results in terms of their factor loading, t-values and standard errors. It is also important to address incremental and absolute fit issues. A comparison of the following goodness-of-fit values against those in Hu and Bentler (1998) showed that the proposed research framework was satisfactory (RMSEA= 0.028; RMSEA 9 à per cent conf. interval (0.015; 0.039); RMR=0.05; GFI=0.948; NNFI=0.978; AGFI=0.933; CFI=0.995; RFI=0.974; IFI=0.995). Moreover, the ration of chi-square to degrees of freedom of 1.295 (x2/df) was lower than the threshold of 3 required for an acceptable framework fit (Kline, 1998). Additional, the chi-square is 189.014 with a p value of 0.01. Thus, it was possible to conclude that the items represented a reasonable measure of the constructs under examination.

Convergent validity and discriminant validity were also evaluated to confirm the measurement framework. Convergent validity was assessed by comparing the coefficients and the standard error of the items. As shown in Table 2, the results revealed that each coefficient was greater than twice its associated standard error (Anderson and Gerbing, 1988). Two tests were used to examine convergent validity. Convergent validity would be achieved if the values of average variance extracted (AVE) for each factor is greater than 0.50 and the CR of all the constructs exceeds 0.80 (Fornell & Larcker, 1981).The results, see Table 2, confirmed the convergent validity of the measurement framework. On the other hand, discriminant validity was examined by using intra-factor correlations. The results in Table 3 showed that inter-factor correlation was within an acceptable range. Therefore, it was concluded that the measure had adequate levels of discriminant validity.

Table 2. Construct measurements summary: Confirmatory factor analysis and scale reliability

Construct	Variable	Loading	t-value	Std. Error
Green practices α= .881 AVE=0.694 CR=0.881	Eco-design and life cycle assessment (Zhu et al., 2005)	0.82	18.80	0.072
	Green manufacturing (Rao and Holt, 2005)	0.78	17.49	0.069
	Reverse logistics (Zhu et al., 2005; Chan et al., 2016; Lai et al., 2013; Abdullah and Yaakub, 2014; Huang et al., 2015)	0.83	19.09	0.071
	waste management (Rao and Holt, 2005; Badurdeen et al., 2009)	0.79	17.91	0.072
Lean management α= .834 AVE=0.694 CR=0.901	JIT (Panizzolo, 1998)	0.83	19.18	0.072
	Set-up time reduction (Doolen and Hacker, 2005)	0.83	19.28	0.072
	Cellular manufacturing (Shah and Ward, 2003)	0.85	19.99	0.068
	Waste elimination (Schulze and Störmer, 2012)	0.82	18.80	0.070
Process innovation α= .911 AVE=0.774 CR=0.911	Fast response to the new processes introduced by other companies within the same sector (Leiponen, 2000; Rao & Drazin, 2002)	0.92	22.37	0.066
	Pioneering disposition to introduced new process (Leiponen, 2000; Rao & Drazin, 2002)	0.88	20.95	0.067
	Number of changes in the process introduced in one year (Leiponen, 2000; Rao & Drazin, 2002)	0.84	19.46	0.068
Green supply chain performance α= .985 AVE=0.894 CR=0.985	Economic efficiency (Rao and Holt, 2005; Zhu et al., 2013)	0.92	23.32	0.068
	Performance (Chan et al., 2016)	0.95	24.62	0.064
	Integration (Green et al., 2008)	0.95	24.84	0.065
	Collaboration (Azevedo et al., 2012; Diabat et al., 2013; Diabat and Govindan, 2011; Holt and Ghobadian, 2009)	0.95	24.54	0.063
	Responsiveness (Aramyan et al., 2009)	0.95	24.96	0.062
	Cost (Zhu et al., 2008 ; Zhang et al., 2012)	0.95	24.62	0.061
	Value creation (Govindan et al., 2014c ; Zhu et al.,2013)	0.94	24.49	0.065
	Sustainability (Zhu et al., 2013 ; Scur et Barbosa, 2016)	0.95	24.69	0.066

Table 3. Inter-factor correlations

Factors	[1]	[2]	[3]	[4]
[1] Green practices	0,880			
[2] Lean management	-0,279	0,806		
[3] Process innovation	-0,238	0,327	0,833	
[4] Green supply chain performance	-0,343	0,786	0,741	0,945

The survey instrument was prone to the common method variance (CMV). Most researchers agree that CMV is a potentially seriously biasing threat. It can lead to wrong conclusions about relationships between variables by inflating or deflating the findings (Craighead et al., 2011). CFA was used to examine the possibility that common method bias threatened the interpretation of our results. The results showed that all measurement items continued to load on their originally assigned latent variables, suggesting that common method bias was not a serious threat in this study.

