Do lean production and lean supply chain practices really improve operational performance?

¿Las prácticas de la producción esbelta y la cadena de suministro esbelta realmente mejoran el rendimiento operacional?

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Abstract: Lean production practices and the implementation of lean thinking in the supply chain are not only aimed at reducing businesses' waste, but also at improving operational performance. This study aims to explore the integration of lean production into operational performance through lean supply chain. To this end, a survey was conducted on a sample of 460 manufacturing firms. The results show that lean production has a positive impact on operational performance, as does lean supply chain. Similarly, lean supply chain has a positive impact on operational performance, and also acts as a catalyst of the relationship between lean production and operational performance. In this context, the findings allow us to conclude that lean production improves the operational performance of manufacturing firms; however, when lean supply chain acts as a mediating variable, it significantly improves the company's operational performance.

Keywords: Lean production, lean supply chain, operational performance, manufacturing firms

Resumen: Las prácticas de producción esbelta y la implementación de un pensamiento más esbelto en la cadena de suministro no solo tienen como objetivo reducir los desechos generados por las organizaciones, sino también mejorar el rendimiento operativo. Sin embargo, la publicación de estudios que han analizado y discutido la relación entre la producción esbelta, la cadena de suministro esbelta y el rendimiento operacional son relativamente escasas. Por lo tanto, este estudio tiene como objetivo explorar la integración de la producción esbelta en el rendimiento operativo, a través de la cadena de suministro esbelta, para lo cual se distribuyó una encuesta a una muestra de 460 empresas manufactureras. Los resultados obtenidos sugieren que la producción esbelta tiene un impacto positivo en el rendimiento operativo, al igual que en la cadena de suministro esbelta. Del mismo modo, la cadena de suministro esbelta tiene un impacto positivo en el rendimiento operativo, pero también actúa como un vehículo en la relación entre la producción esbelta y el rendimiento operacional. Bajo este contexto, los resultados obtenidos permitieron concluir que la producción esbelta mejora el rendimiento operacional de las empresas manufactureras, sin embargo, cuando la cadena de suministro esbelta actúa como una variable mediadora, mejora significativamente el rendimiento operacional de las empresas.

Palabras clave: Producción esbelta, cadena de suministro esbelta, rendimiento operacional, empresas manufactureras

1. Introduction

The traditional supply chain must evolve to adapt to the new requirements of manufacturing firms, as several authors state, to become an adjusted supply chain (Vafaeenezhad et al., 2019; Carvalho et al., 2017; Dey et al., 2019; Guo et al., 2021; Sabogal-De la Pava et al., 2021; Digalwar et al., 2020), in this way García-Buendía et al. (2021) explains that this change helps both with sustainable development as with the operational performance of these companies. In this way, studies such as those carried out by Ortiz-Barrios et al. (2020), and Hadian et al. (2020) conclude that there are factors that are too complex when managing this evolution, such as the selection of members or cost reduction.

The concept of lean supply chain is not new, in recent years it has been a trend among academics and scientists (Pishchulov et al., 2019; Sharma et al., 2020), some authors such as Sharma et al. (2020), and Shoukohyar and Seddigh (2020) attribute this to the social pressure that manufacturing companies experience due to environmental pollution and excessive use of resources. However, few studies have analyzed and discussed the synergies obtained from lean production and lean supply chain activities as mentioned by Sezen et al. (2012), and Reves et al. (2015), who found in their respective studies that most published studies theoretically analyzed both concepts, and there are few empirical research contributions, which is why empirical evidence of this link is needed.

In studies recently published in the literature, García-Buendía et al. (2021), and Sonar et al. (2022), analyzed the existing relationship between lean production and the lean supply chain, finding divergent results in the few published studies, for which they called on the scientific, academic and business community to guide their future research in providing robust empirical evidence, to clarify the effects, whether positive or negative, of these relationships, since they considered that the relationship between lean production and the lean supply chain cannot be considered conclusive and is still open to debate.

