The ambiguous impact of supplier involvement in product development on supplier relationship resilience and company performance

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Abstract

Purpose – I aimed to obtain a deeper insight into the link between supplier involvement in product development (SIPD), supplier relationship resilience and company performance.

Design/methodology/approach – To collect data, a survey among 500 Polish manufacturing companies was conducted. I used quantitative methods (structural equation modeling) to test several research hypotheses referring to a single supplier–customer relationship. Thanks to the use of multi-construct measurement of SIPD and supplier relationship resilience, the study provides detailed research results on the topic.

Findings – Collaborative practices implemented during SIPD increase procurement flexibility and decrease redundancy in the relationship with the involved supplier. Communication during SIPD increases supplier flexibility and procurement flexibility. Increased supplier flexibility and increased procurement flexibility in the relationship with the involved supplier as well as collaborative practices during SIPD positively impact company performance. I confirmed the indirect effect between communication during SIPD and company performance when the mediators are supplier flexibility and procurement flexibility. Decreased redundancy in relationship with involved supplier does not impact company performance.

Practical implications – Supply chain managers need to rethink SIPD practice to effectively ensure supply chain resilience (SCRES), especially in the face of the contemporary global crisis and black swans affecting the supplier base. My article provides important managerial insights into drivers of SCRES and company performance.

Originality/value – To the best of my knowledge, this research is among the first to conclude that SIPD does not have an unequivocally positive or direct impact on supplier relationship resilience. The research fills the gap by analyzing the impact of SIPD on two main SCRES elements. The study examines supplier relationship resilience, understood as flexibility and redundancy elements, in a single supplier–buyer relationship perspective. Thus, the presented considerations go beyond the traditional understanding of flexibility and redundancy in supplier relationship management, that is through the prism of double or multi sourcing and having back up-suppliers.

Keywords Supplier-customer relationship, Joint product development, Supply chain resilience, Supply chain risk, Supply chain flexibility, Redundancy, Supplier integration

Paper type Research paper

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Introduction

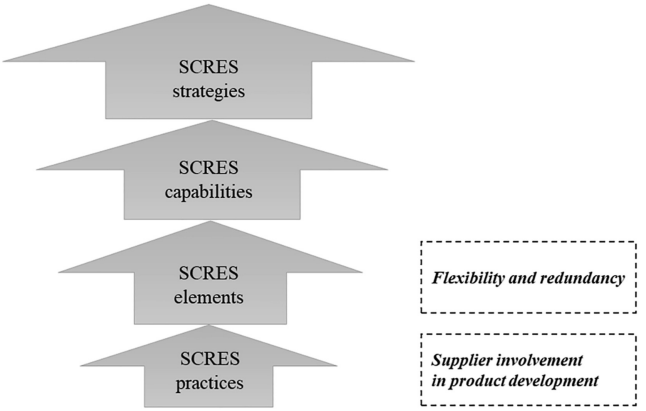
As shown by global crises (e.g. supply shortages, capacity limitations, demand shocks), risk anticipation and an agile response to a volatile environment are critical to maintaining business continuity and the long-term enterprises' viability. Nowadays, researchers recommend adopting a broader management perspective aimed at building supply chain resilience (SCRES). This approach requires the implementation of a variety of strategies and capabilities that not only prepare organizations for risk and uncertainties (proactive strategy), but also allow them to operate at a minimum acceptable level during a disruption (concurrent strategy), while also supporting the recovery of businesses after crises recede (reactive strategy) (Tukamuhabwa, Stevenson, Busby, & Zorzini, 2015; Chowdhury & Quaddus, 2016; Ali, Mahfouz, & Arisha, 2017; Geske & Novoszel, 2022).

Scholars understand supply chain management as "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert, Cooper, & Pagh, 1998). There are eight key business processes in the supply chain (Croxton, Garcia-Dastugue, Lambert, & Rogers, 2001). In this article, two of them, that is supplier relationship management process and product development and commercialization process were the integrated subject of my considerations.