The survey was administered across thirteen countries in all regions of the world. In order to verify that respondents completed the questionnaire using the same frame-of-reference and interpreted the rating scale intervals similarly, the measurement equivalence had to be examined. According to Rungtusanatham et al. (2008), ignoring equivalence issues may lead to conclusions that are ambiguous at best and erroneous at worst. Table 4 shows a country specific sample overview of the analyzed and confirmed practices in lean, green and process innovation. The country-specific mean and standard deviation value were listed for all practices.

Table 4. Measurement equivalence

Country	Lean practices (Mean/S.D)	Green Practices (Mean/S.D)	Process innovation (Mean/S.D)
Morocco	3.57/1.15	3.19/1.05	3.07/1.47
South of Africa	3.25/1.54	3.84/1.32	3.65/1.15
Germany	3.66/1.42	3.47/1.06	3.57/1.31
France	3.05/1.27	2.59/1.21	3.72/1.20
Italy	3.74/1.36	3.62/1.13	3.18/1.59
Spain	3.00/1.50	3.47/1.20	3.53/1.33
Sweden	3.81/1.31	3.54/1.38	3.80/1.32
Finland	3.27/1.47	4.09/1.18	3.79/1.20
USA	2.96/1.33	3.72/1.33	3.58/1.50
Austria	3.38/1.24	2.61/1.42	4.15/1.39
Brazil	3.19/1.39	3.73/1.61	3.62/1.43
Malaysia	3.42/1.13	4.17/1.40	3.09/1.52
India	3.07/1.24	3.50/1.60	3.97/1.36

4. Results

To examine the hypotheses and research framework, a series of ordinary least square (OLS) regression analyses were carried out. There are three main reasons for the use of OLS in this research. First, given that this research is confirmatory in nature, OLS is considered the most appropriate tool (Todman and Dugard, 2007). It is unbiased, relatively easy, consistent, and has an asymptotically normal sampling distribution (Hutcheson and Sofroniou, 1999). In addition, OLS will provide the best estimates when all of the assumptions are met and is not influenced by the scale of the variables (Greene, 2002; Tabchinik and Fidell, 2001). Second, OLS has been widely used to study the green manufacturing, innovation and supply chain management (King and Lenox, 2001; Oke, 2013; Sarkis et al., 2010; Wiengarten, 2016). Third, OLS is the most common tool used to study the effects of multiple variables on one response measure. Thus, given that this study aims to examine the impact of Lean, Green and process innovation on green supply chain performance, use of OLS is well-justified.

Prior to performing the OLS analysis, data characteristics for linearity, homoscedasticity, normality, and multicollinearity were tested (Hair et al., 2010; Kennedy, 1999). Linearity, homoscedasticity and equality of variables were tested and confirmed through plotting the standardized residuals against the standardized predicted values. The residuals are randomly distributed around the zero horizontal line, which shows linear regression models are appropriate for the data. On the other hand, the visual verification showed that there is no clear pattern in the residual distribution, which shows that the assumption of homoscedasticity is fulfilled. Moreover, the assumption of normality is evaluated using the normal probability plot of residuals. The residuals lie reasonably close to a straight line, indicating that the normal distributed of residuals is fulfilled.

In order to examine multicollinearity, the method proposed by Belsley et al. (1980) was used. Firstly, the variance inflation factors were calculated and analyzed to detect any possible threats, see Table 5. The results obtained confirmed that multicollinearity was not a major problem in this study. These preliminary analyses indicate that data fulfill the required conditions for OLS analysis.

The regression analysis was carried out in two separate frameworks reflecting the two interactions item (i.e. lean and process innovation; green practices and process innovation). In the first step we entered our control variables company size and industry. In the second step lean practices (framework 1) and green practices (framework 2), and process innovation, and the third step the interaction term (framework 1: lean and process innovation; framework 2: green practices and process innovation).

