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Triple-A (agile, adaptable, and aligned) Supply Chain (SC) has been analyzed as a source of competitive advantage but the influence of variables that mediate in this relationship is an underexplored field. The present study seeks to advance the Triple-A SC framework by considering and testing the mediating effects of SC collaboration and innovation levels on the Triple-A SC–operational performance (efficiency and responsiveness) relationship. The research model was tested with partial least squares structural equation modeling (PLS-SEM) using a sample of 277 Spanish manufacturing firms with a minimum of 50 employees from 14 different sectors. The results show that SC collaboration and innovation levels significantly mediate relationships between Triple-A SC and operational performance. Additionally, we found that collaboration level plays a more important role in responsiveness than efficiency, while innovation level has similar effects on both performance dimensions. This work contributes to knowledge on the impact of Triple-A SC on operational performance and alerts managers to the need to strengthen their levels of collaboration with SC partners and innovation over their main competitors.

Keywords: Triple-A supply chain; agility; adaptability; alignment; collaboration; innovation; performance

1. Introduction

Supply chains (SCs) play an increasingly important role in the world economy and their design requires significant investments to implement SC capabilities and improve performance. Triple-A SC is a powerful weapon for achieving superior performance in a dynamic environment (Hou et al., 2023; Kakhki, Rea, and Deiranlou, 2023). Lee (2004) established the Triple-A (or AAA) SC conceptual framework, which stated that only SCs that are agile, adaptable, and aligned provide superior SC performance and a sustainable competitive advantage. A Triple-A SC is capable of rapidly identifying and reacting to sudden changes in demand and supply (agility), adapting strategies, products, and/or technologies to changes in market structures (adaptability), and aligning the incentives, information, and processes of all the partners in the SC (alignment) (Lee, 2004; Alfalla-Luque, Machuca, and Marin-Garcia, 2018). Consequently, a Triple-A SC should respond to long- and short-term changes through strategies, structures, and processes that allow rapid reactions through volume and variety flexibility, and market changes to be adapted to and anticipated by synchronizing and coordinating processes and activities along the SC.

More recently, Lee (2021) has revitalized this framework stating that "the AAA concept is still applicable, and that winning SCs should still be agile, adaptable, and aligned" (p. 174), so the Triple-A framework "continues to be essential for the current SCs" (Cohen and Kouvelis, 2021, p. 635) and it "is even more relevant today" (Erhun, Kraft, and Wijnsma, 2021, p. 645). The post-pandemic SC emphasizes the need to revisit the strength and depth of AAA capabilities (Patrucco and Kähkönen, 2021) to establish a Triple-A SC strategy whose successful implementation to address unanticipated events is conducive to gaining an immediate competitive advantage and streamlining SC management (Huma and Ahmed, 2022). As evidenced by the consequences of COVID-19, there is a pressing need to revive and broaden the scope of Triple-A SC capabilities and a dire need for the SC to improve its ability to deal with SC disruption and provide better disaster response (Khan, Piprani, and Yu, 2023; Trickle, Schiffling, and Verma, 2024). Triple-A SC's importance can be partly attributed to SCs' increasing relevance in the world economy, global SC design's need for substantial investments in resources and efforts, and deploying and implementing Triple-A SC capabilities in pursuit of improved performance (Marin-Garcia, Machuca, and Alfalla-Luque, 2023). This, along with the fact that firms have limited resources, makes it critical to find the most suitable way to improve the effect of Triple-A SC on performance. However, empirical evidence on this topic is still scarce and fragmented (Marin-Garcia, Alfalla-Luque, and Machuca, 2018; Feizabadi, Maloni, and Gligor, 2019; Huma and Ahmed, 2022).

Previous research has developed the theoretical foundations of the Triple-A SC capabilities and their influence on performance and competitive advantages (e.g., Whitten, Green, and Zelbst, 2012; Attia, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Feizabadi, Gligor, and Motlagh, 2019; Machuca, Marin-Garcia, and Alfalla-Luque, 2021). However, although said research reveals a significant consensus on the Triple-A positive influence, findings have been inconsistent and depended on the particular performance measures analyzed (Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018). Therefore, more empirical research focused on the different performance measures is needed (Huo, Guo, and Tian, 2022).

Additionally, previous studies have also called for further investigation with other samples and countries (Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Marin-Garcia, Machuca, and Alfalla-Luque, 2023) and more attention and research efforts need to be directed at the Triple-A SC framework (Dubey, Singh, and Gupta, 2015; Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Feizabadi, Maloni, and Gligor, 2019; Garrido-Vega et al., 2021; Huma and Ahmed, 2022; Trickle, Schiffling, and Verma, 2024). Specifically, several studies call for the identification of factors that could contribute to knowledge and practice for higher performance in the Triple-A SC context (Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Feizabadi, Maloni, and Gligor, 2019; Machuca, Marin-Garcia, and Alfalla-Luque, 2021). This is key to both measuring and benchmarking effective Triple-A SC implementation (Feizabadi, Maloni, and Gligor, 2019). In this line, the possible mediation of some relevant variables in the Triple-A SC-performance relationship is a gap in the previous research that needs to be considered (Farrukh Shahzad et al., 2023). Although the mediation effect has been analyzed in the SC management (SCM) strategies-performance relationship (Ataseven and Nair, 2017), scarce evidence of its existence has been found in the Triple-A SC framework (Whitten, Green, and Zelbst, 2012; Farrukh Shahzad et al., 2023).

Concerning the performance measures to analyze the mediated relationship, in line with the call for the study of different performance measures (Huo, Guo, and Tian, 2022), this research considers non-financial performance measurement. Analysis of operational performance is important as financial measures are not an accurate indication of the competitive requirements that dynamic and challenging markets compel organizations to address (Santa, Hyland, and Ferre, 2014) and they are the key to the success of the capabilities considered in this research. This paper will focus on the two traditional measures of SC operational performance (Fisher, 1997; Lee, 2004): speed/responsiveness and cost-effectiveness/efficiency.

Considering the above issues, and going back to Triple-A SC's origins, the conceptual framework established by Lee (2004) does not hypothesize about possible mediation or moderation variables in the link between Triple-A SC capabilities and performance. Consequently, this has become a major research gap in the field (Whitten, Green, and Zelbst, 2012; Farrukh Shahzad et al., 2023) and the present paper responds to the need to investigate whether any variables mediate the relationship between Triple-A SC and operational performance measures. Therefore, the research question could be stated as follows: Do Triple-A SC capabilities contribute to operational performance, and what mediating variables are relevant? In other words, do companies with more agile, adaptable, and aligned SCs achieve greater efficiency and responsiveness, in part through some mediation variables?

Regarding the many factors that could impact the relationship between Triple-A SC and operational performance, due to the lack of studies focused on this topic in the Triple-A SC context, the present study has considered mediators in the previous SCM literature and focuses on two of the most relevant and widely studied of these in recent research on SCM: SC collaboration (e.g., Levi-Bliech et al., 2018; Kim, Lee, and Lee, 2019; Baah et al., 2022; Uddin and Ahkter, 2022; Ramos, Patrucco, and Chavez, 2023) and innovation (e.g., Ju, Park, and Kim, 2016; Khalil, Khalil, and Khan, 2019; Huo, Guo, and Tian, 2022; Bahrami, Shokouhyar, and Seifian, 2022; Jaouadi, 2022). The fact that collaboration in SC and innovation have been widely used as mediators in other relationships between some SC practices/capabilities/strategies and performance points to their possible intervention as mediators in the Triple-A SC-operational performance link. Both factors could allow firms to improve over their competitors and previous research supports supplier and customer collaboration (e.g., Soosay and Hyland, 2015; Kim, Lee, and Lee, 2019; Amoako-Gyampah, 2020; Cadden et al., 2021; Jafari et al., 2023) and process and product innovation (e.g., Gunday et al., 2011; Ju, Park, and Kim, 2016; Zimmermann, Ferreira, and Carrizo Moreira, 2016; Bahrami, Shokouhyar, and

Seifian, 2022) bringing improvements to performance. However, findings on the relationships between SC collaboration (e.g., Villena, Revilla, and Choi, 2011) and innovation (e.g., Shi et al., 2018) and performance have also been inconclusive. Given this gap, the main objective of the present research is to analyze whether SC collaboration and innovation levels have mediating effects on the Triple-A SC-operational performance relationship, that is, whether the Triple-A SC's effect on efficiency and responsiveness is mediated by greater levels of collaboration and innovation over main competitors.

