

Agile and resilient approaches to supply chain management: influence on performance and competitiveness

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Abstract Supply chain management must adopt different and more innovative strategies that support a better response to customer needs in an uncertain environment. Supply chains must be more agile and be more capable of coping with disturbances, meaning that supply chains must be more resilient. The simultaneous deployment of agile and resilient approaches will enhance supply chain performance and competitiveness. Accordingly, the main objective of this paper is to propose a conceptual framework for the analysis of relationships between agile and resilient approaches, supply chain competitiveness and performance. Operational and economic performance measures are proposed to facilitate the monitoring of the influence of these practices on supply chain performance. The influence of the proposed agile and resilient practices on supply chain competitiveness is also examined in terms of time to market, product quality and customer service.

Keywords Agile approach · Resilient approach · Supply chain performance · Competitiveness

1 Introduction

Supply chains must adopt new strategies to improve their ability to respond rapidly and cost effectively to unpredictable changes in markets and increasing levels of environmental turbulence, both in terms of volume and variety. That is, supply chains need to have an agile approach to deal with all these changes. In addition to changes in customer preferences, supply chains are vulnerable to disruptions, and consequently, the risk to business continuity has increased [1]. Resilience is referred to as the ability of supply chains to cope with unexpected disturbances. Whereas in the past the principal objective in supply chain design was cost minimization or service optimization, the emphasis today has to be upon resilience [2]. Both agile and resilient approaches influence supply chain performance and competitiveness. These two approaches will contribute to more competitive supply chains in terms of time to market, quality and customer service, thereby improving market share and reinforcing leadership [3].

The simultaneous integration of different supply chain management strategies or approaches is not a new topic in the context of supply chain management. Naylor et al. [4] coined the concept of “leagile”, the integration of lean and agile paradigms in a total supply chain strategy. Christopher and Towill [5, 6] also state that lean and agile are not mutually exclusive paradigms and may be combined to develop highly competitive supply chains. However, this seminal research does not consider the effect of supply chain disruptions on the companies and consequent supply chain competitiveness. If supply chain disruption occurs, organizations cannot maintain their performance level and competitiveness [7]. This paper argues that the resilient approach is critical to sustaining supply chain competitiveness, and therefore, it should be considered along with other

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management approaches: the agile approach is responsible for quick response to demand variations, generating an important competitive advantage, and the resilient approach sustains the current level of supply chain performance even when disruptions occur. The main objective of this paper is to propose a conceptual framework to explore the relationships between agile and resilient practices and the performance and competitiveness of supply chains. This paper focuses on the following research questions:

- How can agile and resilient approaches be deployed in the supply chain context? What are the main characteristics of agile and resilient supply chains?
- How can agile and resilient practices contribute to improved supply chain performance and competitiveness? What are the main strategic priorities supported by these supply chain management approaches?

The organization of this paper is as follows. In the second section, a review of literature related to agile and resilient supply chain management approaches is presented, identifying the practices associated with each approach. In Sect. 3, a literature review of performance measurement is presented with a focus on performance measurement systems in the supply chain context. Next, in Sect. 4, the relationships between agile and resilient practices and supply chain competitiveness and performance are explored. Finally, a conceptual framework is proposed as a means to explore the relationships between agile and resilient practices and several performance measures and some competitive priorities. The paper closes with the main conclusions that can be drawn from the analysis.

2 Agile and resilient approaches

In competitive markets, organizations experience high rates of change in their environments. Azevedo et al. [8] point out the following changes: (1) customer service to relationship management; (2) adversarial relationships to collaborative relationships; (3) forecasting to end-casting; (4) functional integration to process integration; (5) vertical to virtual integration; and (6) share of information among supply chain entities. These changes have been stimulated by the following factors [9]: the internationalization of sourcing and distribution as a response to the perpetual search for cheap manufacturing labour; the restructuring of existing distribution systems to drive down costs; the breakdown of trade barriers in order to create larger economic areas of cooperation; the emerging importance of reverse logistics as a means of managing waste and protecting the environment; and the rationalization of the supply network organizations into global operators offering integrated solutions to their customers.

The objective of a supply chain is to deliver the right product, in the right quantity, in the right condition, to the right place, at the right time and for the right cost. Because customer requirements change constantly, supply chains must be adaptable to future changes in order to respond appropriately to market requirements. Moreover, rupture conditions in supply chains are observed when organizations are subject to disruptions caused by sudden and unforeseen events. One can thereby infer that the ability to cope with disturbances will also determine supply chain performance.

2.1 The agile approach to supply chain management

The agile supply chain management approach is designed to create the ability to respond rapidly and cost effectively to unpredictable changes in markets and increasing levels of environmental turbulence, both in terms of volume and variety [10, 11]. Baramichai, Zimmers and Marangos [12] consider that “an agile supply chain is an integration of business partners to enable new competencies in order to respond to rapidly changing and increasingly fragmented markets”.

Agarwal, Shankar and Tiwari [10] show that the agile supply chain management approach depends on the following variables: market sensitivity, customer satisfaction, quality improvement, delivery speed, data accuracy, new product introduction, centralized and collaborative planning, process integration, use of IT tools, lead-time reduction, service-level improvement, cost minimization, uncertainty minimization, trust development and the minimization of resistance to uncertainty.