Table 5. OLS analysis

	Framework 1: Lean practices	Framework 2: Green practices
Variable	Std. Estimate	Std. Estimate
Control variable		
Industry	-0.004	-0.013
Organization size	0.003	0.005
Independent variables		
Lean practices	0.187**	
Green practices		0.191**
Moderator: process innovation	-0.059	0.096
Interactions		
Lean practices X process innovation	0.117*	
Green practices X process innovation		0.095*
Step 1:Adjusted R^2/Sig. F change	0.012 0.003	0.011 0.003
Step 2:Adjusted R^2/Sig. F change	0.045 0.000	0.044 0.000
Step 3:Adjusted R^2/Sig. F change	0.048 0.003	0.047 0.013
Max variance inflation factors	1.116	1.066
Notes: *Sign. At the level 0.05; ** Sign. At the level 0.001		

H_1 proposed that the implementation of LM has a significant and positive impact on the performance of green supply chains. The initial results presented in Table 5 showed that the implementation of LM practices such as JIT, set-up time reduction, cellular manufacturing, and waste elimination do significantly improve green supply chain performance (β=0.187; p<0.001). Our findings are consistent with the previous empirical research which has highlighted that the implementation of LM practices can have a significant effect on green supply chin performance (Martínez-Jurado and Moyano-Fuentes, 2014).

In H_2 it was hypothesized that the implementation of green practices have a significant and positive impact on green supply chain performance. The results presented in Table 5 suggested that, as expected, the adoption of green practices such as eco-design and life cycle assessment, green manufacturing, reverse logistics, and waste management do significantly improve green supply chain performance (β=0.191; p<0.001). Therefore, the results confirmed the findings of previous studies regarding the positive relationship between green practices and GSC performance (Zhang et al. 2012; Vinodh et al., 2011).

H_3 assumed that the adoption of process innovation has a significant and positive impact on GSC performance. Previous literature on process innovation has suggested that this type of innovation activity is a comprehensive and systematic mechanism to improve different performances (Brem et al., 2016; Salerno et al., 2015; Zailani et al., 2015; Lau et al., 2010; Lambertini and Mantovani, 2009). However, contrary to this, the results obtained from our analysis, and presented in Table 5, showed that the adoption of process innovation practices do not improve GSC performance.

In the final hypothesis, it was suggested that the implementation of LM and green practices have a stronger positive impact on green supply chain performance when combined with the adoption of process innovation. To study these potential synergetic effects, interaction terms were calculated, modelling process innovation as the modeling variable. In this context, H_{4a} tested the synergetic effects between process innovation and lean practices. Adding the two way interaction to the OLS Framework 1 contributed to a significant change in the variance explained (R^2 adj: 0.048, p=0.003), and the interaction terms was significant (β =0.117, p<0.001). To interpret this finding, the significance of the slopes was calculated at low and high levels of process innovation. The results showed that the implementation of LM practices were more strongly associated with green supply chain performance when the adoption of process innovation was higher (β =0.28; p<0.001) than when process innovation was low (β =0.17; p<0.05). This suggested that the implementation of LM practices does have a higher payoff rate in terms of GSC performance when the firm is also adopting process innovation. In this perspective, it is concluded that there is a synergetic effect between process innovation and LM practices.

H_{4b} was formulated to investigate the synergetic effects between process innovation and green practices. Adding the two way interaction to the OLS Framework 2 contributed to a significant change in the variance explained (R^2 adj: 0.047, p=0.013), and the interaction terms was significant (β =0.095, $p<0.05$). To interpret this finding, the significance of the slopes was calculated at low and high levels of process innovation. The results showed that the implementation of green practices was more strongly associated with GSC performance when the adoption of process innovation was higher (β =0.29; $p<0.001$) than when process innovation was low (β =0.15; $p<0.05$). This indicated that the implementation of green practices does have a higher effect in terms of GSC performance when the firm is also adopting process innovation. In this perspective, it is concluded that there is a synergetic effect between process innovation and green practices.

4.1 Additional contextual analysis

While all hypotheses were supported throughout this study, it also holds true that there exists contextual factors (regional differences and firm size) that may affect the implementation level of lean, green and process innovation and accordingly, green supply chain performance (Maneesh and Vasco, 2018; Cherrafi et al. 2016a). The literature on green lean, process innovation and green supply chain in general, suggest that the context in which these practices is implemented can influence the performance achieved (Maneesh and Vasco, 2018; Debashree et al. 2018). According to Nevil et al. (2018) the improvement efforts toward green supply chain vary depending on different regions of the world because every region has its own culture, diversity, people, and way of thinking, perceptions, government and unique requirements. We therefore include regional differences and firm size as contextual factors. Table 6 presents a contextual analysis (non-Europe vs. Europe, small vs. medium/large firm, and developing vs. developed countries).