With this goal in mind, this paper contributes to previous research in various ways. First, as its main contribution, this is a pioneering exploratory study in testing the mediating effect of SC collaboration and innovation levels in the link between Triple-A SC and operational performance. Second, as a natural extension to the previous research, it provides new evidence on the relationship between Triple-A SC and operational performance by identifying factors aimed at achieving greater performance (Li, Wu, and Holsapple, 2015; Feizabadi, Maloni, and Gligor, 2019; Machuca, Marin-Garcia, and Alfalla-Luque, 2021), which contributes to better knowledge and practice in Triple-A SC contexts. Third, it addresses calls for more research on the Triple-A SC–performance relationship (Hou et al., 2023) using operational performance (Huo, Guo, and Tian, 2022) and different samples and countries (Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Marin-Garcia, Machuca, and Alfalla-Luque, 2023).

The theoretical foundation of this study is the paradigm of the dynamic capabilities view (DCV), which is widely used in the SCM domain, in general, and in the Triple-A SC context, in particular (e.g., Whitten, Green, and Zelbst, 2012; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Aslam et al., 2018; Machuca, Marin-Garcia, and Alfalla-Luque, 2021; Khan, Piprani, and Yu, 2023; Marin-Garcia, Machuca, and Alfalla-Luque, 2023). According to the DCV (Teece, Pisano, and Shuen, 1997), SC agility, adaptability, and alignment are dynamic capabilities (Whitten, Green, and Zelbst, 2012; Machuca, Marin-Garcia, and Alfalla-Luque, 2021) that respond to changing business environments by adapting their SC resources and generate improvements into performance and competitive advantage (Dyer, 1996). As dynamic capabilities, they are able to integrate, modify or renew internal and external resources/capabilities to address rapidly changing environments (Teece, Pisano, and Shuen, 1997; Pavlou and El Sawy, 2011), which enables managers to compete in the current turbulent marketplace by adapting to changing customer demand (Aslam et al., 2018). Understanding how Triple-A SC positively impacts operational performance requires exploring variables that can mediate the relationship. As Schilke, Hu and Helfat (2018) state, the literature has not thoroughly explored the additional mechanisms to explain the relationships between dynamic capabilities and other types of variables such as mediation.

The remainder of this paper is divided into five sections. Section 2 summarizes the theoretical background and states the hypotheses to be tested. Section 3 gives a description of the methodology used. Section 4 analyses the empirical findings. A discussion of the results and the conclusions follow in Section 5. Finally, academic and practical implications and limitations are outlined, and directions for additional research are proposed in Section 6.

2. Research background and hypothesis development

2.1. Triple-A SC and performance

SC success depends on the SC's ability to perform better during periods of vulnerability and this, in turn, depends on the SC's ability to articulate an SC that can leverage all three

"As" simultaneously (Khan, Piprani, and Yu, 2023; Trickle, Schiffling, and Verma, 2024). *SC agility* "is a company's ability to quickly adjust tactics and operations within its SC to respond or adapt to changes, opportunities, or threats in its environment" (Gligor et al., 2013). It is identified as a crucial element of competitiveness that directly impacts effective on-time production (Swafford, Ghosh, and Murthy, 2006) by enabling swift and cost-effective responses to unforeseeable market changes and increased environmental turbulence regarding both variety and volume (Altay et al., 2018). *SC adaptability* can be defined as the organizations' dynamic capability to adjust their SC strategies to meet changing needs and environments, and said changes are often in response to the maturity of the product or the market (Lee, 2021). The complex and turbulent market environment also requires an adaptable SC to increase the chance of survival, and this has become a key prerequisite for achieving a sustainable competitive advantage (Tuominen, Rajala, and Möller, 2004). An adaptable SC entails more flexibility in network relationships and more attention to changing management (Erhun, Kraft, and Wijnsma, 2021; Morita et al., 2024). Finally, an *aligned SC* seeks to bring the interests of all the SC partners into line by sharing information, responsibilities and roles, and incentives and, in the final instance, to highly synchronize SC processes and activities (Lee, 2004). When entities in the SC ecosystem are not aligned, isolated decision-making can harm overall performance and produce inefficient results (Erhun, Kraft, and Wijnsma, 2021) as some partners may seek to optimize their operations rather than maximize SC performance as a whole (Mak and Max Shen, 2021). Consequently, companies should develop AAA capabilities to generate profits in the SC ecosystem (Sodhi and Tang, 2021).

Business' capabilities represent its potential to meet its objectives through their targeted deployment and are its bedrock for competing in the market (Mikalef et al., 2019). However, theoretical and empirical research on Triple-A SC capabilities is still limited and demands further exploration (Marin-Garcia, Machuca, and Alfalla-Luque, 2023). Some empirical studies have analyzed the Triple-A SC framework considering the individual impact of each Triple-A SC capability on performance (e.g., Dubey, Singh, and Gupta, 2015; Dubey and Gunasekaran, 2016; Attia, 2016; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Feizabadi, Gligor, and Motlagh, 2019; Gligor et al., 2020; Marin-Garcia, Machuca, and Alfalla-Luque, 2023; Khan, Piprani, and Yu, 2023; Kakhki, Rea, and Deiranlou, 2023). Notwithstanding, only a minimal number of studies such as the present paper have followed Lee's (2004) original conceptual framework to analyze the impact of Triple-A SC as a whole on performance: in Egyptian (Attia, 2015), US (Whitten, Green, and Zelbst, 2012), and multi-country samples (Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Feizabadi, Gligor, and Motlagh, 2019; Machuca, Marin-Garcia, and Alfalla-Luque, 2021). Research determines that a positive relationship exists between Triple-A SC and SC performance (Whitten, Green, and Zelbst, 2012; Attia, 2015), firm performance (financial performance and market performance) (Feizabadi, Gligor, and Motlagh, 2019), cost, flexibility, delivery, and financial competitive advantages (Alfalla-Luque, Machuca, and Marin-Garcia, 2018), operational and relational performance (Yang, 2021), and cost, delivery, flexibility, and quality competitive advantages (Machuca, Marin-Garcia, and Alfalla-Luque, 2021). However, a positive Triple-A SC-performance relationship has not been supported with quality (Alfalla-Luque, Machuca, and Marin-Garcia, 2018). All these studies call for future research to clarify the Triple-A SC-performance relationship in other samples.

Sanghotra et al. (2011) state that non-financial performance measures must be considered, not only because they are measurable, but because they are also consistent with organizational strategies and objectives. Thanks to superior resources and their implementation, SC capabilities can generate competitive advantages in operational performance (Pashaei and Olhager, 2019). As a result, shop-floor level performance is largely measured and reported using non-financial indicators (Abdel-Maksoud et al., 2005; Nawanir et al., 2013). The present study focuses on two main operational performance measures, efficiency and responsiveness, which are two key competitive factors (Danese, Romano, and Bortolotti, 2012; Vidalakis and Sommerville, 2013; Moyano-Fuentes, Sacristán-Díaz, and Garrido-Vega, 2016; Seth and Panigrahi, 2015; Dubey et al., 2022; Park, Braunscheidel, and Suresh, 2023). In line with the DCV, Triple-A SC implementation is expected to improve operational performance (Marin-Garcia, Machuca, and Alfalla-Luque, 2023).

To contribute new evidence to the previous research on the link between Triple-A SC and operational performance, and as most of the research supports a positive influence, the following hypothesis is proposed:

> *H1: Triple-A SC is positively related to operational performance (H1a: efficiency, H1b: responsiveness).*

2.2. The mediating role of SC collaboration level

There is a broad consensus that external collaboration with customers and suppliers is a core capability of SCM (Barratt, 2004) and this has been analyzed in previous research (e.g., Paula et al., 2019). SC collaboration has been defined in multiple ways and is even used interchangeably with coordination, cooperation, and integration (Zacharia, Nix, and Lusch, 2009). The present paper follows the Cao and Zhang definition (2011, 166): "a partnership process where two or more autonomous firms work closely to plan and execute SC operations toward common goals and mutual benefits", and focuses on the level of SC collaboration with suppliers and customers achieved by firms over their main competitors.