Supplier base can be a source of both threats and opportunities for the supply chain (e.g. Manuj & Mentzer, 2008; Pfohl, Gallus, & Thomas, 2011; Ivanov, 2021, pp. 29–41). On the one hand, trusted, communicative and flexible partners enhance purchasing and manufacturing agility, while on the other hand, cooperation with bottleneck suppliers, and global and single sourcing may seriously disrupt value-added processes (Sheffi, 2001; Chopra & Sodhi, 2004). This is mainly due to the domino phenomenon, in which the effects of risk spread along the supply chain links, temporarily hindering their performance (Jüttner, 2005; Hertz, 2006). Therefore, building supplier relationship resilience is particularly important to manage uncertainties effectively and ensure that the level of customer service is at a higher level than the competition when external disruption occurs.

This article is in line with the comprehensive definition which explains that SCRES is the "ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state to increase customer service, market share and financial performance." Moreover, the article also follows the SCRES framework by Ali *et al.* (2017), who indicate that I should consider supply chain resilience at four levels, that is strategies, capabilities, elements and practices. The study aimed to explore the relationship between the two main SCRES elements (flexibility and redundancy) for building the ability to adapt and perform concurrent strategy, and one SCRES practice (Figure 1). The researched practice was supplier involvement in product development (SIPD). Increasing flexibility and redundancy are key elements when dealing with disruptions (Ali *et al.*, 2017; Mackay, Munoz, & Pepper, 2020; Kamalahmadi, Shekarian, & Mellat Parast, 2021). Creating these elements is possible through the use of various practices under the umbrella of supplier relationship management. It is therefore interesting whether, in the supplier-manufacturing company relationship, both elements are effectively reinforced.

I chose this research direction for several reasons, which constitute the novelty and importance of the discussed issues. First, the results of the literature analysis showed that there are some studies in which the authors noticed the impact of SIPD on supply chain risks and resilience (Zsidisin & Smith, 2005; Tang, Zimmerman, & Nelson, 2009; Tang & Musa, 2011; Melnyk, Closs, Griffis, Zobel, & Macdonald, 2014). However, these are mainly qualitative studies and there is currently no in-depth statistical research examining dependencies between supplier involvement in product development and such SCRES elements as flexibility and redundancy. Therefore, this article continued prior research, filling the research gap of quantitative research and aimed to recognize the importance of SIPD in building supplier



Source(s): Own elaboration following the SCRES framework presented by Ali *et al.* (2017)

Figure 1.
SIPD, flexibility and redundancy positioning in the SCRES concept

relationship resilience. Second, joint product development practices are becoming ever more popular today. They stress that it is not only customers who should be involved in the product development but also first and second-tier suppliers (e.g. Lockstrom, Schadel, Moser, & Harrison, 2011; Sjoerdsma & Van Weele, 2015), leading to broader concepts appearing, such as open innovations (Chesbrough & Garman, 2009; Dziurski & Sopińska, 2020). Thus, detailed conclusions for SCRES and supplier relationship management could be transferred to other areas of cooperation in the supply chain. Third, the crises (e.g. COVID-19 pandemic) confirm that relationships with key suppliers in the area of purchasing and product development are especially important for maintaining business continuity (Mańkowski, Szmeter-Jarosz, & Jezierski, 2022). For example, when global disruption occurs, there can be a need not only for a sudden increase or decrease in product volumes, but also to re-design a product or even start production of a new product line. The study is all the more interesting, because it concentrates on flexibility and redundancy elements in a single supplier–buyer relationship. This means that the presented considerations go beyond the traditional understanding of flexibility and redundancy in supplier relationship management, that is through the prism of double or multi-sourcing and having backup suppliers. Further, the discussion on the influence of flexibility and redundancy on the costs and effectiveness of SCRES is an ongoing one (Kamalahmadi *et al.*, 2021). Therefore, the presented model also includes the company's performance. Finally, I attempted to formulate general recommendations for managers on how to develop a relationship with a supplier involved in product development to ensure more resilient supplier relationship in a VUCA (volatile, uncertain, complex, ambiguous) world. I presented all these issues through the lens of two main theories used in past studies on SIPD, mainly resource dependency theory (e.g. Primo & Amundson, 2002; Van Echtelt, Wynstra, Van Weele, & Duysters, 2008) as well as relational theory (e.g. LaBahn & Krapfel, 2000; Petersen, Handfield, & Ragatz, 2005).