Table 6. Contextual analysis

Hypotheses	Aggregated sample (n=374)	Firm size		Regions			
		Small (<250) (n=184)	Medium/large (>250) (n=190)	Non-Europe (n=180)	Europe (n=194)	Developing countries (n=204)	Developed countries (n=170)
H1	0,507	0.627	0.713	0.18	0.749	1.151	0.203
H2	0,713	0.15	0.2	0,15	0,2	0.922	0.041
H3	0,467	-0.143	-0.161	0.08	0.184	0.340	0.041
H4a	0,216	0.193	0.265	0.140	0.384	0.459	-0.042
H4b	0,211	0.260	0.274	0.126	0.329	0.340	-0.054
Hypotheses	Aggregated sample (n=374)	Firm size		Regions			
		Small (<250) (n=184)	Medium/large (>250) (n=90)	Non-Europe (n=180)	Europe (n=194)	Developing countries (n=104)	Developed countries (n=170)
H1	0,507	0.627	0.713	0.18	0.749	1.151	0.203
H2	0,713	0.15	0.2	0,15	0,2	0.922	0.041
H3	0,467	-0.143	-0.161	0.08	0.184	0.340	0.041
H4a	0,216	0.193	0.265	0.140	0.384	0.459	-0.042
H4b	0,211	0.260	0.274	0.126	0.329	0.340	-0.054

These results indicate that contextual factors (regional differences and firm size) impact the implementation level of LM, green and process innovation practices, and their impact on the performance of GSCs. For the aggregated samples (n=374), all hypotheses were supported. However, differences were noticeable between small (employees <250) and medium/large firms (employees >250) in terms of the strengths of relationship between green practices and GSC performance. For small firms, the impact of green practices on GSC performance was not statistically significant, while medium/large firms displayed a strong and significant relationship. Firms from Europe (n=194) showed a bigger and statistically significant impact of the adoption of green practices on GSC performance when combined with process innovation while non-European countries did not. Another interesting observation on regional variances suggested that developed countries presented all statistically significant relationships in all the relationships while those from developing countries showed somewhat inconclusive results to the proposed relationships. These results indicate that these contextual factors affect GSC performance. Future studies may explore further about these contextual factors and the underlying causes of these differences.

5. Discussion of results

5.1. Effect of lean practices on GSCs performance (H_1)

The results of the analyzes suggested that the adoption of lean practices such as JIT, set-up time reduction, cellular manufacturing, and waste elimination can significantly contribute to the improvement of the performance of GSCs, see Table 5. This in line with the wide amount of evidence found in the academic literature which suggests that LM may act as an effective catalyst and approach to tackle some of the fundamental environmental and sustainability challenges currently faced by organizations and their supply chains (Cherrafi et al., 2016a; Campos et al., 2016; Martínez-Jurado and Moyano-Fuentes, 2014; Mollenkopf et al., 2010). The positive effect of LM on GSC performance may be partially explained due to the ability of its JIT, set-up time reduction, cellular manufacturing and waste reduction practices to lessen inventory levels, excess capacity, and transport and production times (Carvalho et al. 2017; Carvalho et al., 2011). For instance, it is well established in the academic literature that a JIT system, enabled by manufacturing cells and the reduction of set-up time and waste, has a significant positive effect on the reduction of inventory, which exposes problems (Belekoukias et al., 2014). Subsequently, the consumption of material is reduced through better quality that is achieved by eliminating the exposed problems from the root cause, and in this way eliminating/reducing wastes such as scrap and rework (Shingo, 1989). In addition, following the JIT's advice of having smaller deliveries, smaller vehicles can be utilised, resulting in less fuel consumption and CO_2 emissions (Garza-Reyes et al., 2016). Similarly, since JIT, set-up time reduction, cellular manufacturing, and waste elimination will reduce inventory, the energy required to safely store it will also be reduced (Franchetti et al., 2009). Finally, according to Chiarini (2014), by grouping in a single cell machines, staff, and workplaces dedicated to similar products, the transportation of material can be greatly reduced; resulting in a significant reduction of energy consumption of electric vehicles used to move material. In summary, all this evidence intends to explain how LM, through some of its most common practices, can have a positive effect on the reduction of material consumption, waste and energy consumption. These benefits will ultimately go beyond a company's internal operations to also be experienced in their supply chain operations, ultimately contributing to improve their green performance. This is aligned to the results obtained in this study, which also reinforce the idea that sustainability may be considered the next evolutionary step of LM as suggested by Govindan et al. (2014a) and Fliedner and Majeske (2010).