Therefore, the aim of this empirical study is to analyze and discuss the impact of lean production on lean supply chain and operational performance of manufacturing firms. To achieve this goal, a study was conducted in manufacturing companies in the automotive industry in Mexico, using a sample of 460 observations and estimation the research model using partial least squares structural equation modeling (PLS-SEM) statistical technique of SmartPLS 4.0 software (Ringle et al., 2022). It is important to point out that the analysis of the automotive industry is interesting because, the integration of leanness and environmental sustainability in the automotive industry supply chain has been rarely analyzed (García-Buendía et al., 2021), particularly because, on the one hand, it is one of the industries that generate a high percentage of pollution and, on the other hand, it is the industry that has an important participation in the countries' GDP.

The results obtained in this study provide solid empirical evidence that lean production has a significant positive impact on both lean supply chain and operational performance levels, and that lean supply chain also has a significant positive impact on the operational performance level of companies owned by the automotive industry. Moreover, this empirical study contributes to the literature on lean manufacturing, especially regarding the inconsistency of empirical findings in previously published literature on the relationship between lean production and operational performance, since positive and negative results have been found (Losonci & Demeter, 2013), and the relationship between lean production and green supply chains, since there are positive, negative and unrelated results in the literature (García -Buendía et al., 2021).

2. Literature review

2.1. Lean Production and Operational Performance

Lean production has been discussed and analyzed in scientific literature since the beginning of the century (Schonberger, 2007; Holweg, 2007), not only has it been investigated around management but in different areas throughout this time and since different economies, cultures, and perspectives (Losonci & Demeter, 2013). As a result, in the past decade, lean production has been recognized as one of the most efficient and effective business strategies, which can not only achieve a higher level of competitiveness but also improve a high percentage of business performance and operational performance of manufacturing firms (Losonci & Demeter, 2013). In addition, operational performance is one of the most used indicators in the lean production literature to measure the performance level of manufacturing firms (Huo et al., 2021).

However, even though various studies have been published on the importance of lean production in manufacturing firms, particularly during the last two decades (Tortorella et al., 2021), and the increase in popularity of the concept of lean production among the scientific, academic and business community (Maldonado-Guzmán et al., 2023), the positive effects of lean production on operational performance are considered vague and inconclusive (De Giovanni & Cariola, 2021) because, some studies published in the literature have found positive results confirming the relationship between lean production and operational performance (e.g., Callen et al., 2000; Kinney & Wempe, 2002; Fullerton et al., 2003), while others have found a negative relationship between the two concepts (e.g., Huson & Nanda, 1995; Balakrishnan et al., 1996; Ahmad et al., 2004).

These inconsistencies in the results obtained from the relationship between lean production and operational performance have allowed the scientific and academic community to explore new facets of applying lean production to significantly improve results at the operational performance level (Grigg et al., 2020). In this context, Tortorella et al. (2021) and De Giovanni and Cariola (2021) demonstrated that the adoption and implementation of lean production can not only significantly improve efficiency in production processes, but also the level of operational performance of organizations. In a more recent study, Maldonado-Guzmán et al. (2023) also demonstrated that the application of lean production in manufacturing companies in the automotive industry generates a positive impact on the level of operational performance. Therefore, the following research hypothesis is proposed.

H1: The higher level of adoption of lean production, the higher level of operational performance.

2.2. Lean Production and Lean Supply Chain

The concept of lean is generally considered in the literature as a management system, that gradually includes a set of tools implemented in the production field to manage the system and can be applied to any organization and any sector of economic production activities (García -Buendía et al., 2021). Therefore, it should not be surprising that the lean literature is related to various functional aspects of manufacturing firms, including the supply chain (De Giovanni & Cariola, 2021). However, it is also true that the results found in the literature on the relationship between lean production and lean supply chain are too ambiguous and inconsistent (García-Buendía et al., 2021; Sonar et al., 2022), which is why the existing relationship between both concepts can be considered inconclusive (García-Buendía et al., 2021).