To provide an overview on how the agile approach is deployed in the supply chain management context, a representative sample of the main agile supply chain practices, as found in the literature, is shown in Table 1. The agile practices were clustered into three levels within the supply chain: (1) agile practices developed upstream: these practices are associated directly with interactions between a firm and their suppliers; (2) practices deployed by firms in their daily internal operations; and (3) agile practices deployed downstream: those that concern all kinds of flows (materials and information) between the firms and their downstream partners involved in delivery activity.

2.2 The resilient approach to supply chain management

There is evidence that the tendency of many companies to seek low-cost solutions, due to pressure on margins, may have led to leaner but also to more vulnerable supply chains [8]. Resilient supply chains may not be the lowest-cost supply chains, but they are more capable of coping with the uncertainties in the business environment.

Table 1 Agile practices in the supply chain context

Agile supply chain management practices	References				
	[4]	[13]	[14]	[10]	[15]
Agile practices developed upstream					
Use of IT to coordinate/integrate activities in design and development				✓	✓
Use of IT to coordinate/integrate activities in procurement					✓
Ability to change quantity of supplier’s order					✓
Ability to change delivery times of supplier’s order					✓
Speed in reducing development cycle time					✓
First choice partner			✓		
Practices deployed by firms in their daily internal operations					
Use of IT to coordinate/integrate activities in manufacturing			✓	✓	✓
Integrated supply chain/value stream/virtual corporation	✓				
Centralized and collaborative planning				✓	
Rapidly reconfigure the production process	✓				
To produce in large or small batches		✓			
To accommodate changes in production mix					✓
To reduce manufacturing throughput times to satisfy customer delivery					✓
To reduce development cycle times					✓
To minimize setups times and product changeovers		✓			
Organized along functional lines			✓		
Facilitate rapid decision-making			✓		
Agile practices deployed downstream					
Use of IT to coordinate/integrate activities in logistics and distribution					✓
To alter deliver schedules to meet customer requirement					✓
To increase frequency of new product introductions			✓	✓	✓
Speed in adjusting delivery capability					✓
Speed in improving customer service				✓	✓
Speed in improving delivery reliability					✓
Speed in improving responsiveness to changing market needs					✓
Speed in increasing levels of product customization					✓
To capture demand information immediately			✓		
Retain and grow customer relationships			✓		
Products with substantial added value for customers			✓		

Resilience is the supply chain’s ability to cope with unexpected disturbances. The goal of supply chain resilience analysis and management is to prevent the shift towards undesirable states, that is, states in which failure modes could occur. The dual aims of resilient approaches are [16]: (1) to recover to the desired state of the system that has been disturbed, doing so within an acceptable time period and at an acceptable cost; and (2) to reduce the impact of a disturbance by changing the effectiveness level of a potential threat.

The ability to recover from a disturbance is related to the development of responsiveness capabilities through flexibility and redundancy [17]. Hansson and Helgesson [18] propose that robustness can be treated as a special case of resilience, since it implies the return of the system to the

original state after a disturbance occurs. In addition, Tang [19] proposes the use of robust supply chain strategies to enable a firm to deploy the associated contingency plans efficiently and effectively when facing a disruption, thereby making the supply chain more resilient. A representative sample of the main resilience practices related to the upstream, focal firm and downstream levels in the supply chain context, as found in the literature, is shown in Table 2.

2.3 Agile approach versus resilient approach

Although some researches [20–22] refer to the agile and resilient approaches as the means to improve supply chain performance, they do not provide an overview on the

Table 2 Resilient practices in the supply chain context

Resilient supply chain management practices	References			
	[17]	[20]	[19]	[21]
Resilient practices developed upstream				
Sourcing strategies to allow switching of suppliers	✓			
Committing to contracts for material supply (buying capacity, whether it is used or not)	✓			
Flexible supply base/flexible sourcing			✓	
Developing visibility to a clear view of upstream inventories and supply conditions		✓		
Practices deployed by firms in their daily internal operations				
Designing production systems that can accommodate multiple products and real-time changes	✓			
Multi-skilled workforce	✓			
Excess of capacity requirements	✓			
Postponement			✓	
Minimal batch sizes		✓		
Strategic stock		✓	✓	✓
Make-and-buy trade-off			✓	
Strategic disposition of additional capacity and/or inventory at potential “pinch points”		✓		
Developing visibility to a clear view production and purchasing schedules		✓		
Creating total supply chain visibility				✓
Lead-time reduction		✓	✓	
Process and knowledge backup				✓
Supply chain risk management culture		✓		
Developing collaborative working across supply chains to help mitigate risk		✓		
Resilient practices deployed downstream				
Maintaining a dedicated transit fleet	✓			
Flexible transportation			✓	
Silent product rollover			✓	
Developing visibility to a clear view of downstream inventories and demand conditions		✓		
Demand-based management				✓

differences and synergies between them. To fill this gap, Table 3 characterizes the agile and resilient approaches according to the following supply chain features: purpose, manufacturing focus, alliances, organizational structure, sourcing, inventory policy, lead-time focus and product design policy.