5.2. Effect of green practices on GSCs performance (H_2)

In terms of the effect of green practices such as eco-design and life cycle assessment, green manufacturing, reverse logistics, and waste management, the results of this study indicated that they have a significant positive effect on GSC performance, see Table 5. Since these green practices' main focus is the reduction of the environmental negative impacts of companies' products/services and operations (Garza-Reyes, 2016b) at either product/service, organizational or supply chain levels, their synergy with GSC performance seems logical. Reduction of material consumption, transportation, production resources and hence the minimization of energy and emissions are benefits of these practices (Pagell and Gobeli, 2009; Svensson, 2007) closely associated to the principles and objectives of GSCs. Thus, the results obtained from this research do not only support the logically implicit synergy between green practices and GSC performance, but also that established in the academic literature by authors such as Zhang et al. (2012) and Vinodh et al. (2011). This suggests that organizations that wish to improve the 'greenness level' of their supply chain can consider the adoption of practices including eco-design and life cycle assessment, green manufacturing, reverse logistics, and waste management as a catalyst to achieve this endeavor.

5.3. Effect of process innovation on GSCs performance (H_3)

The academic literature shows a wide consensus regarding the positive effect of process innovation on different types of organizational performance that include customer satisfaction, operational performance, financial performance, and competitive advantage (Brem et al., 2016; Salerno et al., 2015; Zailani et al., 2015; Lau et al., 2010; Lambertini and Mantovani, 2009). However, the results of this study indicate that the adoption of process innovation practices such as (1) fast response to the new processes introduced by other companies within the same sector, (2) pioneering disposition to introduced new process, and (3) number of changes in the process introduced in one year, do not have a direct contribution to the improvement of GSC performance, see Table 5. A possible explanation for this may be the fact that all these process innovation activities take place, and are adopted, primarily at a firm level, for which their effect on the performance of the wider supply chain of firms may not be strongly felt. Nevertheless, the success of some specific process innovation activities, for example, those involving product design practices, is crucially dependent upon the alignment with corresponding supply chain configurations. For example, Pero et al. (2010) and Van Hoek and Chapman (2007) indicate the need for aligning product design and supply chain management and design. This may suggest a stronger and direct effect of this specific process innovation practice on the performance of GSCs. Therefore, although an indirect positive effect between process innovation and GSC performance was found to actually exists, see following section regarding H_4, further studies need to be conducted to determine whether process innovation positively and directly affects GSC performance. Additionally, since the results of this study contradict those of the previous academic literature, a suggestion to perform further studies in relation to this aspect is recommended as part of a future research agenda to validate the results of this study and advance knowledge in this subject area.

5.4. Combined effect of lean/green practices and process innovation on GSCs performance (H_4)

Despite the results of this study indicated that process innovation does not have a direct positive effect on GSC performance (H_3), further results (H_4) also suggested that process innovation has an ‘amplifying’ effect which contributes for LM and green practices to offer a higher payoff rate in terms of green supply chain performance when these are coupled with process innovation activities. Thus, it was concluded that there is a synergetic positive effect between process innovation and LM/green practices, where the first enhances the former. Due to the lack of previous studies in the academic literature exploring the relationship between process innovation and LM/green practices and their effect on GSC performance, it is not possible to establish an alignment, or misalignment, of these results to the academic theory. However, since it has been previously established that LM fosters innovation, including process innovation (He et al., 2015), the synergetic positive effect between process innovation and lean/green practices and their positive impact on GSC performance can be considered aligned to this principle and findings. Due to their nature and current maturity, LM and green practices may be substitutable and transferable across organizations and supply chains. However, when these are adopted in a company’s processes innovatively and in a way in which such adoption is rare and difficult to imitate, then the benefits and payoffs of LM and green practices may be magnified. This magnified LM/green positive effect will not only be felt within the internal company’s operations but also throughout its supply chain operations as indicated in the academic literature (Carvalho et al., 2017; Martínez-Jurado et al., 2014; Hajmohammad et al., 2013) and as established by the results of this study obtained when testing H_3 and H_4. These conditions may explain some of the reasons of the magnifying effect created by process innovation on the effect of LM and green practices on the positive performance of GSCs.