On the one hand, prior research has identified that the presence of several crucial antecedents, such as attitudes and behaviors, interaction patterns, technologies, and SC strategies and practices, is required for a high level of SC collaboration (e.g., Ramanathan and Gunasekaran, 2014; Kim, Lee, and Lee, 2019). Feizabadi, Maloni, and Gligor (2019) suggest that organizations that implement Triple-A SC should encourage SC collaboration to obtain all the potential benefits of the Triple-A SC strategy. However, the antecedents to SC collaboration have been glossed over in the literature and their effect on collaborative advantage and company performance has not been investigated until recently (Chi, Huang, and George, 2020). Only a few studies consider the isolated effects of SC agility, adaptability, and alignment on SC collaboration. For example, Carvalho, Azevedo, and Cruz-Machado (2012) find that an agile SC strategy increases the level of collaboration with suppliers and customers when seeking higher responsiveness and flexibility. Nyaga et al. (2013) find a positive influence on the collaboration of SC partners' adaptability behavior. Some papers also support the positive influence of IT alignment on collaboration (e.g., Kim, Cavusgil, and Cavusgil, 2013; Dubey et al., 2021; Chi, Huang, and George, 2020). Li, Hu, and Zhang (2024) found a positive relationship between SC alignment and adaptability in cooperation performance, a construct closely linked to SC collaboration. Therefore, it can be supposed that the SC collaboration level tends to rise as the implementation level of the Triple-A SC increases.

On the other hand, organizations recognize that effective and efficient SC collaboration is a source of competitive advantages (Pradabwong et al., 2017). The ultimate goal of SC collaboration is to achieve differential performance and create and sustain a competitive advantage for SC partners (Hui, He-Cheng, and Min-Fei, 2015; Srivastava, Iyer, and Rawwas, 2017). Thus, since SC collaboration creates a fluid and synchronized relationship between partners to meet customer demand and improve performance, it is considered a driving force for an effective and efficient SC (Ramanathan and Gunasekaran, 2014). SC partners can obtain greater resources, complementary skills, capabilities, recognition, and rewards through collaboration when competing for finite resources, so SC competitiveness depends strongly on non-marketable capabilities through collaboration (Zacharia, Nix, and Lusch, 2009). This drives responsiveness at the SC level and reduces costs for all SC partners (Kim, Lee, and Lee, 2019). Consequently, companies have striven to improve the level of SC collaboration to leverage suppliers' and customers' resources and capabilities and, in doing so, achieve a stronger competitive position (e.g., Cao and Zhang, 2011; Liao, Hu, and Ding, 2017).

Growing research interest confirms the impact of SC collaboration on performance (Soosay and Hyland, 2015). The most prominent traditional operational benefits of SC collaboration include cost reductions, enhanced quality and inventory management, shorter cycle times, delivery improvements, greater flexibility and adaptability to cope with uncertainty and variability, responsiveness, and enhanced customer service levels (e.g., Zacharia, Nix, and Lusch, 2009; Cao and Zhang, 2011; Hui, He-Cheng, and Min-Fei, 2015; Kim, Lee, and Lee, 2019). Baah et al. (2022) found that SC collaboration and agility significantly impact SC performance through useful information-sharing. Al Humdan et al. (2023) indicated that SC agility improves resource allocation and cost use via collaboration and integration and, thus, generates value for the end customer, with the outcome of waste elimination and a positive knock-on effect on cost performance.

It can be deduced from all the above that implementing Triple-A SC can influence the achievement of a higher collaboration level and that the latter normally entails improvements in efficiency and responsiveness. Therefore, it would seem logical to think that SC collaboration level can play a mediating role by channeling part of Triple-A's impact to operational performance. SC collaboration is still considered a crucial mediator between several SC practices/capabilities/strategies and performance (Wu, Chuang, and Hsu, 2014; Hui, He-Cheng, and Min-Fei, 2015; Salam, 2017; Srivastava, Iyer, and Rawwas, 2017; Levi-Bliech et al., 2018; Kim, Lee, and Lee, 2019). For example, Levi-Bliech et al. (2018) found that both internal and external collaboration mediate the relationship between mobile technologies in the SC and operational performance. However, the relationship between information-sharing and performance shows inconclusive results: Baihaqi and Sohal (2013) confirmed full mediation of SC collaboration whereas Baah et al. (2022) could not find any mediating effect. Consequently, this research argues that companies with more agile, adaptable, and aligned SCs achieve greater efficiency and responsiveness, partly through a higher collaboration level with customers and suppliers than their competitors. The following hypothesis is formulated based on the above:

H2: The level of SC collaboration positively mediates the relationship between Triple-A SC and operational performance (H2a: efficiency, H2b: responsiveness).

2.3. The mediating role of innovation level

Innovation is recognized as critical for SCM as it helps achieve performance and competitive advantages (Cheng, Chen, and Huang, 2014; Paula et al., 2019; Abdallah, Alfar, and Alhyari, 2021; Jaouadi, 2022). Innovation plays a crucial role in responding to changing customer demands and needs through timely product and service modifications and organizational process improvement (Bahrami, Shokouhyar, and

Seifian, 2022). Although innovation can be defined and classified in different ways, this study follows the Oslo Manual definition (OECD, 2018) and considers it according to its object or purpose as a product (good and/or service) or process, i.e., the development of new or significantly changed products and processes (Najafi-Tavani et al., 2018). Specifically, this research understands the level of innovation as a company's ability to adequately alter its products and processes compared to its closest competing organizations (Guimaraes, 2011).

It has been surmised that dynamic capabilities create income by combining assets and capabilities in new ways, with outcomes that can define the market, e.g., innovation (Mikaleft et al., 2019; Bhatti et al., 2024). Previous empirical research has identified dynamic capabilities that significantly contribute to product and process innovation (Cheng, Chen, and Huang, 2014; Ju, Park, and Kim, 2016; Mikalef et al., 2019; Jaouadi, 2022). In line with the DCV, SC capabilities represent a fledgling theoretical vision for driving innovation and performance throughout the SC (Bhatti et al., 2024).

While previous research has not considered the AAA SC capabilities (Triple-A SC framework) jointly as an antecedent of innovation, several studies have considered that some of the 3As are. For example, Bhatti et al. (2024) analyze the impact of SC agility and adaptability on innovation and find a direct, positive, and significant effect. These authors highlight the need for further research to analyze other capabilities such as SC alignment as innovation drivers. Regarding SC agility, some papers find a positive influence of an agile SC on innovation (e.g., Swafford, Ghosh, and Murthy, 2006; Ayoub and Abdallah, 2019; Yildiz and Aykanat, 2021). For example, Swafford, Ghosh, and Murthy (2006) state that SC agility improves a company's ability to produce innovative products and quickens time-to-market. Ayoub and Abdallah (2019) find that SC agility affects SC innovativeness and that SC innovativeness fully mediates the SC agility-performance relationship. Yildiz and Aykanat (2021) confirm the positive impact of agility on innovation.

Focusing on SC adaptability, it seems logical that, by its very definition (adapting strategies, products, and/or technologies to changes in market structures), SC adaptability should have a positive effect on the level of innovation. In fact, some studies find that it enhances innovation in line with the aim of adaptability to modify products and technologies (Schoenherr and Swink, 2015; Zhang et al., 2018; Feizabadi, Maloni, and Gligor, 2019). For their part, Schoenherr and Swink (2015) recognize that SC adaptability is a dynamic capability that acts as an enabler of innovation by outstripping the competition in new product introductions. They conclude that SC adaptability is positively associated with product innovation and that both are positively related to new product launch success. Meanwhile, Zhang et al. (2018) support SC adaptability's mediation between supplier knowledge integration and product innovation performance.