In this context, the adoption and application of lean production throughout the supply chain of manufacturing firm to optimize the flow of information and materials is often referred to as a lean supply chain, where the goal of a lean supply chain is to eliminate industrial waste, improve the quality of products and services, reduce costs, and increase sales flexibility (Lamming, 1996; Womack & Jones, 1997). Therefore, lean production practices can be adopted and implemented in any type of organization, not only for manufacturing firms, and can be integrated among all members of the supply chain (Vonderembse et al., 2006), thereby achieving significant positive effects of a lean supply chain (Gupta et al., 2019). In this way, the use of lean production, as well as lean supply chain, requires efficient coordination and collaboration at all levels of the company and of the companies' supply chain participants (Sonar et al., 2022).

Relatively few studies focus on analyzing and discussing the relationship between lean production, and lean supply chain (e.g. Gupta et al., 2019; Lu et al., 2019; Mohammed et al., 2019; Tundys et al., 2019; Mohammed et al., 2021; Mathiyazhagan et al., 2021), other studies focus on the use of bibliometric analysis (Filser et al., 2017; Pinho & Mendes, 2017; Redeker et al., 2019; García-Buendía et al., 2021), so far only partial approaches address the impact of lean production, which requires the scientific and academic community to guide their research to provide solid empirical evidence for the relationship between these two concepts (Sonar et al., 2022). Therefore, the following research hypothesis is proposed.

H2: The higher level of adoption of lean production, the higher level of lean supply chain.

2.3. Lean Supply Chain and Operational Performance

Several researchers and scholars have studied the relationship between lean supply chain and operational performance of manufacturing firms in various industries such as construction (Zhang & Qi, 2013; Ahmed & Huma, 2018), industrial processes (Panwar et al., 2017), food industry (Ding et al., 2014), healthcare industry (Habidin et al., 2014; Matt et al., 2018), and automotive industry (Wee & Wu, 2009; Tortorella et al., 2017), and obtained mixed results (García-Buendía et al., 2021). To provide a solid study linking lean supply chain and operational performance, Jayaram et al. (2014) conducted a study in which they found a positive and significant impact between the two concepts, while *Apte and Goh (2014)* found that lean supply chain, measured by reducing inventory and minimizing lead time, can improve operational performance of manufacturing firms.

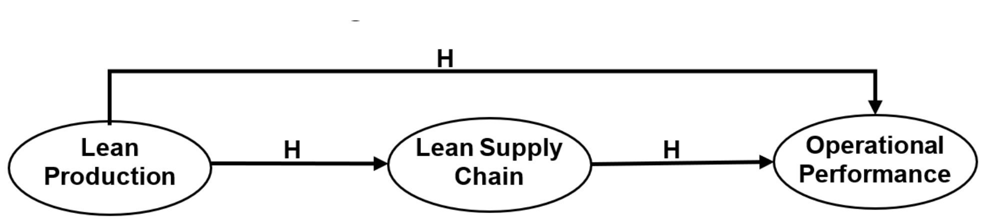
Furthermore, the impact of lean supply chain on operational performance is varied from the perspective of industry-specific characteristics (García-Buendía et al., 2021). Osman et al. (2015) studied the impact of lean supply chain on operational performance and found a positive relationship between the two constructs, these results are linked with studies of Karakadilar and Hicks (2015) in Turkish automotive industry manufacturing companies, and Rana et al. (2016) study conducted in retail companies. In recent studies, Tortorella et al. (2017) investigated the impact of supply chain practices on the operational performance of manufacturing firms and found a significant positive relationship between the two concepts.