Theoretical background

Supplier involvement in product development

Birou and Fawcett (1994) regard SIPD as "participation," whereas Wagner (2012) as "collaboration" between a company and its supplier in the new product development (NPD) process. This collaboration is characterized by partnership, trust and commitment (Wagner, 2012)

as well as sharing costs, technology and capabilities, which strengthens the interdependence between cooperating companies (Chien & Chen, 2010). Lockstrom *et al.* (2011) listed several supplier integration areas, one of which was joint product development. In turn, Luzzini, Amann, Caniato, Essig, and Ronchi (2015) included SIPD, supplier development and supplier integration in order fulfillment into supplier collaboration.

According to the results of a systematic literature review (SLR), SIPD is most often expressed as combining the three following measurement areas (Wieteska, 2019). The first area is the extent of supplier involvement in product development (e.g. the degree of supplier involvement and the level of supplier's responsibility for the project). The timing and the degree of supplier involvement in product development depends on knowledge, capabilities and the product itself (Handfield, Ragatz, Petersen, & Monczka, 1999; Wynstra & Ten Pierick, 2000). Supplier involvement can occur at each phase of the new product development process, that is idea generation, business/technical assessment concept development, engineering and design, prototype build test and pilot/ramp-up for operations (Handfield *et al.*, 1999). The second area is the collaborative practices that can be performed during SIPD, for example cost information sharing, jointly set goals and cross-functional NPD teams (Primo & Amundson, 2002; Parker, Zsidisin, & Ragatz, 2008; Wagner, 2010, 2012; Li, Gu, & Wang, 2010; Kähkönen, Lintukangas, & Hallikas, 2015) and the third one concerns extensive (e.g. frequent, intensive) communication with the partner during the joint product development process (Hartley, Zirger, & Kamath, 1997; Culley, Boston, & Mcmahon, 1999; Hoegl & Wagner, 2005; Jayaram, 2008; Najafi Tavani, Sharifi, Soleimanof, & Najmi, 2013). In this article, I understand SIPD as the supplier's participation in various stages of product development based on a partnership, extensive communication and the long-term perspective of cooperation (Birou & Fawcett, 1994; Carr, Kaynak, Hartley, & Ross, 2008; Wagner, 2012).

Flexibility and redundancy in supplier relationship management

As the concept of SCRES requires the configuration of various processes and resources, it is vital to develop individual and appropriate resilience for each supply chain area and then to integrate particular SCRES abilities and elements. For example, Pereira, Christopher, and Da Silva (2014) recognized the interconnections of procurement issues (activities) and its most often cited enablers. According to the research, flexibility and redundancy mainly concern supplier relationship management. Flexibility is mainly related to such enablers as supplier base, supplier selection and development, transportation modes or product flexibility, whereas redundancy is associated with the supplier base, internal stock and redundancy of critical goods (Pereira *et al.*, 2014).

Flexibility can refer to both agile and lean companies (Hohenstein, Feisel, Hartmann, & Giunipero, 2015). Thus, it is a special element that may increase supplier relationship resilience for each supply chain network. In general, flexibility entails the creation of capabilities, whereas redundancy involves the maintenance of capacity during disruption (Rice & Caniato, 2003). Keeping flexibility means that the supply chain is able to react and adapt to the changing requirements with a minimum of time, effort and cost. In turn, redundancy is the ability to exploit existing spare capacity and inventory to cope with disturbance and replace the loss of capacity or resources (Pereira *et al.*, 2014; Tukamuhabwa *et al.*, 2015; Nogalski, Niewiadomski, & Szpitter, 2020).

According to the literature, flexibility in the area of supplier relationship management is one of the key supply chain flexibility dimensions, and it can be built through both procurement flexibility or supplier flexibility (Pujawan, 2004; Chu, Chang, & Huang, 2012; Fayezi, Zutshi, & O'Loughlin, 2014; Wieteska, 2020). Scholars usually explain procurement flexibility as keeping a wide base of suppliers to rapidly reconfigure the supply base and