Finally, regarding SC alignment, several studies have analyzed innovation as a consequence and concluded a positive relationship between the two (Feizabadi, Maloni, and Gligor, 2019). For example, Chen, Daugherty, and Landry (2009) conceptualize SC process integration (process alignment) as an antecedent of innovation. Mahapatra, William, and Padhy (2019) propose theoretically that SC alignment practices drive innovation in the supply base. In this context, the literature review of the Triple-A SC capabilities developed by Feizabadi, Maloni, and Gligor (2019) concludes that consequences such as innovation should be analyzed for the entire Triple-A SC framework. This is in line with the recent paper by Lee (2021), which argues that the AAA framework should consider innovation a critical factor and states that leading

Triple-A SC companies should focus their attention on innovation to rapidly offer novel products and processes.

Regarding the innovation-firm performance relationship, the growing research interest seen over the last five decades confirms that innovation is imperative for survival, growth, and achieving superior performance and competitive advantages in a highly turbulent environment (Ratten, Ferreira, and Fernandes, 2017). From a DCV perspective, the ability to develop innovations in both products and processes should lead to competitive advantages (Cheng, Chen, and Huang, 2014; Adebanjo, Teh, and Ahmed, 2018). Thus, innovative companies are usually more profitable and competitive than non-innovators (Mohnen and Hall, 2013). Evidence on the relationship between innovation and operational performance is limited compared to financial measures and findings are inconsistent (e.g., Gunday et al., 2011; Al-Sa'di, Abdallah, and Dahiyat, 2017; Shi et al., 2018; Pérez-Luño, Bojica, and Golapakrishnan, 2019; García-Fernández, Claver-Cortés, and Tarí, 2022). Although it seems theoretically and logically reasonable that a high level of process innovation can lead to better responsiveness and efficiency, a high level of product innovation can also enhance both. Product innovation can take quite different forms and have different objectives. For example, modular product design is a way to achieve flexibility in production, in the product mix, evidently, but also in volume. In the same way, seeking parts standardization in new product design can increase flexibility in production while simplifying planning, helping to reduce the number of suppliers, etc. As a result, there is a consistent body of work that points to innovation having different effects on operational performance. One of the main operational benefits of a high level of innovation is a quicker response, with new product launches and processes with shorter time-to-market and lower costs (Gunday et al., 2011; Wang and Wang, 2012;

Kafetzopoulos and Psomas, 2015; Khalfallah et al., 2022; Arshad Ali and Mahmood, 2024). So, innovative firms are able to respond to demand changes and adapt their product ranges and processes more rapidly (Wang and Wang, 2012). Koufteros and Marcoulides (2006) find that high innovation performance can improve the speed and quality of operations and enable quality defects to be detected and resolved more quickly. Innovation can also improve production volume, product-mix flexibility, and cycle times (Gunday et al., 2011; Iranmanesh et al. 2021; Khalfallah et al., 2022; Arshad Ali and Mahmood, 2024), quality, delivery, costs (Gunday et al., 2011; Wang and Wang, 2012; Kafetzopoulos and Psomas, 2015; Iranmanesh et al. 2021; Khalfallah et al., 2022; Arshad Ali and Mahmood, 2024) and productivity (Wang and Wang, 2012; Kafetzopoulos and Psomas, 2015).

Consequently, Triple-A SC and innovation have been shown to have an impact on operational performance. At the firm level, Camisón and Villar López (2010) find that product and process innovation mediate the link between flexible production system and organizational performance. In this line, innovation has been studied as a mediating variable between SCM practices and strategies, and operational performance. The SCM literature is showing a growing interest in the study of the mediating role of innovation in the relationships between dynamic capabilities and performance (e.g., Ju, Park, and Kim, 2016; Zhou et al., 2019; Bahrami, Shokouhyar, and Seifian, 2022; Jaouadi et al., 2022; Tipu and Fantazy, 2023). Bahrami, Shokouhyar, and Seifian (2022) find that Big Data analytics capabilities improve SC performance through SC innovation. In this line, Tipu and Fantazy (2023) conclude that innovation fully mediates the relationship between the Big Data analytics capability and sustainable SC performance. Ju, Park, and Kim (2016) find that product and process innovation mediate the link between SC dynamic capabilities and operational performance. The said authors state that SC agility capability has a positive effect on product and process innovation and, thus, on achieving an improvement in operational performance (quality, cost, flexibility, and delivery). Focusing on agility, Yildiz and Aykanat (2021) show the partial mediation role of innovation in the agility-firm performance relationship. Along this line, this research argues that firms with more agile, adaptable, and aligned SCs achieve greater efficiency and responsiveness, partly through a higher level of innovation in products and processes than their competitors. Therefore, the following hypothesis is formulated:

H3: The level of innovation positively mediates the relationship between Triple-A SC and operational performance (H3a: efficiency, H3b: responsiveness).

Figure 1 presents all the above hypotheses in the proposed research model, including the control variables described in Section 3.2.

-------------------- FIGURE 1 --------------------

3. Methodology

3.1. Data description and sample selection

The research model was tested with data gathered using a questionnaire based on prior research. The questionnaire was addressed to the head of SCM, logistics, or Operations Management in medium-sized enterprises in Spain. The choice of companies within the same geographical, cultural, legal, and political environment allows to minimize the impact of other variables that cannot be controlled in empirical research (Rojo, Llorens-Montes, and Perez-Arostegui, 2016). As in previous studies (Aslam et al., 2018), we used a single-respondent survey, which continues to be a viable tool in SC research when the necessary care is taken (Montabon, Daugherty, and Chen., 2018). In this sense, for example, secondary data have been used to verify the representativeness of our sample, qualified informants (top managers) have been selected, and the data have been collected by a prestigious market research company.

The sampling frame consists of 2,650 Spanish manufacturing companies with ≥ 50 employees taken from the "Iberian Balance Sheet Analysis System" (SABI) database. These companies belong to 14 sectors according to the "Spanish Standard Industrial Classification", excluding industrial sectors that are not in an intermediate position in their SC.

The survey was administered by telephone using a CATI (Computer Assisted Telephone Interview) system. A web-based questionnaire was also designed to facilitate the response process. Data were collected from January to July 2018. A total of 277 companies (10.5% response rate) returned valid questionnaires (sampling error = 5.49%; confidence level of 95% for $p = q = 0.5$). Sector distribution of companies is similar in the population and sample (Table 1). The mean number of employees in the companies in the sample is 184 and the maximum is 3,380, while the mean company age is 38.6 years, with a minimum of 8 and a maximum of 114 years.

--------------------- TABLE 1 ---------------------

Common method bias was addressed using the MacKenzie and Podsakoff (2012) guidelines. The survey instrument was tested with a panel of five international SCM researchers and a pilot study was then conducted with five top managers of SCM to minimize ambiguities and respondent bias. Dependent and independent variables were placed in two separate sections of the survey with different Likert scales (strongly disagree-strongly agree vs. much better-much worse). Additionally, post hoc analyses were carried out after data collection. First, a full collinearity test (Kock, 2015) was conducted with VIFs ranging from 1.47 to 2.34, all under the level of 3.3 which would indicate problems. Second, Harman's single factor test (principal axis factoring) yielded a proportion of shared variance of 23.5%, far below 50%, which would indicate the possibility of common method bias. Third, the correlation matrix among the construct variables (see Table 3) was also examined to determine whether there were any extremely high correlations (>0.90). No highly-correlated constructs were found (Iftikhar et al., 2022).

No significant differences in gross operating profits, annual sales, and number of employees (SABI database) were found between population and sampling distributions. A random number of companies that did not answer the questionnaire also received telephone calls and no specific characteristics were detected. In general, there is no apparent non-response bias in the sample. Finally, the first 40 responses and the last 40 responses were compared (Armstrong and Overton, 1977; Rogelberg and Stanton, 2007) and no significant differences were found ($\alpha = 0.05$) for any of the questionnaire variables. Therefore, there does not seem to be any late response bias. In conclusion, the study sample appears to be random and statistically representative of the population.

3.2. Measures

Triple-A SC has been developed as a second-order construct (Whitten, Green, and Zelbst, 2012; Attia, 2015) with three components: SC agility, SC adaptability, and SC alignment. SC agility items have been adapted from previous research (Tachizawa and Gimenez, 2010; Qi et al., 2011). SC adaptability and SC alignment scales have been adapted from the scale developed by Marin-Garcia, Alfalla-Luque, and Machuca (2018). All items have been measured using a five-point Likert scale (from 1: 'strongly disagree' to 5: 'strongly agree'. These three first-order constructs are considered reflective, i.e., items are the consequence of the latent variable. Likewise, Triple-A SC has been modeled as a reflective-formative second-order construct measured with composite indicators as each 'A' represents a different aspect of the construct.