Table 3 shows the synergies between the agile and resilient approaches. In terms of purpose, the agile approach pursues the responsiveness of the supply network, but the resilient approach seeks to avoid/minimize the negative effects of disturbances. Both approaches promote collaboration among partners while seeking lead-time reduction. These two approaches rely on flexible suppliers. In addition, the agile supply chain also demands supplier responsiveness and quality. Agility can therefore be seen as an essential capability for building resilient supply chains [21]. Accordingly, Christopher [19] states that, “One of the most powerful ways of achieving resilience ... is to create networks, which are capable of more rapid response to changed conditions. This is the idea of agility”.

The agile and resilient supply chain management approaches are supported by specific combinations of supply chain skills or characteristics that promote the appropriate response to changes in markets and/or overcome the negative effects of disturbances. Supply chain agility increases the speed and flexibility with which activities can be performed; the faster flow can be achieved throughout the supply chain, the quicker customer needs can be satisfied [24]. In addition, the agile supply chain should be responsive to customer needs with high levels of efficiency and efficacy; this is competency [14, 25]. Jüttner and Maklan [26] capture the essence of supply chain resilience in four main characteristics: flexibility, velocity, visibility and collaboration. Despite the differences in their purpose, these two approaches contribute to the development of similar skills or characteristics in supply chain behaviour (Table 4).

The degree of flexibility, velocity, responsiveness, competence, visibility and collaboration will influence the supply chain behaviour supporting the quick response to

Table 3 Comparison of agile and resilient approaches

Supply chain features	Agile approach	Resilient approach
Purpose	Understand customer requirements by interfacing with customers and market and be adaptable to future changes [23]	The system's ability to return to its original state or to a new, more desirable one after experiencing a disturbance, and avoiding the occurrence of failure modes
Manufacturing focus	With the ability to respond quickly to varying customer needs (mass customization), deploying excess buffer capacity to respond to market requirements [23]	The emphasis is on flexibility and redundancy (minimal batch sizes and capacity surplus), with schedule planning based on shared information [20]
Alliances (with suppliers and customers)	Exploit a dynamic type of alliance known as the "virtual organization" for product design [23]	Supply chain partners join an alliance network to develop security practices and share knowledge [21]
Organizational structure	Create virtual organizations with partners that vary with different product offerings, which change frequently [23]	Create a supply chain risk management culture [20]
Sourcing	Supplier attributes involve speed, flexibility and quality [23]	Flexible sourcing [19]
Inventory policy	Respond to customer demand [23]	Strategic emergency stock in potential critical points [19]
Lead-time focus	Invest aggressively in ways to reduce lead times [23]	Reduces lead time [19]
Product design policy	Design products to meet individual customer needs [23]	Postponement [19]

Table 4 Supply chain characteristics across agile and resilient supply chain management approaches

Supply chain characteristics	Agile approach	Resilient approach
Flexibility	Ability to implement different processes and apply different facilities to achieve the same goals [14]. It is related to the promptness with which and the degree to which a firm can adjust its supply chain speed, destinations, and volume to respond to changes in demand [27]	Number of possible states a supply chain can take and number of changes it is able to cope with. It includes redundancy as one mode to increase system flexibility. It ensures that changes caused by the disruption can be absorbed by the supply chain through effective responses [26]
Velocity	Ability to complete an activity as quickly as possible [14]	Speed with which a supply chain can recover from a disruption. It focuses on the pace of flexible adaptations [26]
Responsiveness	Ability to identify changes and respond to them quickly, reactively or proactively, and also to recover from them [14]. It is related to the market sensitiveness and quick response to real demand [27]	It is related to the processes' ability to be responsive to an unexpected event, that is to shift, stabilise and re-synchronise in a reasonable timeframe [28]
Competence	Ability to efficiently and effectively respond to market changes in terms of volume and variety [25]	It is related to the efficiency/redundancy trade-off. Capacity and inventory can provide slack, supporting a proper response to disturbances. However, they could hinder efficiency gains in supply chains [20]
Visibility	It is related capturing data on demand direct from the point-of-sale-use and sharing data between buyers and suppliers, creating a virtual supply chain that supports a direct respond to market needs [6]	It addresses information about entities and supply chain events, for example end-to-end orders or inventory. Ensures confidence in the supply chain and prevents over-reactions, unnecessary interventions and ineffective decisions in a risk event situation [26]
Collaboration	It is related to collaboration across each partner's core business processes, and company specific issues on the demand side such as quality, cost, etc. and company-specific issues on the supply side such as buyer-supplier relations, vendor managed inventory, information sharing [25]	It is related to the predisposition of the parties to align forces in the case of a disturbance event. It contributes to reduced uncertainty and increased event readiness [26]

changes in demand in terms of volume and variety (agility) and the recovery after a disturbance occurrence (resilience). Therefore, these supply chain skills or characteristics will influence the supply chain performance and competitiveness.

3 Supply chain performance and competitiveness

Performance measurement is crucial to better supply chain management [29]. It can facilitate understanding and integration among partners in the supply chain while

revealing the effects of strategies and potential opportunities in supply chain management. A number of research studies address the design and implementation of performance measures in the supply chain context [30–34].

In addition, various sets of measures and rules have been proposed as means to evaluate supply chain performance. Anderson et al. [32] assert that a supply chain performance measurement system should include a balanced collection of four to six performance measures, including productivity, quality and customer satisfaction. Beamon [30] proposes measures related to resources, output and flexibility.