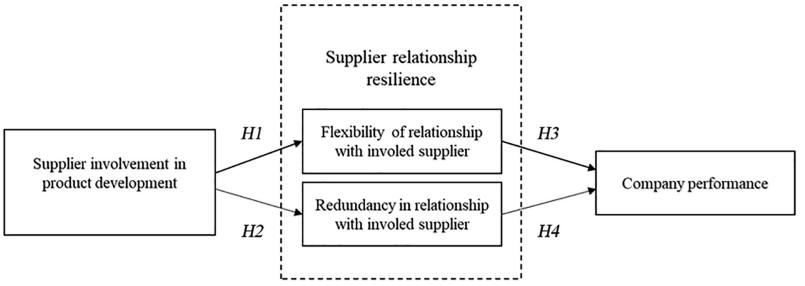
switching the orders between them (Duclos, Vokurka, & Lummus, 2003; Pujawan, 2004). However, at the same time, procurement flexibility relates to the specific practices performed in a relationship with a single supplier. This applies especially to cooperation with suppliers of strategic or bottlenecks goods, where the company cannot implement double or multi-sourcing. Such procurement flexibility is mainly related to extending communication (Hoegl & Wagner, 2005; Huang, Mak, & Humphreys, 2003; Parker *et al.*, 2008; Wieland & Wallenburg, 2013) as well as supplier–buyer integration practices (McGinnis & Vallopra, 1999; Van Echtelt, Wynstra, & van Weele, 2007; Van Echtelt *et al.*, 2008).

Supplier flexibility is supplier's ability to effectively respond to the changes that the client makes to orders. It is divided into supplier volume flexibility, supplier mix flexibility, supplier delivery flexibility and supplier product flexibility (Fantazy, Kumar, & Kumar, 2009; Chu *et al.*, 2012). Moreover, in the supplier-customer relationship, logistics flexibility is also mentioned. Scholars understand it mainly as delivering small volumes or choosing a faster mode of transport (Pujawan, 2004; Tachizawa & Giménez, 2009; Wieteska, 2020).

Redundancy is related to the idea of "doing more of the same" (Mackay *et al.*, 2020). Scholars understand it as keeping reserve resources for use when a disruption occurs. These are various buffers to the uncertainties of a global environment (Sheffi & Rice, 2005). According to the literature, redundancy is mainly keeping safety buffers (Christopher & Peck, 2004), stocks of critical components (Stecke & Kumar, 2009) and spare capacity (Rice & Caniato, 2003). Furthermore, backup suppliers and, if possible, multi-sourcing are redundancy initiatives (Tang, 2006; Zsidisin & Wagner, 2010). Some authors underline that especially multi-sourcing can be considered a practice that enhances both flexibility and redundancy, depending on the research context (Mackay *et al.*, 2020).

Theoretical model and hypotheses development

As SIPD relates to high engagement of suppliers and favors single sourcing (Asmus & Griffin, 1993; Gadde & Snehota, 2000), I adopted a single supplier-customer relationship and dyadic perspective, which is the cooperation between key suppliers involved in NPD and manufacturing company (customer). In light of the identified research gap of the quantitative analysis of the impact of SIPD on SCRES, I proposed a theoretical model to evaluate the relationship between supplier involvement in product development (SCRES practice), the flexibility of relationship with the involved supplier (SCRES element), redundancy in relationship with involved supplier (SCRES element) and company performance (Figure 2).



Note(s): I expressed individual relationships in the form of hypotheses, which I will justify in the following considerations

Source(s): Own elaboration

Figure 2.
Theoretical model

Supplier involvement in product development, flexibility of relationship with involved supplier and redundancy in relationship with involved supplier

To explore the potential impact of SIPD on the supplier relationship resilience, I referred to the two main SCRES elements, which are flexibility and redundancy. As a result of the adopted conceptual lens, I assumed that flexibility (i.e. procurement flexibility, supplier flexibility, logistics flexibility) and redundancy are examined in relationship with a single supplier.

Cooperation with supplier involved in product development process is based on common goals, supplier-customer integration and the mutual sharing of various resources, for example knowledge, information and physical assets (McGinnis & Vallopra, 1999; Primo & Amundson, 2002; Hoegl & Wagner, 2005; Kähkönen *et al.*, 2015; Moradlou, Roscoe, & Ghadge, 2022). Moreover, SIPD follows specific communication procedures (Nellore & Söderquist, 2000; Wynstra & Ten Pierick, 2000; Lee & Wang, 2012). Next, it is recommended that exchange of information during NPD be frequent, and extensive, and engage various departments (Dowlatshahi, 1998; Culley *et al.*, 1999; Hoegl & Wagner, 2005; Danese & Filippini, 2010). All of these practices can be particularly important for building supplier relationship resilience, especially in the light of procurement flexibility, which involves long-term and intensive cooperation based on sharing information and joint planning (De Toni & Nassimbeni, 1999; Swafford, Ghosh, & Murthy, 2006; Tachizawa & Giménez, 2009). Moreover, procurement flexibility also relates to the internal integration as well as the implementation of information and communication technologies (Christopher, 2000; Tachizawa & Giménez, 2009).