SC collaboration and innovation levels are perceptual and relative measures to assess firms' results over their main competitors. Specifically, respondents were asked to compare their firm's measures with their competitors' on a five-point Likert scale (from 1: "poor, low" to 5: "much better than average". As perceptual measures can be subject to bias, objective firm performance data were collected in line with Danese and Kalchschmidt (2011), and a significant correlation was confirmed between perception measurements and objective data (standardized by industry). *SC collaboration level* measures the degree of external collaboration with suppliers and customers compared to the firm's main competitors (Klassen and Vachon, 2009). *Innovation level* measures the degree of process and product innovation compared to the closest competing organizations (Ritter and Gemünden, 2003; Hsu et al., 2014). This means that both variables have been measured as results (levels compared to the main competition), not as the activities or practices that companies engage in to achieve SC collaboration and innovation.

Operational performance considers two different measures, which is consistent with previous research: a) *Efficiency*: including the unit cost of manufacturing, inventory turnover, and cycle time (from raw materials to delivery) (Danese, Romano, and Bortolotti, 2012; Alfalla-Luque, Marin-Garcia, and Medina-Lopez, 2015), and b) *Responsiveness*: including simultaneously achieving flexibility and delivery performance (Bortolotti, Boscari, and Danese, 2015; Alfalla-Luque, Marin-Garcia, and Medina-Lopez, 2015). These two measures have habitually been used to characterize SC (efficient vs. responsive) since Fisher's (1997) work.

Three control variables used in previous studies (Gunasekaran et al., 2017; Gölgeci et al., 2019; Cândido and Ferreira, 2021; Riggs et al., 2023) were added to the model as they could affect the performance variables: *Age* (company age in number of years); *Size* (average workforce during the last 3 years on a logarithmic scale), and *Industry sector* (measured through a construct made up of dummy variables, following Benitez et al. (2020)). Including these control variables also enabled to mitigate the risk of endogeneity for potentially omitted variables.

4. Data analysis and results

The research model was tested using partial least squares structural equation modeling (PLS-SEM) with SmartPLS 4 (Ringle, Wende, and Becker, 2022). This technique is increasingly being used in many disciplines, including SCM. PLS-SEM is an alternative to CB-SEM (covariance-based) and represents a measurement philosophy based on composites instead of common factors (Hair et al., 2017). PLS-SEM is a better choice when the model includes formative measured constructs, the purpose of the research is to explore extensions of established theories, and the focus is on the prediction and explanation of key target constructs or identifying key driver constructs (Hair et al., 2019).

Applying the inverse square root method (Kock and Hadaya, 2018), our sample of 277 observations is sufficient for detecting minimum effect coefficients of 0.15 with a significance level of 5%, assuming a power level of 80%. Missing values represent an average of 2.15% for the indicators, with a maximum of 7.58% in two items. The mean replacement option was used for their treatment. Although neither skewness nor excessive kurtosis exceeds ±2 in any item, the Cramér-von Mises test indicates that the data do not follow a normal distribution.

The model was evaluated in two stages: a) assessment of the measurement model, and b) assessment of the structural model following the Sarstedt et al. (2022) guidelines. All the constructs were modeled as multidimensional latent variables with 2 to 6 indicators measured on a five-point scale. SC collaboration and innovation levels were modeled as formative (Mode B) composites as their indicators are not necessarily correlated. Triple-A SC was modeled as a second-order construct using the disjoint two-stage approach, with Mode A (correlation weights) for the first stage and Mode B (regression weights) for the second stage. Path weighting scheme was chosen for estimation (Becker et al., 2023). Statistical significance was tested by bootstrapping with 10,000 subsamples, one-tailed tests, and percentile confidence intervals (Becker et al., 2023).

4.1. Measurement model

For composites estimated in Mode A (reflective), the scales' psychometric properties were tested by verifying the indicators and constructs' reliability, convergent validity, and discriminant validity. Reliability was analyzed at the individual indicator level, for which factor loadings should be significant and above 0.70. All the indicators in the measurement model were highly significant ($p < 0.001$), and only two of the 24 loadings were slightly below 0.70. Construct reliability was assessed with two criteria: Cronbach's alpha (Fornell and Larcker, 1981) and composite reliability (Nunnally and Bernstein, 1994). According to Hair et al. (2017, 112), true reliability usually lies somewhere between the two (Cronbach's alpha can be considered a lower limit, and composite reliability an upper limit). Values above 0.70 are considered acceptable for demonstrating internal consistency reliability. All constructs are above this threshold except for *efficiency*, which have a Cronbach's alpha only slightly below. Notwithstanding, composite reliabilities for *efficiency* are over 0.80 (Table 2).

Convergent validity was evaluated through average variance extracted (AVE), which must be over 0.50 for construct measurement to be accepted. As Table 2 shows, all AVEs were above this threshold, so convergent validity seems to be met.

-------------------- TABLE 2 --------------------

Discriminant validity of the constructs is also demonstrated by the Fornell-Larcker criterion, as all between-construct correlations (lower triangular matrix) are below the square root of the constructs' AVEs (diagonal) matrix (Table 3). This conclusion is reinforced by the HTMT (Heterotrait-Monotrait) ratios, which are all below 0.85 (upper triangular matrix).

-------------------- TABLE 3 --------------------

The three composites estimated in Mode B (formative) are evaluated in Table 4. First, indicator collinearity is examined, and it is concluded that this is not a problem as all the VIFs are below the threshold value of 3.3 (Hair et al., 2017). Then, the significance of the regression weights is examined, and the results show that all indicators are significant at $p < 0.05$.

-------------------- TABLE 4 --------------------

Finally, the saturated model presents an SRMR of 0.06, which is below the recommended 0.08 cut-off (Henseler, 2021) and, therefore, acceptable. Given these results, this study's measurement model is concluded to be reliable and valid, so the structural model can be analyzed.

4.2. Structural model

Direct effects analysis

First, the VIFs were checked in the structural model and gave a maximum value of 1.77, well below 3 (Hair et al., 2017), so there were no multicollinearity issues. Second, we tested for potential nonlinear relationships, including interaction terms to represent quadratic effects between all the independent and dependent variables in our model. The results of bootstrapping with 5,000 samples show that neither of the quadratic effects is statistically significant, so the linear effects model is appropriate. Next, the structural model path coefficients that represented the hypothesized relationships (Figure 2) were analyzed.

-------------------- FIGURE 2 --------------------

As expected, all the coefficients were positive and statistically significant, and, therefore, all the direct effects in our model were supported. Re: H1, *Triple-A S*C direct effects are significant on *efficiency* (c_1) and *responsiveness* (c_2), and, consequently, H1 is supported. *SC collaboration level* positively influences both performance measures, although this influence is stronger on *responsiveness* (b_2) than on *efficiency* (b_1). *Innovation level* also has significant direct effects on each of the performance measures, with similar impacts for both performance aspects (b_3 and b_4). In addition, *Triple-A SC* has a direct effect on the levels of *SC collaboration* (a_1) and *innovation* (a_2) and these are the strongest relationships in the model.

Regarding the control variables, only one of the six relationships is significant and indicates that size has a small negative impact on the degree of *responsiveness*.

Indirect effects

The indirect effect analysis addresses the two mediation hypotheses in the model. Table 5 shows the total, direct, and indirect effects of Triple-A on operational performance. The effects of *SC collaboration level* and *innovation level* as mediating variables between *Triple-A SC* and performance variables are significant ($p < .05$). In both cases, mediation is partial since direct effects still account for 46% and 36% of the variance of *efficiency* and *responsiveness*, respectively, even in the presence of mediators. In addition, *SC collaboration* seems to be more important as a mediator for *responsiveness*, whereas *innovation* is a more important mediator for *efficiency*. Consequently, H2 (for *SC collaboration level*) and H3 (for *innovation level*) are supported, and both two variables (*SC collaboration* and *innovation levels*) are effective mediators between Triple-A SC and Operational performance.