6. Concluding remarks, limitations and future research directions

This paper investigates the casual relationships between LM, green and process innovation practices and their impact on the performance of GSCs. To do this, the study proposes a framework to model and establish such relationships based on some of the most common lean, green, process innovation and GSC practices, see Table 2. Consequently, this study fills a research gap as previously established in Sections 1 and 2, and extends our knowledge in the sustainability, lean management, innovation and supply chain management fields by:

- Exploring and helping us to understand the effect that LM, green and process innovation practices have on the performance of GSCs;
- Investigating and establishing the synergetic relationship between LM, green and process innovation practices, and their combined effect on GSC performance; and
- Quantifying and explaining the given relationships and effects.

These theoretical implications and contributions are relevant to the theory of the aforementioned fields as green lean, process innovation, and supply chain sustainability have been extensively investigated, but mainly treated as independent research subjects. Combining these subjects as part of the same research stream is a challenge and the originality of this research.

Similarly, the practical implications and contribution of this study are equally relevant within the industrial context, especially for supply chain and operations managers who aim to gain a better understanding of the relationship and effect of contemporary operational practices on the green performance of their supply chains. In particular, the lack of a clear understanding and knowledge of the relationship between LM, green and process innovation on the performance of GSCs may create an obstacle for these managers, and their organizations, to justify the implementation of GSCs. In addition, the insight of the relationships and effects of these practices provided by this study can also assist managers to take better decisions and formulate appropriate strategies for effectively developing and/or adopting GSC practices within their organizations. This will help their companies to not only improve profitability but also contribute to tackle some of the major sustainability challenges currently faced by humankind and comply with governmental environmental regulations.

Although this study was conducted within the context of the manufacturing sector, other industrial segments such as services, grocery, healthcare, logistics and transport, among others, can also benefit from this research and the results derived from it. Similarly as the manufacturing industry, all these other sectors are also under increasing pressure to become more sustainable in their supply chains and internal operations. The effective implementation of a GSC, enhanced by the simultaneous adoption of LM, green and process innovation practices can provide them with the opportunity to achieve this venture. In a similar manner, this study may encourage organizations not currently embarked on, or fully committed to, sustainability, but devoted to the adoption and sustainment of operations improvement approaches such as LM or process innovation to contemplate the synergies and benefits they can bring to make their supply chains and operations more sustainable.

In terms of research limitations, this study was restricted by various confining factors which constrained the scope and extent of the research and it results. These are essential to be highlighted to be considered in future studies and to guide the direction of the future research agenda. Firstly, this research was conducted within the context of the manufacturing sector only. This presents an opportunity to gain added insights into the relationship of LM, green and process innovation practices and their effect on the GSCs performance of companies operating in order business sectors. This can provide further light into the effect and role that specific industry characteristics can have on the relationships of the studied practices and their impact on the performance of GSCs. Secondly, due to the quantitative nature and strategy followed in this research to collect data by using a survey instrument based on a Likert-style rating, the present study suffers from the limited ability of the respondents to express their views and opinions other than those pre-set as answers. This limitation can be overcome in future researches by also conducting qualitative interviews with some selected organizations. This strategy will also contribute in gaining further validation of the results obtained. Since the research was only focused on industrial experts, it omitted the views of academic experts. Thus, besides considering pragmatic sources only, future studies can also be underpinned by academic and research experts in the field. This will ensure that theoretical dimensions of the research are also included and considered as part of the research, which will derive in an improved robustness of the study. Finally, since the results of this study suggested a positively combined-synergetic effect of lean, green and process innovation on the performance of GSCs, the proposal of a framework to integrate these three concepts seems as an ideal path for future research to advance knowledge in this field.