Carefully partner evaluation founds decisions regarding when and how much to involve suppliers in product development. The engaged supplier needs appropriate capabilities, knowledge and skills. According to the literature, among the general criteria for selecting supplier for joint product development – besides such elements as quality and purchase costs – can be generally understood supplier flexibility (Birou & Fawcett, 1994; Huang *et al.*, 2003; Wagner & Hoegl, 2006; Sjoerdsma & Van Weele, 2015). This leads to the assumption that SIPD strengthens supplier relationship resilience, also in terms of supplier flexibility.

Finally, I may assume that there is a relationship between SIPD and logistics flexibility. Especially when it comes to strategic or critical goods, which must always be delivered according to the delivery schedule, regardless of the circumstances. Mainly, in the event of an emergency (e.g. supplier production delay, sudden demand), a faster mode of transportation is usually chosen or a customer order in a specific volume or mix needs to be delivered (Pujawan, 2004).

Maintaining inventory, time buffers and surplus capacity is a critical part of building SCRES. Therefore, especially in today's VUCA world, it is important to verify to what extent redundancy is strengthened as a result of the increasingly used strategies in the area of supplier relationship management, including SIPD. The literature contains a very limited number of publications that directly refer to keeping reserve resources and joint product development. Among the practices favoring SIPD, authors indicate single sourcing, a reduction of raw materials and component inventories as well as proximity of partners (Asmus & Griffin, 1993). A critical aspect influencing business-to-business cooperation is balancing power in asymmetric relationships (Siemieniako & Mitręga, 2018). Thus, past research emphasizes that SIPD should be based on close relationship, trust and commitment (Handfield *et al.*, 1999; Wagner, 2012; Büyüközkan & Görener, 2015). The detailed assessment of suppliers engaged in the NPD is also intended to ensure reliable cooperation (Wagner & Hoegl, 2006; Sjoerdsma & Van Weele, 2015). Thus, such attributes may also encourage resigning from buffers to the uncertainties.

In light of the above considerations, I hypothesized:

H1. Supplier involvement in product development, understood as the degree of supplier involvement in product development, collaborative practices and communication with the involved supplier increases the flexibility of the relationship with the involved supplier.

H2. Supplier involvement in product development, understood as the degree of supplier involvement in product development, collaborative practices and communication with the involved supplier decreases redundancy in the relationship with the involved supplier.

Supplier involvement in product development and company performance

In the literature, there are two main areas of research on SIPD and performance. Firstly, it was proved that there is a positive relationship between SIPD and NPD performance expressed as time, quality and cost (e.g. Danese & Filippini, 2010; Ye, Huo, Zhang, Wang, & Zhao, 2018) as well as product performance understood as quality and innovativeness (e.g. Wagner, 2010; Hoegl & Wagner, 2005). Secondly, by involving suppliers in product development, the company may achieve many positive effects in terms of financial and non-financial performance as well as business and operational performance (e.g. Petersen *et al.*, 2005; Najafi Tavani *et al.*, 2013).

Although many authors studied SIPD and performance, the previous research still has gaps. First, by investigating a single supplier-customer relationship and the SCRES perspective. Second, by measuring SIPD in a more detailed way. Mainly, expressing SIPD as the degree of supplier involvement in product development, collaborative practices with the involved supplier and communication during SIPD. Therefore, I hypothesized:

H3. Supplier involvement in product development, understood as the degree of supplier involvement in product development, collaborative practices as well as communication with involved supplier, positively impacts company performance.

The flexibility of relationship with involved supplier, redundancy in relationship with the involved supplier and company performance

Scientists and business practitioners stress the importance of studying how to create effective and robust supply chains (Kamalahmadi & Parast, 2016). Preparation for uncertainties and risks is aimed at mitigating the negative (e.g. financial, environmental) consequences of disruptions while still maintaining high-performance levels through quick recovery (Longo & Oren, 2008). On the other hand, risk prevention, treatment and control require investment in resources; new or additional capabilities as well as security improvement (e.g. insurance). As SCRES may bring about additional expenses or savings, it is recommended that the SCRES measures should be balanced against the need to maintain a cost-efficient supply chain (Dahlman, 2008).