--------------------- TABLE 5 ---------------------

Explanatory power and effect sizes

The analysis of the results continues with an exploration of the whole model with the coefficients of determination and the effect sizes. The determination coefficients (R^2) represent the explanatory power of the model and measure the combined effects of the exogenous variables on the endogenous variables. R^2 range from 0.23 for innovation level to 0.44 for responsiveness (Figure 2) and adjusted R^2 are only slightly smaller (0.23 to 0.43). Values between 0.10 and 0.25 could be interpreted as indicating small explanatory power and moderate between 0.25 and 0.45 (Marin-Garcia and Alfalla-Luque, 2019). Consequently, on average the values indicate moderate explanatory power, so this research model is appropriate and useful.

Regarding effect sizes, Figure 2 also shows the f^2 values for the direct effects in the model. The f^2 statistic measures the change in R^2 when a specified variable is omitted from the model, enabling the importance of this variable's impact on the endogenous constructs to be evaluated. Considering the effects as small, medium, or large according to the Cohen (1988) thresholds (0.02, 0.15, and 0.35), the biggest effects are those of *Triple-A SC* on *SC collaboration level* (large) and *innovation level* (medium). The remaining effects (six) are all small.

Predictive power

Finally, the model's predictive power has been checked with the PLSpredict procedure (Shmueli et al., 2019) with cross-validation prediction errors calculated with 10 folds and 10 repetitions. The procedure has two steps: First, Q^2 is examined to see whether it is positive for the constructs; second, the prediction errors of the indicators from PLS are compared with the values obtained from naïve linear regression (LM). As can be seen in Table 6, all the obtained Q^2 values are positive, which means that PLS model prediction errors are smaller than simple mean prediction errors. Root mean squared error (RMSE) has been used to assess the degree of prediction power in the second step as prediction errors are not highly asymmetrically distributed. The comparison of the indicators' RMSE showed that these are smaller in PLS than LM for all the indicators in *SC collaboration level*, which indicates high predictive power. For *responsiveness* and *efficiency*, the majority of the indicators were smaller, which indicates medium predictive power. However, for *SC innovation level*, none of the two indicators is smaller, which means that predictive power is not confirmed for this construct in the model.

--------------------- TABLE 6 ---------------------

5. Discussion and conclusions

Today's uncertain and fast-changing business context represents a major challenge for firms everywhere in the world and creates the need to be able to respond at a competitive cost due to the volatility of market demands and the fast rate at which technology is changing in today's business context (Napoleone et al., 2023). To gain a competitive advantage, Triple-A SC must achieve cost and responsiveness efficiencies to respond rapidly to the global and fast-changing market environment through flexibility and fast deliveries. As Lee (2004) states, greater speed and cost-effectiveness are the "popular grails" of SCM. Although previous research has analyzed the link between Triple-A SC and operational performance, the potential significance of mediating variables in the Triple-A SC-operational performance relationship has not been considered and the possible levers to improve performance are not fully understood. Therefore, it is imperative to understand what the fundamental mediating mechanisms are, and the present study aims to fill this gap as its main contribution.

DCV theoretically underpins the relationships tested in this research. From a DCV perspective, Triple-A SC capabilities enhance companies' competitiveness through their resource interdependence. Dynamic capabilities are expected to optimize overall SC performance (Cheng, Chen, and Huang, 2014). The results of this study support this as they conclude a positive impact of Triple-A SC capabilities on operational performance. Specifically, the direct effect of the Triple-A SC is significantly positive on both measures considered, efficiency and responsiveness, in line with Alfalla-Luque, Machuca, and Marin-Garcia (2018). This contributes to the previous research by contributing new empirical evidence on the Triple-A SC-performance relationship. However, a detailed comparison cannot be made with the other studies that focus on this topic (Whitten, Green, and Zelbst, 2012; Attia, 2015; Feizabadi, Gligor, and Motlagh, 2019; Machuca, Marin-Garcia, and Alfalla-Luque, 2021; Yang, 2021), as they have analyzed the performance measures using an aggregated construct. Attia (2015) and Whitten, Green, and Zelbst (2012) concluded a positive impact of Triple-A SC on global SC performance, Feizabadi, Gligor, and Motlagh (2019) on firm performance, Machuca, Marin-Garcia, and Alfalla-Luque (2021) on competitive advantages, and Yang (2021) on operational and relational performance. In general, the present study confirms that Triple-A SC is related to operational performance and contributes to previous research by analyzing the Triple-A SC's impact on different performance measures. As Alfalla-Luque, Machuca, and Marin-Garcia (2018, 55) state, "Continuing to analyze the competitive advantages individually would seem to be appropriate, as they have different effects that can lead to inappropriate conclusions if they are only analyzed using an aggregated single construct".

The results show that although Triple-A SC is positively linked to efficiency and responsiveness, the direct effects are not strong (.16 in both). This justifies the aim of this study and its main contribution: to analyze the levels of SC collaboration and innovation over the main competitors as mediating factors in this relationship. The indirect effects analysis suggests that the levels of SC collaboration and innovation reinforce the impact of Triple-A SC capabilities on operational performance. Indeed, most of the effect is produced through the analyzed mediating variables. The role of SC collaboration level as a mediator is disparate since it participates not only in the strongest indirect effect, in the relationship between Triple-A and responsiveness (.19), but also the weakest, between Triple-A and efficiency (.08). Innovation level, however, plays a more balanced mediating role for both performance dimensions (.12 for efficiency and .11 for responsiveness). We also found that innovation level plays a stronger mediating role for efficiency (32% of the total effect of Triple-A SC on efficiency) and SC collaboration level seems to be a more important mediator for responsiveness (41% of the total effect). Consequently, one of the principal contributions of this study is that it develops the Triple-A SC framework by finding that the effect of Triple-A SC is crucial but needs to be strengthened to bring relevant improvements to efficiency and responsiveness through the achievement of other variables/elements such as high levels of SC collaboration and innovation.

These mediating roles are due to Triple-A SC capabilities strongly influencing SC collaboration and innovation levels (.57 and .48, respectively). This supports Triple-A SC enabling the achievement of a higher level of SC collaboration with customers and suppliers and a higher level of product and process innovation. Consequently, as expected according to previous research, an agile, adaptable, and aligned SC allows, inter alia, knowledge/information sharing with partners, process integration, the detection of short- and long-term changes in real demand and supply, coordination of partners' interests with the SC's overall interests, coordinated lead times and logistics processes, and knowledge of real demand along the SC (Marin-Garcia, Alfalla-Luque, and Machuca, 2018), thus raising the levels of SC collaboration (Carvalho, Azevedo, and Cruz-Machado, 2012; Nyaga et al., 2013; Kim, Cavusgil, and Cavusgil, 2013). The same goes for innovation level, which, according to Mikalef et al. (2019), is a primary consequence of dynamic capabilities. In fact, our results are consistent with previous research on the relationship between Triple-A SC capabilities and innovation (Schoenherr and Swink, 2015; Zhang et al., 2018; Yildiz and Aykanat, 2021; Bhatti et al., 2024).

The mediating role of SC collaboration level is also due to its impact on operational performance, stronger on responsiveness than on efficiency (.33 *vs.* .14), which is an interesting finding for practitioners and academics. These results are in line with the previous research, which found a positive relationship between SC collaboration and performance (Zacharia, Nix, and Lusch, 2009; Cao and Zhang, 2011; Soosay and Hyland, 2015; Kim, Lee, and Lee, 2019; Amoako-Gyampah, 2020; Cadden et al., 2021; Jafari et al., 2023). Due to the turbulent and unpredictable marketplace and increasing global competition, upstream and downstream firms along the SC need collaborative intra-organizational processes that generate mutually beneficial SC partnerships (Alfalla-Luque, Medina-Lopez, and Dey, 2013). When collaboration between SC partners falls short, imbalances can arise between capacity and production planning. Some issues like work realignment or logistics would be essential for improvements in cost, quality, and speed.