Pozzi et al. (2017) confirmed that the application of lean thinking in the supply chain significantly improved the operational performance of the company, while Tortorella et al. (2018) found that lean supply chain practices not only improved the efficiency of manufacturing companies but also improved their operational performance. Therefore, if the purpose of lean supply chain is to reduce industrial waste and improve process efficiency, manufacturing firms are expected to have an impact on their operational performance level (Jasti & Kodali, 2015; Berger et al., 2018). However, as there are mixed results on the relationship between both concepts, it is necessary to provide more robust empirical evidence on the positive effects between these two concepts (García-Buendía et al., 2021). Therefore, the following research hypothesis is proposed.

H3: The higher level of adoption of lean supply chain, the higher level of operational performance.

Figure 1, Presented below, shows the approach of the three hypotheses in the research model.

Figure 1. Research Model



3. Methodology

3.1. Sample Design and Data Collection

This empirical study was conducted among manufacturing companies in the automotive industry in Mexico, a sector that includes 950 firms as of January 30, 2020, organized by different chambers of commerce and regional, national, and international economic organizations, although this study is not targeted at specific business groups or associations. It was considered appropriate to focus this study on companies in the automotive industry, especially since this industry has received the least attention in the lean production and lean supply chain literature (Tortorella et al., 2016). Additionally, the data were collected through a paper survey of 460 companies selected through simple random sampling, with a maximum error of ±4% and a confidence level of 95%, and the survey period was from April to September 2020 for manufacturing firms.

Additionally, the implementation of a procedure to avoid biased answers was considered pertinent, in which the respondents were informed of the anonymous treatment of their correct or incorrect answers, for which they should answer the questions honestly (Podsakoff et al., 2003). This protocol had the objective of reducing the possibility of obtaining lenient answers and that they were socialized among the companies surveyed, so that they were more consistent with the answers that are generally accepted. Thus, the bias of the common method was analyzed considering the unique factor of Harman (Podsakoff & Organ, 1986), which establishes that the factorial analysis must have a common factor that explains at least 40% of the total variance. In this sense, the relationships between the variables considered in the research model of this study did not occur due to the variance of the common method.

3.2. Variables and Analysis

An exhaustive review of the literature was carried out to identify the most appropriate scales for the measurement of lean production, lean supply chain and operational performance. To measure lean production, Farias et al. (2019) used a scale, who believed that lean production can be measured using 6 items; to measure lean supply chain, this was developed by Cua et al. (2001), Li et al. (2005), Narashiman et al. (2006), and Shah and Ward (2007), who believed that this concept can be measured using 5 items, while to measure operational performance, a scale proposed by Piyathanavong et al. (2019) who believed that this concept can be measured using 6 items. All items in the three measurement scales were measured using a five-point Likert scale with a restricted range of 1 = strongly disagree to 5 = strongly agree. Table 1 shows the 17 items used to measure the three concepts.

In addition, the data of this study were analyzed using SmartPLS 4.0 software (Ringle et al., 2022), and PLS-SEM to evaluate the reliability and validity of the measurement scales of the three concepts used in the research model. Reliability was measured using Cronbach's alpha, composite reliability index (CRI), and the variance extracted index (AVE) (Hair et al., 2019), while discriminant validity was measured using Fornell and Larcker criteria, and heterotrait-monotrait ratio (HTMT) (Henseler et al., 2015; Hair et al., 2019), two of the most cited indices in the literature. The results showed that the factor loadings of the 17 items were all above 0.6, indicating that all items balanced lean production, lean supply chain, and operational performance (Table 1).

The use of PLS-SEM to answer the three hypotheses proposed in the research model stems mainly from two issues. On the one hand, it is the most appropriate statistical technique in those theories that are not yet fully developed in the literature (Hair et al., 2019), various knowledge disciplines (Hair et al., 2012; Ringle et al., 2012; Sarstedt et al., 2014; do Valle & Assaker, 2015). On the other hand, if the main goal of the study is to predict and explain the concepts of the research model (Rigdon, 2012), this helps to explain both the measurement error of the concepts and the multiple regression score of the sum of the concepts on the relationship between lean production, lean supply chain, and the level of operational performance of manufacturing firms (Hair et al., 2021).