Sánchez and Pérez (2005) confirmed a positive relationship between supply chain flexibility and company performance. They also identified that companies implement activities aimed at enhancing flexibility in the supplier-customer relationships less frequently, despite these activities having a greater impact on company performance than basic flexibility capabilities. Certainly, this aspect requires further research. Camison and Lopez (2010) recognized that a positive effect of flexible manufacturing systems on organizational performance is mediated by incorporating product, process and organizational innovation. Scholars also noted that the flexibility of product changes is greatest in the initial stages, and these changes also generate the lowest costs. Therefore, involving suppliers as early as in the first stages of NPD (Cadden & Downes, 2013) is recommended. Finally, Kamalahmadi *et al.* (2021) noted that although keeping backup

suppliers is more effective than flexible procurement, the most desirable in terms of lowering investments and the expected total cost of disruption is a hybrid practice.

It is important to design flexible slack systems with a number of buffers (Datta, 2017) as insufficient redundancy and additional resources (e.g. safety stocks) increases vulnerability (Stecke & Kumar, 2009), which may increase operational risk costs when a disruption occurs. In the face of disruption, as recent global crises show, inventory buffers and alternative suppliers are crucial for maintaining the continuity of procurement and manufacturing and the required level of customer service (Christopher & Peck, 2004; Norrman & Jansson, 2004; Sheffi & Rice, 2005). Having satisfactory redundancy enables a company to deal with external pressures and improve company performance. However, exaggerated redundant resources would lead to excessive costs and damage performance (Xiaohong & Siying, 2012). Therefore, such SCRES strategies as keeping safety stock and effective slack capacity should be within the cost margins (Shuai, Wang, & Zhao, 2011). Although redundancy is one of the key SCRES elements in the context of efficiency, disproportionate spare capacity and increased inventory are considered wasteful (Christopher & Peck, 2004). Scholars recognize that optimal inventory positively impacts the financial performance of an organization (Isaksson & Seifert, 2014). Interestingly, scholars noted that keeping redundancy is expensive but relatively simple to implement, whereas building flexibility is cost-effective but more difficult to perform (Wang *et al.*, 2016). Furthermore, flexibility reduces the total cost of the supply chain and redundancy especially improves the lead time ratio (Carvalho, Barroso, Machado, Azevedo, & Cruz-Machado, 2012; Mackay *et al.*, 2020).

In light of the above considerations, the investigation of the relationship between SIPD and supplier relationship resilience, from the perspective of flexibility and redundancy elements, seems to expand and supplement previous studies. Therefore, I hypothesized:

H4. Increased flexibility of relationship with involved supplier positively impacts company performance.

H5. Decreased redundancy in relationship with involved supplier positively impacts company performance.

Material and methods

Operationalization of the presented approach required that each area is expressed with adequate sub-constructs (Figure 2). I developed these based on the appropriate literature (Appendix). SIPD is expressed with three sub-constructs, that is the degree of supplier involvement in product development (DSI), collaborative practices during supplier involvement in product development (CPSI) and communication during supplier involvement in product development (CSI). The flexibility of relationships with suppliers (FRS) included three sub-constructs, namely: supplier flexibility (SF), procurement flexibility (PF) and logistics flexibility (LF). This three-dimensional approach covered all areas in the supplier relationship that should be characterized by flexibility. Redundancy in relationships with suppliers (RED) consisted mainly of buffers that support agility and responsiveness. The last sub-construct in the model describes company performance (CP). This was expressed by four items concerning aspects that were especially important in terms of operational competitiveness and the consequences of SIPD for flexibility and redundancy. The performance measures were subjective, following best practices from previous studies on SIPD and performance.

The research instrument covered all four research areas: supplier involvement in product development, the flexibility of the relationship with the involved supplier, redundancy in relationship with the involved supplier and company performance. In the developed questionnaire, I expressed each sub-construct through statements based on previous studies.

Each statement represented one observable variable, measured with the five-point Likert scale. The respondents expressed their opinion on the studied issues using a 1–5 scale (5 – highly agree, 1 – highly disagree). The survey was preceded by preliminary research on a sample of twelve companies representing selected industries, two companies from each industry. This was intended to assess the questionnaire in terms of its content and structure. The collected comments and remarks were used to polish the revised version of the questionnaire. A key to ensuring the credibility of the answers is whether the vocabulary used is understandable not only to scientists, but, above all, to the business practitioners to whom the questionnaire is addressed.