The mediating role that innovation level plays also involves a direct effect on operational performance. This in line with the prior research (Koufteros and Marcoulides, 2006; Gunday et al., 2011; Wang and Wang, 2012; Kafetzopoulos and Psomas, 2015; Adebanjo, Teh, and Ahmed, 2018; Iranmanesh et al. 2021; Khalfallah et al., 2022; Arshad Ali and Mahmood, 2024). However, unlike collaboration level, innovation level seems to have similar effects on both performance dimensions (.24 on efficiency and .23 on responsiveness). In line with Bhatti et al. (2024), firms need to develop dynamic capabilities to achieve an innovative SC that enables flexibility and efficiency to be obtained.

The proposed research model explains a significant part of operational performance, but responsiveness (with an R^2 value of .44) is better explained than efficiency (.26). The model's explanatory power is also moderate for the mediating variables, SC collaboration level (.32) and innovation level (.23). Thus, the Triple-A SC seems to be a relevant antecedent for explaining the level of SC collaboration and innovation, and all three capabilities are meaningful antecedents to operational performance. This is in line with the trade-off cost-effectiveness versus greater speed considered in the Triple-A SC framework by Lee (2004). In our sample, Triple-A SC has a direct effect on both performance measures but the mediating variables (SC collaboration and innovation levels) have a stronger impact on responsiveness than on efficiency and generate a SC that reacts faster to the changing and unpredictable marketplace. As Lee (2004) states, SC efficiency is required, but on its own it does not guarantee that a company will outperform the competition.

An additional finding regarding the control variables shows that size negatively influences responsiveness, i.e., larger companies seem to be less responsive. This could be due to larger companies being more rigid, or less flexible, than smaller firms.

This paper also contributes to widening the knowledge of the link between Triple-A SC and performance by responding to the call for more research made by Hou et al. (2023). It also provides new evidences in a Spanish multi-sector sample of manufacturing firms, answering the call made by several authors to the need to analyze different samples (Li, Wu, and Holsapple, 2015; Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Marin-Garcia, Machuca, and Alfalla-Luque, 2023; Hou et al., 2023; Jia et al., 2024). Part of the previous research focused either on a single country: Attia (2015) in the Egyptian textile industry and Whitten, Green, and Zelbst (2012) in cross-sectoral US companies, for example, or multi-country samples in manufacturing firms in the automotive components, equipment, and electronics sectors (Alfalla-Luque, Machuca, and Marin-Garcia, 2018; Machuca, Marin-Garcia, and Alfalla-Luque, 2021) or a variety of manufacturing and services industries (Feizabadi, Gligor, and Motlagh, 2019).

Cultural, legal, social, and other country aspects could have an impact on the link between Triple-A SC and performance. The literature on the possible influence of national culture on performance is extensive (e.g., Schroeder and Flynn, 2001; Naor et al., 2010; Arana-Solares et al., 2019) and still marked by Bird and Kotha's (1994) convergence vs. divergence debate. Present results add to this literature by showing that this relationship appears to be robust to factors in the Spanish manufacturing sector. Following the convergence perspective (Machuca et al., 2021), a positive relationship exists between Triple-A SC and operational performance, similar to the majority of the previous studies in other countries.

Finally, this paper also extends the research by Bhatti et al. (2024) by including SC alignment in the analysis as an antecedent of innovation, which said authors suggested as further research.

To summarize, this study offers relevant and original contributions related to new empirical evidence for Lee's (2004) conceptual framework and supports not only the impact of Triple-A SC on performance (as found in the previous research), but also the previously unresearched mediating effects of SC collaboration and innovation levels on this relationship.

6. Implications, limitations, and further research

Several managerial implications can be drawn from this study. The COVID pandemic has demonstrated that firms cannot compete and survive successfully without an SC with AAA capabilities (Patrucco and Kähkönen, 2021; Tickle et al., 2024). The competitive environment has been shown to have a direct impact on the Triple-A SC whatever strategy the firm adopts and whatever way the environment impacts the strategy (Garrido-Vega et al., 2021). Present findings suggest that to remain competitive, SC managers should be aware that their efforts to improve the implementation level of the Triple-A SC should be accompanied by more intense collaboration with SC partners and improvements in the level of process and product innovation than their main competitors. Importantly, practitioners should acknowledge that concentrating solely on achieving Triple-A SC is insufficient and a strategic collaboration upstream and downstream and improvement to the level of innovation are needed. This suggests that firms should invest in strategies that promote customer and supplier collaboration levels along the SC as they all depend on each other; the performance of each individual member impacts all other members and the efficiency of the whole SC (Alfalla-Luque, Medina-Lopez, and Schrage, 2013). Practitioners also need to improve the level of innovation over their main competitors to help the AAA capabilities improve speed, flexibility, and cost along the SC. To be more specific, the present research demonstrates to managers that the impact of Triple-A SC on responsiveness is stronger than on efficiency through SC collaboration and innovation levels and that the role of SC collaboration level is the key to a responsive SC.

Researchers on this topic will find some new contributions on the Triple-A SC framework. Findings show that developing Triple-A SC capabilities as a bundle is useful for companies intending to improve their SC collaboration level. Similarly, firms wishing to compete on innovation need to know that the level of Triple-A SC implementation can help them raise their level of innovation in processes and products. Furthermore, the results demonstrate that these three variables have a clear influence on two important performance measures: efficiency, and responsiveness.

Although this research has made significant contributions, it has some limitations that could form the basis for future research. The aim of the analysis is exploratory in nature and data are cross-sectional and collected from only one country. Despite this, one of the study’s main strengths is worth highlighting: this is one of the few empirical articles on this topic that analyzes a broad, multi-sector (14 different sectors) sample and uses a relatively large sample (277 companies). A logical extension of the Triple-A SC framework is to develop research in other geographical settings, conduct longitudinal studies, analyze interactions and interdependencies among Triple-A SC capabilities, and consider different performance measures (operational, financial, and market). Another notable limitation concerns the limited number of items in the scales used to measure the two mediating variables. Although this simplicity makes them easy for respondents to understand, they may not capture the depth and breadth of SC collaboration and innovation levels. Besides, although the two analyzed mediating factors are consistent with the prior SC research, other SC factors such as SC resilience, environmental dynamism, uncertainty, SC structure and complexity, competitive intensity, product characteristics, and implementation time could play mediating—and even moderating—roles in the Triple-A SC-performance relationship. Further, the potential impact of SC collaboration level on performance may be contingent on factors such as absorptive capacity and relational traits (e.g., relationship quality) which it might be interesting to analyze to capture the true mediating impact of inter-firm collaborations on the relations between Triple-A SC and performance. This would extend the research and allow new insights to be gained since, as Mak and Max Shen (2021, 664) state, the Triple-A SC "will continue to inspire practitioners and researchers in SCM in the years to come".

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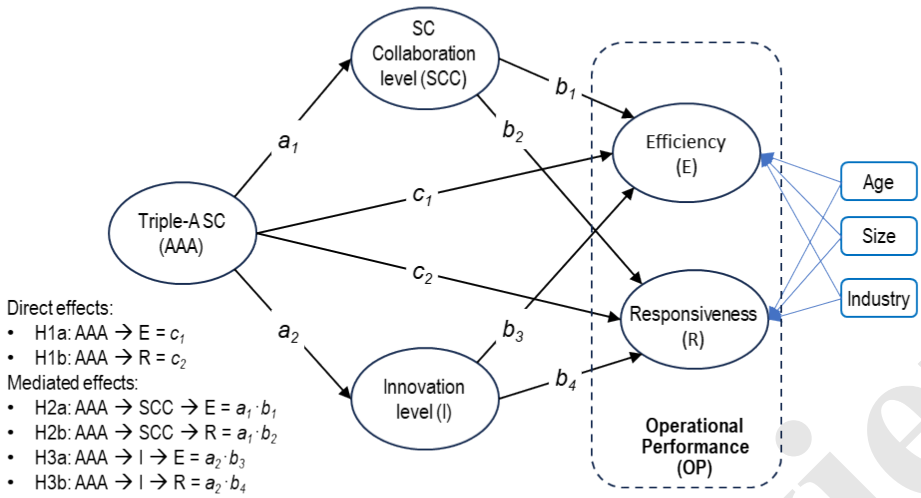