Table 1. Measurement Model Assessment

Indicators	Constructs	Factor Loads (p-value)
Lean Production (LEP)		
Cronbach's Alpha: 0.934; Dijkstra–Henseler's rho (ρA): 0.942; CRI (ρc): 0.932; AVE: 0.700		
LEP1	An approach to produce only what the customer wants just when the customer wants it, thereby the production systems are flexible enough to accommodate shifting demand immediately.	0.752 (0.000)
LEP2	Lot size refers to the quantity of an item ordered for delivery on a specific date or manufactured in a single production run.	0.676 (0.000)
LEP3	Activities that continuously improve all functions and involve employees from the CEO to the assembly line workers.	0.875 (0.000)
LEP4	Preventive maintenance is maintenance that is regularly performed on a piece of equipment to lessen the likelihood of it failing.	0.995 (0.000)
LEP5	A situation where employees participate directly to help an organization to fulfill its mission and meet its objectives by applying their ideas, expertise, and efforts towards problem solving and decision making.	0.804 (0.000)
LEP6	Cycle time, also called throughput time, is the amount of time required to produce a product or service.	0.880 (0.000)
Lean Supply Chain (LSC)		
Cronbach's Alpha: 0.940; Dijkstra–Henseler's rho (ρA): 0.942; CRI (ρc): 0.939; AVE: 0.735		
LSC1	We and our major supplier have continuous improvement programs	0.812 (0.000)
LSC2	Our major supplier delivers to us on a JIT basis	0.844 (0.000)
LSC3	Our major supplier delivers to us on short notice	0.834 (0.000)
LSC4	We can depend on on-time delivery from our major supplier	0.950 (0.000)
LSC5	Our major supplier is linked to us by a pull system	0.898 (0.000)
Operational Performance (OPE)		
Cronbach's Alpha: 0.903; Dijkstra–Henseler's rho (ρA): 0.910; CRI (ρc): 0.903; AVE: 0.611		
OPE1	Cost and resource reduction	0.704 (0.000)
OPE2	Lead time reduction	0.712 (0.000)
OPE3	Flexibility and inventory turnover increase	0.705 (0.000)
OPE4	Labor productivity increase	0.772 (0.000)
OPE5	Quality increase (defect reduction)	0.847 (0.000)
OPE6	Performance comparison to direct competition	0.922 (0.000)

The results obtained also show that Cronbach's alpha, CRI, and Dijkstra-Henseler rho values are all above 0.9 (0.934–0.940–0.903; 0.932–0.939–0.903; 0.942–0.942–0.910), indicating that the research model fits the data very well (Bagozzi & Yi, 1988; Hair et al., 2019), and the AVE values are above 0.5 (0.700–0.735–611), indicating that the measures of lean production, lean supply chain, and operational performance are in the line with the literature (Fornell & Larcker, 1981; *Bagozzi & Yi, 1988*). On the other hand, the Fornell and Larcker criterion is significant because the AVE values are greater than the square of the correlation between each pair of constructs. The same is true for HTMT, with values higher than 0.08 (0-305-0.240-0.370), indicating the existence of discriminant validity between lean production, lean supply chain, and operational performance measurement scales (Henseler et al., 2015). Table 2 shows the results obtained in more detail.

Table 2. Measurement Model. Reliability, Validity, and Discriminant Validity

PANEL A. Reliability and Validity				
Variables	**Cronbach's Alpha**	**CRI**	**Dijkstra-Henseler rho**	**AVE**
Lean Production	0.934	0.932	0.942	0.700
Lean Supply Chain	0.940	0.939	0.942	0.735
Operational Performance	0.903	0.903	0.910	0.611

PANEL B. Fornell-Larcker Criterion				**Heterotrait–Monotrait ratio (HTMT)**		
Variables	**1**	**2**	**3**	**1**	**2**	**3**
1. Lean Production	**0.837**					
2. Lean Supply Chain	0.307	**0.869**		0.305		
3. Operational Performance	0.245	0.372	**0.781**	0.240	0.370	

Note: PANEL B: Fornell-Larcker Criterion: Diagonal elements (bold) are the square root of the variance shared between the constructs and their measures (AVE). For discriminant validity, diagonal elements should be larger than off-diagonal elements.