I used computer-assisted telephone interviewing (CATI) method. Data was collected with the assistance of an external company that had sufficient resources. The source of information about potential respondents (e.g. telephone contact, address) was the Bisnode Database (www.bisnode.pl). The research covered only manufacturing companies, as most SIPD practices described in the literature focus on supply chain links for these types of companies. They represented six manufacturing industries: computer, electronic and optical, electrical, machine, automotive and metal, divided according to Statistics Poland (https://stat.gov.pl/en/). The statistical sample included 10,051 companies, with answers obtained from 500 enterprises. I calculated the number of companies representing each sector by considering the principle of "probability proportional to size." Based on the guidelines for sample selection, the assumption of a maximum error of 5–4% and a confidence level of 95%, the minimum sample size should be 370, and the maximum – 566 (Naukowiec.org, 2023). Partially for economic and time reasons, I received. responses from 500 companies, which was thus in line with scientific principles.

I used several characteristics (mainly their size, origin of capital and target market) to differentiate the organizations (Table 1). The sample characteristics shows that the surveyed companies were mostly participants in international supply chains but with domestic capital and of a range of sizes.

I researched only companies that develop products involving suppliers. Moreover, I emphasized the respondent's knowledge of the investigated topic. I ensured these two assumptions with two filtering questions asked before the survey began. The first filter question was whether the company performed SIPD and, the second, whether the respondent was responsible for at least one SIPD project in the company. The research participants were primarily top management, that is CEOs, members of the board, business owners and managers responsible for purchasing and supply chain management or R&D. Due to the thematic complexity of the researched issues, the assumption of the study was to involve more than one employee of one company in answering questions, if necessary. This approach ensured the data variety.

I implemented a dyadic perspective, that is company (as a client) and supplier. Thus, the questions concerned cooperation with a key supplier in NPD. The researched enterprises declared that the supplier involved in joint product development was located in Poland (91.40%), other European countries (7.60%), Asia (0.60%) or the United States of America (0.4%). I used the developed questionnaire to collect data, which took several weeks. I conducted the survey just before the COVID-19 pandemic. Therefore, I ensured that the results were reliable as they were not compromised by the temporary effects of global supply chain disruptions. For example, black swans (e.g. COVID19-pandemic or the Russia-Ukraine conflict) may have negatively impacted financial performance (Spoz, Skibińska-Fabrowska, Kotliński, & Żukowska, 2021) and consequently, the expenses for supporting processes, for example R&D. They may have also transformed the business model temporarily (Brzeziński, Hadas, & Cyplik, 2021). Furthermore, most researched companies declared implementing an agile strategy focused on product customization to the requirements and expectations of

Table 1.
Characteristics of the surveyed companies

In all	Company size (No. of employees)			The origin of capital		The market for which the company offers its products		Spatial range of activities	
	Small (1–50)	Medium (51–250)	Big (more than 251)	Domestic	Foreign or mixed	National	National and foreign	National	International
500	172	201	127	436	64	169	331	491	9
100%	34.40	40.20	25.40	87.20	12.80	33.80	66.20	98.20	1.80

Source(s): Own elaboration

customers (77.8%) or focusing on lean and a cost-reducing strategy and the choice of the optimized solutions, guided by the effect scale and streamlining production (16.4%).

Analyses and findings

Reliability and factor analyses

To assess the measures' reliability, I used Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE) (Kline, 2015). Based on the calculations, I could conclude whether all sub-constructs met typical requirements-values (Kline, 2015; Nguyen, Alaoui, & Llosa, 2020). Although I carefully developed all sub-constructs following the literature analysis, DSI and LF needed to be excluded from the conceptual model as they did not achieve the required Cronbach's alfa and/or AVE values (Table 2).

For the other sub-constructs, the average variance extracted was greater than 0.5 and CR was greater than 0.7 (Kline, 2015; Nguyen *et al.*, 2020), consequently, I confirmed their convergent validity. For the discriminant validity (Table 3), the Fornell–Larcker criterion suggests that the square root of each construct's AVE should be higher than the correlation with any other sub-construct (Fornell & Larcker, 1981).

Another popular approach for establishing discriminant validity is to assess cross-loadings. In this research, each measurement item correlated weakly with all other constructs except for the one with which it is theoretically associated (Gefen & Straub, 2005).