Other authors, including Gunasekaran and Tirtiroglu [31], argue that supply chain performance should be measured at the strategic, tactical and operational levels and from the perspective of financial and non-financial contexts. With this in mind, some of the measures proposed in the literature are: total cash-flow time, rate of return on investment, flexibility to meet particular customer needs, delivery lead time, total cycle time and degree of buyer–supplier partnership, customer query time, extent of cooperation for improved quality, total transportation cost, accuracy of demand prediction/forecasting methods, product-development cycle time, manufacturing cost, capacity utilization, information carrying cost and inventory carrying cost.

There has been some criticism on some performance measurement systems that have been used and proposed in order to evaluate the performance of supply chains. According to some studies [31, 35, 36], almost no performance measurement systems are adjusted to the actual supply chain necessities. Chan and Qi [37] argue that supply chain performance is measured in oversimplified terms that are counterproductive, given that it fundamentally focuses on cost as the means to minimize individual costs but not to maximize the value to the end customer.

Lambert and Pohlen [38] also criticize the measures used to evaluate supply chain performance. They state that supply chain performance measurement systems are focused on logistics measures (lead time, fill rate, on-time performance) but do not provide information on how well the key business processes have been performed or the extent to which the supply chain has met customer needs. Moreover, the same authors argue that these measures do not provide information on how the overall supply chain has performed and fail to identify opportunities to increase competitiveness, customer value and shareholder value for each firm in the supply chain.

Table 5 provides an overview of operational and economic measures that can be used to evaluate the influence of the agile and resilient approaches on supply chain performance.

The supply chain, as a network, is expected to provide the right products and services on time, with the required specifications, at the right place, to the customer [49].

Accordingly, Martínez-Olvera and Shunk [50] state that customer satisfaction is the supply chain's primary goal, resulting from the combined efforts of the supply chain partners to resolve a multi-objective optimization problem related not only to cost, quality and time but also to flexibility, responsiveness and reliability. Competitiveness and strategy have been discussed mainly in the context of individual firms. Only recently, there has been a shift to the supply chain context. Various studies have developed typologies of supply chain strategies [51]. However, there has been little effort to develop a taxonomy of supply chain strategies that delimits and classifies different strategy groups [52].

Chandler [53] considers that the strategy is the determination of long-term goals and objectives and the adoption of actions and the allocation of resources necessary for achieving those goals. Ansoff [54] identifies competitive advantage as a key element in strategic planning. He notes that the identification of competitive advantage requires uncommon skills in anticipating trends to ensure truly successful results. Andrews [55] argues that strategies must be delineated to improve a firm's capabilities as well as to explore opportunities within its environment. Strategy is the first step towards the delineated objectives [56], and it is generally considered as an enabler by which to attain competitive advantage in a specific market niche [57]. The term "competitive priorities" is rooted in the manufacturing strategy literature dating back to the 1960s, when Skinner [58] initially proposed the concept of competitive priorities. Krajewski and Ritzman [59] define competitive priorities as the capabilities that an organization must possess in order to support the demands of the markets in which the organization wants to compete.

Schnetzler et al. [60] extend the organization strategy domain to the supply chain level: the strategic priorities of an organization should be translated into supply chain management objectives and implemented in operations management. Hofmann [61] also stresses the need for an essential fit between the supply chain strategy and the corporate strategy in order to reach sustainable competitive advantage. Schnetzler et al. [60] define supply chain strategy as a set of prioritized supply chain management objectives, that is, strategic priorities, and a way to operationalize them, to determine appropriate measures to build up and capitalize on so-called logistics success potentials that can result in successful business performance. The objective of a supply chain strategy is to create sustainable competitive advantage and a better position of firms in relation to its competition [60]. Several competitive priorities are referred in the literature, namely low cost, quality, flexibility [62], delivery [63], speed or time [64], innovation, service [62], efficiency and responsiveness [65].

Table 5 Measures and indicators to evaluate the influence of agile and resilient approaches on supply chain performance

Measures	Indicators	References
Operational performance		
Quality	Defect fallow rate	[39, 40]
	Defect-free delivery	[41]
	Quality of delivery goods	[41]
	Order-fulfilment rates	[42]
	Rates of customer complaints	[41, 43]
Delivery	Delivery speed	[10, 41]
	On-time delivery	[43]
	Perfect order fulfilment	[43]
	Delivery reliability	[41]
	Responsiveness to urgent deliveries	[41]
Time	Lead time	[4]
	Cycle times	[8]
	Delivery lead time	[41]
	Order-fulfilment lead time	[43]
Flexibility	Supply and procurement flexibility = number of suppliers by critical parts, raw materials, components	[3]
	Conversion flexibility = level of interoperability of processes, machines, employees	[3]
	Excess capacity = % amount that available capacity exceeds demand	[44]
	Mix flexibility = different product types that may be produced during a time period, or the response time between product mix changes	[30]
	Delivery flexibility = percentage of slack time by which the delivery time can be reduced	[30]
	Volume flexibility = proportion of demand that can be met by the supply chain system	[30]
	Logistics flexibility	[43]
	Transport flexibility	[41]
	New product flexibility	[43]
	Cycle efficiency	Total value-added time/total time in the supply chain
Inventory levels	Finished goods equivalent units	[13]
	Level of safety stocks	[3]
	Order-to-ship (hours)	[13]
Economic performance		
Cost	Manufacturing cost	[13, 43]
	Inventory carrying cost	[13, 42, 43]
	Redundancy cost (to keep some resources in reserve to be used in case of a disruption)	[3]
Economic value added (EVA)	Net operating profit after taxes (–) cost of capital × total assets	[46]
Net operating profit	Gross margins (–) total expenses	[46]
	Profit margins	[15]
Return on assets	Return on global assets	[15, 42]
	Consumer profitability/average SC assets deployed during the period	[45]
Cash-to-cash cycle	Inventory + receivables (–) payables	[47]
Efficiency	Overhead expense = selling, general and administrative expenses/total of sales	[48]
	Operating expenses = (selling, general and administrative expenses + cost of goods sold)/total of sales	[48]