4. Results and Discussion

The results of the PLS-SEM analysis showed that the estimated data had an acceptable statistical level and produced an adjusted R^2 value that was higher than the recommended value of 0.10 (Reinartz et al., 2009; Hair et al., 2011; Henseler et al., 2014; Hair et al., 2019), SRMR (0.030) was lower than the recommended value of 0.08 (Hu & Bentler, 1998), and the geodesic difference (dG) and unweighted least squares difference (dULS) (1.033 and 0.243) were higher than the values obtained in HI99 (1.670 and 0.601), indicating that the research model had an excellent statistical fit to the data (Dijkstra & Henseler, 2015). In conclusion, the data obtained in this study provided sufficient empirical evidence to support the existence of a significant positive relationship between lean production, lean supply chain, and operational performance in manufacturing firms. Table 3 shows the results obtained in detail.

Table 3. Structural Equation Model

Paths	**Path (*t-value; p-value*)**	**95% Confidence Interval**	**f^2**	**Support**
LEP -> OPE (H1)	0.249 (4.717; 0.844)	[0.147 – 0.349]	0.026	Yes
LEP -> LSC (H2)	0.308 (6.288; 0.000)	[0.212 – 0.403]	0.109	Yes
LSC -> OPE (H3)	0.332 (7.664; 0.089)	[0.249 – 0.416]	0.123	Yes
Indirect Effects				
LEP -> LSC -> OPE	0.302 (4.921; 0.000)	[0.165 – 0.406]	0.106	Yes
Endogenous Variable	**Adjusted R^2**	**Model Fit**	**Value**	**HI99**
		SRMR	0.030	0.063
LSC	0.196	dULS	0.243	0.601
OPE	0.162	dG	1.033	1.670

Note: LEP: Lean Production; LSC: Lean Supply Chain; OPE: Operational Performance. One-tailed t-values and p-values in parentheses; bootstrapping 95% confidence intervals (based on n = 5,000 subsamples) SRMR: standardized root mean squared residual; dULS: unweighted least squares discrepancy; dG: geodesic discrepancy; HI99: bootstrap-based 99% percentiles.

The results obtained provide solid empirical evidence supporting our contention that lean production has a significant positive impact on the operational performance of manufacturing firms in the Mexican automotive industry, as well as on lean supply chains. These results are consistent with those of De Giovanni (2017), De Giovanni and Ramani (2017), and De Giovanni and Cariola (2021), who found a positive impact between lean production and operational performance. One of the main reasons that can explain the positive impact of lean production practices and operational performance levels is the flexibility of the production system, which reduces production time and industrial waste. This indicates that the costs associated with the lean production activities are low compared to the benefits achieved for the companies.

On the other hand, lean production impacts positive the lean supply chains which are consistent with the findings of Ortiz-Barrios et al. (2020), Mohammed et al. (2021), and Mathiyazhagan et al. (2021) who argue that manufacturing firms should integrate lean thinking into their supply chains to reduce waste levels and order delivery times. Therefore, the level of operational performance of companies in the automotive industry depends not only on lean production practices, but also on the extent to which these practices are related to a lean supply chain, since according to De Giovanni and Cariola (2021), the level of lean production in manufacturing firms' operational performance may significantly improve when lean thinking is implemented and further developed in the supply chain.