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Appendix A1. Survey items

Code	**Construct: Green practices**
GP1	Eco-design and life cycle assessment
GP2	Green manufacturing
GP3	Reverse logistics
GP4	Waste management
Code	**Construct: Lean management**
LM1	JIT
LM2	Set-up time reduction
LM3	Cellular manufacturing
LM4	Waste elimination
Code	**Construct: Process innovation**
PI1	Fast response to the new processes introduced by other companies within the same sector
PI2	Pioneering disposition to introduced new process
PI3	Number of changes in the process introduced in one year
Code	**Construct: Green supply chain performance**
GSCP1	Economic efficiency
GSCP2	Performance
GSCP3	Integration
GSCP4	Collaboration
GSCP5	Responsiveness
GSCP6	Cost
GSCP7	Value creation
GSCP8	Sustainability

Appendix A2. Variance – covariance matrix

	GP1	GP2	GP3	GP4	LM1	LM2	LM3	LM4	PI1	PI2	PI3	GSCP1	GSCP2	GSCP3	GSCP4	GSCP5	GSCP6	GSCP7	GSCP8
GP1	2,722	1,655	1,893	1,691	,576	,670	,563	,522	-,517	-,543	-,385	1,746	1,608	1,695	1,621	1,646	1,529	1,624	1,677
GP2	1,655	2,400	1,639	1,557	,468	,580	,474	,458	-,541	-,552	-,413	1,593	1,523	1,461	1,419	1,477	1,423	1,475	1,490
GP3	1,893	1,639	2,704	1,741	,563	,759	,579	,562	-,625	-,570	-,503	1,770	1,659	1,712	1,618	1,701	1,618	1,638	1,706
GP4	1,691	1,557	1,741	2,636	,586	,733	,581	,647	-,507	-,464	-,404	1,737	1,623	1,676	1,642	1,660	1,622	1,693	1,733
LM1	,576	,468	,563	,586	2,785	1,917	1,927	1,791	-,508	-,494	-,490	1,531	1,564	1,660	1,515	1,577	1,547	1,569	1,638
LM2	,670	,580	,759	,733	1,917	2,797	1,931	1,779	-,499	-,490	-,462	1,640	1,695	1,702	1,607	1,648	1,683	1,683	1,772
LM3	,563	,474	,579	,581	1,927	1,931	2,566	1,772	-,473	-,429	-,456	1,470	1,533	1,564	1,406	1,585	1,505	1,509	1,616
LM4	,522	,458	,562	,647	1,791	1,779	1,772	2,556	-,422	-,393	-,378	1,488	1,610	1,627	1,476	1,598	1,550	1,611	1,655
PI1	-,517	-,541	-,625	-,507	-,508	-,499	-,473	-,422	2,594	2,082	1,951	-,839	-,732	-,822	-,787	-,769	-,828	-,896	-,783
PI2	-,543	-,552	-,570	-,464	-,494	-,490	-,429	-,393	2,082	2,551	1,858	-,748	-,706	-,732	-,746	-,681	-,783	-,828	-,733
PI3	-,385	-,413	-,503	-,404	-,490	-,462	-,456	-,378	1,951	1,858	2,478	-,739	-,648	-,757	-,768	-,640	-,733	-,824	-,717
GSCP1	1,746	1,593	1,770	1,737	1,531	1,640	1,470	1,488	-,839	-,748	-,739	2,997	2,506	2,565	2,448	2,474	2,372	2,583	2,578
GSCP2	1,608	1,523	1,659	1,623	1,564	1,695	1,533	1,610	-,732	-,706	-,648	2,506	2,779	2,516	2,445	2,426	2,428	2,526	2,581
GSCP3	1,695	1,461	1,712	1,676	1,660	1,702	1,564	1,627	-,822	-,732	-,757	2,565	2,516	2,862	2,499	2,498	2,398	2,590	2,650
GSCP4	1,621	1,419	1,618	1,642	1,515	1,607	1,406	1,476	-,787	-,746	-,768	2,448	2,445	2,499	2,651	2,349	2,338	2,469	2,518
GSCP5	1,646	1,477	1,701	1,660	1,577	1,648	1,585	1,598	-,769	-,681	-,640	2,474	2,426	2,498	2,349	2,611	2,324	2,450	2,523
GSCP6	1,529	1,423	1,618	1,622	1,547	1,683	1,505	1,550	-,828	-,783	-,733	2,372	2,428	2,398	2,338	2,324	2,540	2,381	2,490
GSCP7	1,624	1,475	1,638	1,693	1,569	1,683	1,509	1,611	-,896	-,828	-,824	2,583	2,526	2,590	2,469	2,450	2,381	2,846	2,587
GSCP8	1,677	1,490	1,706	1,733	1,638	1,772	1,616	1,655	-,783	-,733	-0,717	2,578	2,581	2,650	2,518	2,523	2,490	2,587	2,967