In this paper, product quality (satisfaction of customers' needs and requirements), customer service (providing on time the type and volume of product required) and time to market (rapid introduction of new products) are proposed as supply chain competitive priorities. Customers are

becoming more sophisticated and informed; they demand new products or new features in existing products with an increasingly faster time to market [66]. Time to market is the extent to which an organization is capable of introducing new products more quickly than major competitors

[67]. Li et al. [67] evaluate customer service in terms of delivery dependability, the extent to which an organization is capable of providing, on time, the type and volume of product required by customers. Sanchez and Perez [68] distinguish six major dimensions of customer service: product availability, order cycle time, distribution system flexibility, distribution system information, distribution system malfunction and post-sale support. Companies are able to improve service levels by reducing delivery lead times [66]. Sila et al. [69] assert that quality is not only a product characteristic but also means customer satisfaction. According to Zhu et al. [70], if design does not reflect the market requirements, the product will not meet the demands of the market even if manufacturing conforms to the design completely. If manufacturing does not conform to the design specifications, the finished product will have poor quality and fail to satisfy customer needs. Quality management in the design and manufacturing phases is not normally implemented in the same company, but from the perspective of the overall supply chain [70].

It is important that supply chain practices contribute to quicker time to market, but the supply chain should also be able to guarantee the product quality and to increase customer satisfaction through better customer service. The agile and the resilient supply chain management approaches seem to be appropriate for achieving these competitive priorities.

There exists an important relationship between the level of performance of supply chains and their competitiveness. That is, the best performers are also almost of the times the most competitive in the market. Previous studies have shown that there is a significant relationship between competitive advantage and performance [71, 72]. Barney [73] has also conceptualized competitive advantage and performance to be significantly related. In today's constantly changing environment, an organization's supply chain agility is a critical element affecting its global competitiveness [74, 75]. Supply chains more agile become also more competitive since they can improve their responsiveness to flexibility, increased product diversity and customization. These demands come, typically, from further down the supply chain in the finishing sector, or from end customers [76]. Some traditional sectors have already elements of agility because the realities of a competitive environment dictate these changes (e.g. in sectors such as automobiles, food, textiles, chemicals, precision engineering and general engineering) [77]. Vargo and Seville [78] found a measurable link between resilience and cash flow, return on investment and profitability. They argue that more resilient organizations have better cash flow, return on investment and profitability, so they are better performers in economic terms and consequently more competitive. Also, Pettit et al. [79] argue that resilient

supply chains can supplement existing risk management programs enabling a supply chain to survive unforeseen disruptions and create competitive advantage. They consider that the effective implementation of a portfolio of capabilities that is best matched with the supply chain's pattern of vulnerabilities will lead to improved performance. So, it is the balance between capabilities and vulnerabilities that creates a true competitive advantage.

4 Conceptual framework development

Considering the actual context where organizations and their supply chains are under pressure to be more market orientated at the same time as they experience increased vulnerability to risk, the agile and resilient supply chain management approaches seem to provide ways to overcome these challenges. However, it is important to examine how agile and resilient approaches contribute to improve supply chain performance and competitiveness.

Meredith [80] considers that the normal research cycle is iterative process where the stages of description, explanation and testing are essential for develop new theories. Moreover, it is proposed the utilization of conceptual methods to a better balance between theory-building and theory-testing research, since they provide an appropriate description and explanation of the studied phenomena. Since this paper intends to explore the relationships between agile and resilient practices and the performance and competitiveness of supply chains, the utilization of conceptual methods seems to be appropriated. Therefore in a first step, it is suggested a conceptual model to describe the relationships among the considered variables: resilience, agility, supply chain performance and competitiveness. From this model, in a second stage, an explanatory conceptual framework with propositions for future testing is proposed.

The agile and resilient approaches are deployed across supply chains not only in upstream and downstream relations but also inward individual firms. Once agile and resilient practices have been implemented, it is important to evaluate their effects on supply chain performance, namely on operational and economic performance. Supply chain performance is the "bottom line" for supply strategies and their enabling characteristics. Supply chain performance refers to the extent to which a supply chain meets the end-customer requirements [81]. The performance system should be aligned with the supply chain's competitive priorities, allowing the monitoring and control of the system's behaviour in order to achieve the expected results. In the proposed conceptual model, supply chain performance is measured in two dimensions: (i) *operational performance*, which evaluates the supply chain

responsiveness and flexibility; and (ii) *economic performance*, which is related to the effective management of the cost associated with inventories, redundancies in resources and general inventory turnover.