Furthermore, this study provides solid empirical evidence that lean supply chain has a significant positive impact on the operational performance of automotive manufacturing firms and that there is a significant indirect effect between lean production and operational performance. The results obtained are like those of Tortorella et al. (2018), Ruiz-Benitez et al. (2018), and Avelar-Sosa et al. (2018), where it can be found that lean supply chain not only produces a higher level of operational performance in firms, but also improves the relationship between lean production practices and operational performance. Overall, it can be concluded that lean supply chain plays a vital role in improving the operational performance of manufacturing firms because it adopts lean practices that reduce waste and allow for better selection of their products and suppliers, as well as a further improvement in the level of operational performance.

Furthermore, the adoption of lean production by automobile manufacturing firms has significantly improved operational performance through better management of lean supply chains. This number will increase as supply chain practices improve supply, adopt more lean practices, better select suppliers, deliver in the shortest possible time, and reduce the amount of industrial waste. This practice not only significantly reduces the cost of the automobile production process, but also reduces the emission of solid waste and carbon dioxide and other pollutants into the environment, thereby improving operational performance, as most automobile industry manufacturing companies are generally those that cause higher levels of environmental pollution.

In summary, this study confirms that the practice of production system flexibility, shortened production time, and reduced industrial waste combined with lean production has promoted the adoption and implementation of lean thinking in the supply chain and improved the level of operational performance of manufacturing companies in the automotive industry significantly. Therefore, reducing the emission of industrial waste and harmful gases to the environment can alleviate the strong social pressure on manufacturing firms to improve the environment and sustainability of their locations (Hofmann & Jaeger-Erben, 2020). In addition, this study not only provides solid empirical evidence for the relationship between lean production practices, lean supply chain, and operational performance, but also contributes to the literature because no study has analyzed lean supply chain as a mediating variable.

5. Conclusions

First, the studies published in the literature analyzing and discussing the relationship between lean production practices and operational performance, as well as between lean supply chain and operational performance of manufacturing firms, are mixed and considered inconclusive. Therefore, we can conclude that analyzing lean production practices alone can lead to positive results at the operational performance level, compared to analyzing them through lean supply chain. Therefore, if companies improve their operational performance levels, they are more likely to achieve this goal if they implement lean production and lean supply chain practices simultaneously, rather than implementing them separately, even if such implementation involves significant changes in production and sales processes.

Second, this study provides solid empirical evidence indicating that lean production practices have a significant influence on the operational performance of manufacturing firms, and the integration of lean production and lean supply chain can improve operational performance results, leading us to conclude that manufacturing firms that implement both concepts have higher operational performance than those that implement them separately. Additionally, this study has several limitations that are important to consider when performing the interpretation and implications of the results obtained. On one hand, a limitation is that referring to the use of measurement scales of lean production and lean supply chain, as well as operational performance, since these three concepts were measured only with subjective indicators obtained through the application of a survey (subjective data). Therefore, in future studies it will be necessary to use objective data from firms (e.g., improvement time of production processes; reduction of supply chain costs), to verify if the results obtained are like the results obtained in this empirical study.

On other hand, the integration of lean production and lean supply chain with operational performance of manufacturing firms in automotive industry, possibly generate better results if variables related to the managers of the organizations are considered (e.g., leadership, experience, academic training), some variables related to companies (e.g., size; age; location), or other measurement scales of lean production and lean supply chain. Therefore, in future studies it will be pertinent to consider other variables or measurement scales of the three concepts, to verify whether the results differ from those obtained in this study.

Furthermore, this study opens doors for future research. Firstly, due to the positive impact of the relationship between lean production, lean supply chain, and operational performance, the lack of research analyzing these three concepts suggests that analysis in different contexts, sectors, and countries is encouraged. Therefore, future research could pay special attention to the analysis and discussion of lean production and its relationship with the different operational performance dimensions present in the literature, as well as the use of different scales for their measurement. Secondly, analyzing successful case studies in conjunction with the literature approach could provide a deeper understanding of why positive results were achieved in the previous relationship. Regarding the quantitative approach, it would also be interesting to use other statistical techniques besides PLS-SEM, such as neural networks, which can consider more information, more variability and higher data efficiency, but the collection of these data requires higher costs.

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