Figure 1. Proposed model and hypotheses

INDUSTRY	Population		Sample		
	Number	%	Number	%	Response Rate
Food products and tobacco	543	20.49%	48	17.33%	8.84%
Chemicals and pharmaceutical products	422	15.92%	48	17.33%	11.37%
Manufacture of metal products	322	12.15%	43	15.52%	13.35%
Manufacture of machinery and equipment	275	10.38%	34	12.27%	12.36%
Motor vehicles	273	10.30%	23	8.30%	8.42%
Meat industry	158	5.96%	6	2.17%	3.80%
Electrical machinery and materials	141	5.32%	14	5.05%	9.93%
Manufacture of beverages	106	4.00%	7	2.53%	6.60%
Furniture industry	82	3.09%	8	2.89%	9.76%
Informatics, electronics and optics products	81	3.06%	13	4.69%	16.05%
Manufacture of other transport material	77	2.91%	12	4.33%	15.58%
Shoes and Leather	63	2.38%	5	1.81%	7.94%
Other manufacturing industries	60	2.26%	10	3.61%	16.67%
Fabrics and Textile	47	1.77%	6	2.17%	12.77%
Total	2,650	100%	277	100%	10.45%

Table 1. Sample and population companies by industry

Construct	Item	Factor loadings*	Cronbach's alpha / CR	AVE
SC Agility	Our supply chain can adapt to the specifications of the orders made by our customers	.73	.82 / .87	.53
	If necessary, our supply chain can adjust its operations as required to execute our decisions	.75		
	Production planning has the ability to respond quickly to customers' changing needs	.70		
	Our supply chain can increase its short-term capacity when necessary	.68		
	Our supply chain can adjust/accelerate delivery times	.73		
	Our supply chain responds to customer demand	.79		
SC Adaptability	We have a good understanding of where our production technology stands in terms of technology life cycles	.77	.76 / .84	.57
	Our plant is continually on the leading edge of new technology in our industry	.79		
	We monitor economies around the world to detect potential new markets	.75		
	We monitor economies around the world to identify potential new suppliers	.73		
SC Alignment	Our supply chain members have clearly defined goals in our supply chain	.79	.86 / .90	.59
	We emphasize openness of communication in collaboration with our customers	.79		
	We emphasize openness of communication in collaboration with our suppliers	.83		
	Data stored in different databases is consistent across the supply chain	.72		
	We should use unambiguous language and communication with our supply chain partners	.71		
	Our supply chain members understand the goals of our supply chain management	.79		
Efficiency	Unit cost of manufacturing	.69	.63 / .80	.58
	Inventory turnover	.76		
	Cycle time (from raw materials to delivery)	.82		
Responsiveness	On-time delivery performance	.78	.85 / .89	.62
	Fast delivery	.83		
	Flexibility to change product mix	.81		
	Flexibility to change volume	.82		
	Speed of new product introduction into the plant	.70		

Notes: CR: composite reliability; AVE: Average variance extracted; * All the factor loadings are statistically significant at $p < .001$, based on $t(9999)$, two-tailed test.

Table 2. Reflective measurement model evaluation

	1	2	3	4	5
1. SC Agility	**.73**	.39	.51	.41	.52
2. SC Adaptability	.34	**.75**	.55	.30	.32
3. SC Alignment	.44	.47	**.77**	.45	.44
4. Efficiency	.30	.21	.34	**.76**	.65
5. Responsiveness	.44	.27	.38	.49	**.79**

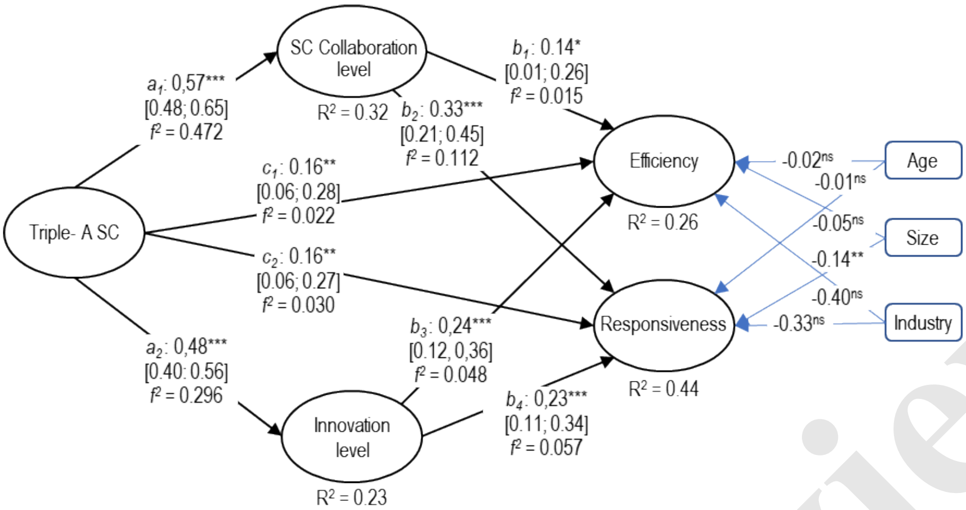
Note: Square root of AVE in the diagonal, correlations in the lower half and HTMT ratios in the upper half.

Table 3. Discriminant validity of measurement model

Construct	Item	Regression weight	t-value	p-value	VIF
SC collaboration level	Supplier collaboration compared to competitors	.66	6.748	.000	1.66
	Customer collaboration compared to competitors	.44	4.209	.000	1.66
Innovation level	Product innovativeness compared to competitors	.44	4.304	.000	1.59
	Process innovativeness compared to competitors	.67	7.239	.000	1.59
Triple-A SC (second-order construct)	SC-Agility	.41	4.373	.000	1.27
	SC-Adaptability	.21	1.818	.035	1.32
	SC-Alignment	.62	6.720	.000	1.45

Notes: VIF: variance inflation factor. All the factor loadings are statistically significant at $p < .001$, based on $t(9999)$/two-tailed test.

Table 4. Formative measurement model evaluation



Notes: ***: $p < 0.001$, **: p<0,01, *: $p < 0.05$, *ns*: non-significant (based on $t(9999)$, one-tailed test, two-tailed for control variables)

Figure 2. Structural model results (direct effects)

Relationship	Path coefficient	Std. Dev.	*t* - statistic	p - value	CI (90%)	Sup-ported?	VAF
Effect of Triple-A SC on Efficiency							
Total effect	.36	.054	6.550	.000	.27; .45	Yes	100%
Direct effect: H1a	.16	.066	2.444	.007	.06; .28	Yes	45.5%
Indirect effects							
• H2a: via SC Collaboration level ($a_1 \cdot b_1$)	.08	.044	1.808	.035	.01; .15	Yes	22.2%
• H3a: via Innovation level ($a_2 \cdot b_3$)	.12	.036	3.162	.001	.06; .18	Yes	32.2%
Effects of Triple-A SC on Responsiveness							
Total effect	.46	.063	7.347	.000	.36; .56	Yes	100%
Direct effect: H1b	.16	.065	2.520	.006	.06; .27	Yes	35.5%
Indirect effects							
• H2b: via SC Collaboration level ($a_1 \cdot b_2$)	.19	.047	4.018	.000	.11; .27	Yes	41.0%
• H3b: via Innovation level ($a_2 \cdot b_4$)	.11	.037	2.936	.002	.05; .17	Yes	23.4%

Note: N = 277. Bootstrapping based on n = 10,000 subsamples. One-tailed test for t Student distribution ($p < .05$). 90% percentile confidence interval. VAF: variance accounted for.

Table 5. Structural model results (decomposition of effects of Triple-A SC on OP)

	$Q^2_{predict}$	RMSE	Predictive power
SC Collaboration level	0.304	0.839	(2/2) high
Innovation level	0.212	0.897	(0/2) not confirmed
Efficiency	0.133	0.940	(2/3) medium
Responsiveness	0.243	0.878	(4/5) medium

Notes: Values obtained with PLSpredict with number of folds k = 10 and number of repetitions r = 10. Last column shows the number of indicators out of the total for each construct in which RMSE from PLS is inferior to RMSE from linear regression.

Table 6. Predictive power of the research model