To provide a global overview and understanding of the influences that agile and resilient practices have on supply chain performance and competitiveness, a range of anecdotal and empirical evidence is presented in the literature. Some of the anecdotal evidences related to the influence of agile practices on supply chain performance and competitiveness are:

- *Ability to change quantity and delivery time of a supplier's order*: Supplier involvement and supplier responsiveness in addressing changes in design, volume, mix, logistics and expedited orders can be instrumental in shrinking time to market [82].
- *Use of IT to coordinate/integrate activities in procurement*: According to Boon-itt [83], supplier integration has a stronger impact upon product quality than internal and customer integration while increasing the level of service by delivering the most urgent products [82]. This practice also improves suppliers' business processes and helps suppliers to be more effective and efficient when synchronizing activities during product design and ramp-up [82].
- *Reduced development cycle time*: Service levels can be improved by reducing delivery lead times due to shorter product/process design and development time [66]. This practice also reduces the time to market [84].
- *Production in large or small batches*: A manufacturing strategy focus on flexibility and batch-size reduction can help organizations decrease time to market [85].
- *Minimizing setups times and product changeovers*: For Mileham et al. [86], this practice is a key prerequisite for increased flexibility, lead-time reduction and more responsive manufacturing.
- *Facilitating rapid decision-making*: A company's speed to market relies on rapid decision-making and the formation of relationships with suppliers. This practice also improves performance in terms of cost and quality [87].
- *Speed in adjusting delivery capability*: In order to counter market forces and reduce the time to market, many companies deploy this practice in order to support the timely supply and delivery of parts and components for their products [88].
- *Capturing demand information immediately*: Product quality is increased by information sharing with customers through understanding customer needs [83] supporting quick response to market change [67].
- *Speed in increasing product customization levels*: It improves product quality in terms of customer

satisfaction through the identification of customer specific wants and needs [83]. The goal of mass customization is to produce customized goods, so economies of scope can be achieved, at low cost, in order to gain from economies of scale. It allows companies to penetrate new markets and capture customers whose special or personal needs could not be met by standard products [89].

- *Increasing frequency of new product introductions*: Customers demand new products or new features in existing products with an increasingly faster time to market [66]. This practice has the same impact on supply chain performance as the reduction in development cycle time, since a speedy reduction in cycle time for development would allow a more rapid increase in the frequency of product introductions [75].

The literature also presents anecdotal evidence regarding the effects of resilient practices on supply chain performance, namely:

- *Sourcing strategies to allow switching of suppliers, flexible supply base and flexible transportation*: The deployment of these upstream practices supports low cost while simultaneously supporting a quicker response to demand than performance in a turbulent business environment [90].
- *Collaborative working across supply chains*: Highly collaborative internal and external practices promote product quality and improve the on-time delivery percentage [91].
- *Developing visibility towards a clear view of upstream and downstream inventories, supply conditions, and demand conditions*: If supply chain partners who exchange information regularly are able to work as a single entity, together they can understand the needs of the end customer better and can thereby respond to market changes more quickly [67].
- *Designing production systems to accommodate multiple products and real-time changes*: This practice is related to the development of product modularity and commonality, meaning a measurement of the extent to which product variants share the same resources and assets [92]. High commonality levels result in simplified planning and scheduling, lower setup and holding costs, lower safety stock, and reduction of vendor lead-time uncertainty [92].
- *Strategic stock*: Because this practice increases the availability of materials, reducing the stock-out ratio, a higher service level is expected [93]. However, high inventory levels generate uncertainties [94] leaving the supply chain more vulnerable to sudden changes [95] and thereby reducing the service level in volatile conditions. Therefore, strategic stocks should be

constituted as buffers between fluctuating customer orders and/or product variety and smooth production output [4].

- *Multi-skilled workforce*: It improves the ability to cope with bottlenecks in processes (which can reduce response times) and changes in due dates [96].
- *Minimal batch sizes*: Batch-size reduction has clearly helped organizations reduce time to market [87].
- *Demand-based management*: It increases profitability through improvements in product availability, delivery accuracy, responsiveness and flexibility [97].

The agile approach makes it possible to improve the supply chain’s responsiveness to customer requirements, to make it more flexible, to enhance its ability to market high-quality products successfully with short lead times and in varying volumes that provide enhanced value to customers. It will also influence the supply chain’s performance in regard to customer satisfaction, average process change-over time, productivity, on-time delivery fulfilment and the ratio of annual sales to average total stocks.

As a way to make the supply chain better performer and to be more competitive, the resilient approach is proposed, in addition to the agile supply chain approach. Through a set of resilient practices, the supply chain will respond

better to disruptions and guarantee respect for the product time to market, without jeopardizing product quality, while also increasing customer service. Resilient practices also influence supply chain performance, since they contribute to a more flexible supply chain (throughout supply and procurement flexibility and also interoperability flexibility—level of interoperability of processes, machines, and people), but also increase the inventory holding cost and redundancy cost necessary to keep some resources in reserve for use in the event of a disruption.

Considering all these anecdotal evidences, this paper proposes a set of agile and resilient practices to supply chains attain better operational and economic performance and improve competitiveness. This conceptual model is presented in Fig. 1.

From the conceptual model, it is possible to infer that at the upstream level, the deployment of agile and resilient practices is mainly related to the increase of supplier flexibility and velocity, at the same time as increasing responsiveness of suppliers to changes in markets or to unexpected events. For example, the agile upstream practice “ability to change quantity and delivery time of supplier’s order” is related to the increase in supplier responsiveness, flexibility in addressing changes in design, volume, mix, logistics and expedited orders, which

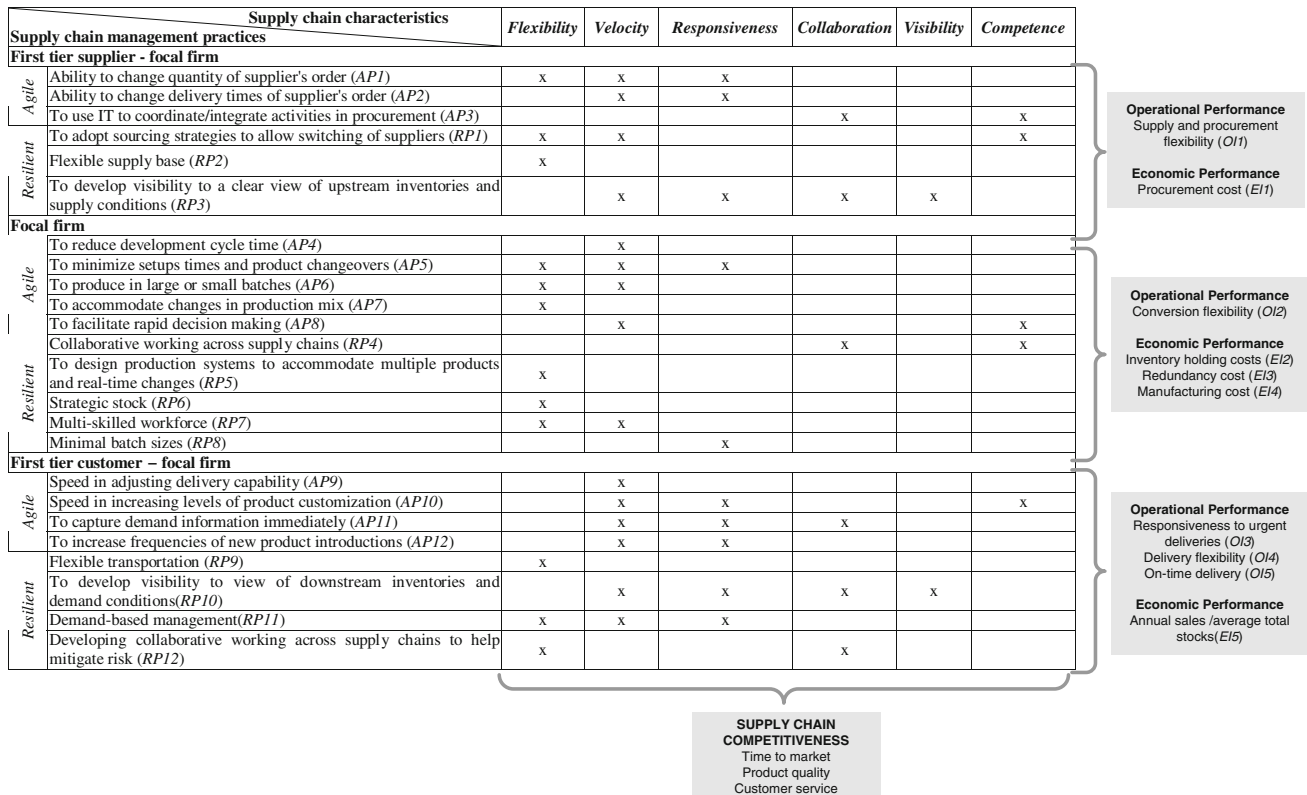


Fig. 1 The proposed conceptual model

contributes to reducing time to market, this is, increasing velocity. At the same time, this upstream practice contributes to increased supply and procurement flexibility, reducing procurement costs.

From the firm perspective, the main focus of these practices is to increase the firm’s operational flexibility and to increase the speed with which activities can be performed. In this way, the company is more able to respond to variations in production mix or to adjust its process in the case of disruption. At the downstream level, the agile approach increases responsiveness to changes in demand and reduces the response time by increasing velocity. Moreover, at the downstream level, the resilient approach also increases delivery flexibility and collaboration with customers, which is essential in the case of supply chain disruptions. Supply chain visibility is improved through resilient upstream and downstream practices, helping companies to anticipate, perceive and effectively manage the real consequences of supply chain disruptions. Supply chain competence is also addressed by some agile and resilient practices at upstream, focal firm and downstream levels. The deployment of agile and resilient practices in the supply chain will develop a set of supply chain characteristics, including flexibility, velocity, responsiveness, collaboration, visibility and competence, all of which support the attainment of organizational goals and enhance supply chain competitiveness.

The proposed conceptual model provides a starting point to conceptual induction process, where a phenomenon is explained through the relationships observed between the systems elements [80]. The framework proposed in Fig. 2 captures the relationships between agile and resilient practices and the supply chain performance and competitiveness: it is expected a positive relationship between resilience and agile practices and supply chain performance and competitiveness.

In the proposed framework, the variables are defined according to the proposed conceptual model. The supply

chain resilience construct is composed by a set of twelve practices (RP_1, \dots, RP_{12}), and the supply chain agility construct is also composed by a set of twelve practices (AP_1, \dots, AP_{12}). These two set of practices are deployed at upstream, focal and downstream level. The supply chain operational and economic performance is assessed using a set of five indicators for each one (OI_1, \dots, OI_5 and EI_1, \dots, EI_5 , respectively). Lastly, the supply chain competitiveness is assessed in terms of time to market, product quality and customer service.

This framework fulfils four of the five Dubin’s requirements for a theory [98]. It allows prediction of the effect of resilience and agile practices on supply chain performance and increases the understanding about supply chain competitiveness. Since very few works analyse the simultaneous deployment of resilience and agile practices in supply chain performance, this framework is not trivial. It includes a clear definition of the considered variables, without employing undefined variables, elements or attributes. However, the framework does not include boundary conditions; it is expected that specificities related to the industry context like product type, production process, country and cultural perspectives can impact on the type of resilience and agile practices employed in the supply chain and in the effect of these practices on supply chain behaviour.

5 Conclusions

This paper has investigated the possibility of merging the agile and resilient approaches in the context of supply chain management. These two approaches have the same global purpose, which is to increase supply chain performance and competitiveness through improved product quality, time to market and customer service. The main difference between the two approaches is a specific purpose. The agile supply chain management approach pursues faster response to changes in markets and customer requirements, while the resilient approach is designed to cope with disturbances in order to sustain supply chain competitiveness.

A comprehensive literature review was performed as a means to categorize performance measurement systems in a supply chain context, as well as to identify the relationships between agile and resilient supply chain management practices, supply chain skills or characteristics and supply chain performance and competitiveness. An inductive research approach was used to develop a conceptual framework from the literature review.

Numerous papers have been published about agile and resilient approaches separately, but few have provided an analysis of their influence on supply chain performance.

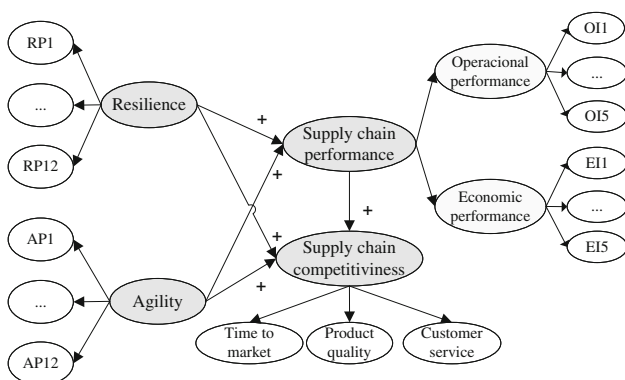


Fig. 2 Conceptual framework

Therefore, this paper employs a simultaneous focus on both approaches and their respective practices. These practices are proposed along the supply chain upstream, downstream and firm inward. Beyond that, a performance measurement system is suggested in order to evaluate the influence of these practices on supply chain performance. At the operational level, the following measures are suggested: supply and procurement flexibility, conversion flexibility responsiveness to urgent deliveries, delivery flexibility and on-time delivery. To evaluate the economic performance, the following measures are suggested: procurement cost, inventory holding costs, redundancy cost, manufacturing cost and annual sales/average total stocks. These measures make it possible to assess supply chain performance. The competitive priorities suggested in the framework are time to market, product quality and customer service. The conceptual framework proposed in this paper can help supply chain managers choose the main agile and resilient practices and implement a performance measurement system that makes it possible to evaluate the influence of these practices on supply chain performance and competitiveness.

The identification of the conceptual relationships among agile and resilient supply chain practices and performance is a contribution that the authors hope will become a first step in the development of new theoretical approaches and empirical research in the field of supply chain management.

This paper makes several contributions. First, this conceptual framework for the influence of agile and resilient practices on supply chain performance and competitiveness is theory-driven and can be applied to any supply chain setting, contributing to the understanding of agile and resilient approaches in supply chain management. Secondly, Tables 1 and 2 provide a taxonomy for agile and resilient supply chain management practices at the upstream, organization and downstream levels. The practitioner can use this taxonomy as a checklist to identify possible practices to achieve their strategic goals. Third, by utilizing the framework proposed here, researchers can develop empirical research studies that can better explore the proposed relationships between the agile and resilient practices to identify synergies, thereby allowing the unification/integration of the two approaches in supply chain management.

Case and field studies could be used to validate the proposed relationships between agile and resilient practices, supply chain performance and competitiveness identified here and perhaps to identify new components. Future simulation studies can be developed to assess the supply chain behaviour when a set of agile and resilient practices is implemented. The analysis of the supply chains dynamics will make it possible to evaluate the consequences (expected and unanticipated) of agile and resilient practices, contributing to substantial improvement in supply chain performance.

The objectives of the study have been successfully accomplished, but the limitations of the study should also be noted. The conceptual framework was developed using anecdotal and empirical evidence presented in the literature, but no validation process was conducted. It is also essential to test the validity of the conceptual framework proposed empirically. In future, researchers should collect large samples of empirical data in order to analyse the influence of agile and resilient practices on supply chain performance and competitiveness. Future research should test the propositions derived from the framework, as it is important to develop scales for the implementation and evaluation of agile and resilient supply chain management practices. In addition, it will be necessary to develop a scale by which to measure the supply chain performance construct. Further research is needed concerning the influence that agile and resilient practices have on the performance of manufacturing supply chains, both in terms of testing the framework proposed here and in terms of the broader understanding of this discipline.

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