Finally, my results show that the fit index for my measurement model was an approximate fit (χ^2 = 1481,082 (df = 362), $p < 0.0001$ – reject the model; χ^2/df = 4.09 < 5 – good fit; GFI = 0.909 > 0.9 – good fit; AGFI = 0.891 ≈ 0.9 – good fit; TLI = 0.898 ≈ 0.9 – good fit; CFI = 0.901 > 0.9 – good fit; PGFI = 0.511 > 0.5 – good fit; RMSEA = 0.100 < 0.1 – fair fit; SRMR = 0.0766 < 0.08 – good fit). If the chi-squared test rejects the model but SRMR≤0.08 and all standardized residuals are small (i.e. there are no large residuals), then I can claim the model fits approximately well (Asparouhov & Muthén, 2018).

Table 2. Descriptive statistics and reliability of measures

Research areas	Latent variables (sub-constructs)	Observable variables*	Mean	SD	Cronbach's alpha	CR	AVE
Supplier involvement in product development (SIPD)	DSI	DSI2, DSI5, DSI6, DSI7, DSI10	1.269	0.982	0.692	0.682	0.345
	CPSI	CPSI3, CPSI5, CPSI6, CPSI8, CPSI9, CPSI10	2.639	0.896	0.791	0.884	0.565
	CSI	CSI1, CSI2, CSI3, CSI5	4.217	0.450	0.778	0.862	0.567
Supplier relationship resilience	SF	SF3, SF4, SF6, SF7, SF8	3.948	0.601	0.753	0.855	0.506
	PF	PF1 PF4 PF5 PF6 PF7 PF8	2.897	0.863	0.785	0.851	0.507
	LF	LF1, LF2, LF3, LF4, LF5	2.665	0.935	0.851	0.860	0.304
	RED	REDS3, REDS4, REDS5	3.033	1.268	0.882	0.890	0.733
Company performance	CP	CP1, CP2, CP3, CP4	3.575	0.502	0.820	0.869	0.638

Source(s): Own elaboration

	SF	PF	RED	PSI	CSI	CP
SF	0.711					
PF	*−0.096*	0.712				
RED	*0.146*	*0.269*	0.856			
CPSI	*0.055*	*0.247*	*0.247*	0.752		
CSI	*0.449*	0.002	*0.265*	*0.265*	0.753	
CP	*0.141*	*0.246*	*0.153*	*0.239*	0.076	0.799

Note(s): Numbers on the diagonal are square roots of AVE for sub-constructs; numbers off-diagonal are correlations between them; italic means the correlation is significant at the level of 0.05 (2-tailed)
Source(s): Own elaboration

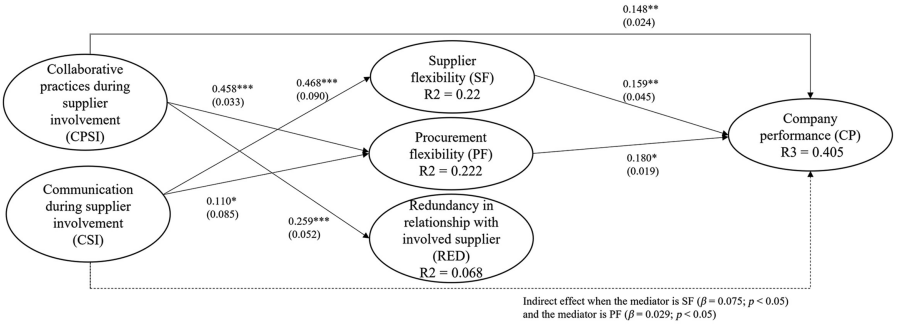
Table 3.
Discriminant validity

Structural model

First of all, note that the model explains 6.8% of RED variation, 22.2% of PF variation, 22% of SF variation and 40.5% of CP variation. Regarding the model fit, my conceptual model achieved an approximate fit of the data ($\chi^2 = 1090{,}322$ (df = 313), $p < 0.0001$ – reject; χ^2/df = 3.48 < 5 – good fit; GFI = 0.919 > 0.9 – good fit; AGFI = 0.909 > 0.9 – good fit; TLI = 0.912 > 0.9 – good fit; CFI = 0.922 > 0.9 – good fit; RMSEA = 0.0733 < 0.08 – fair fit and SRMR = 0.068 < 0.08 – good fit).

The results show that CPSI had a positive significant effect on PF ($\beta = 0.458$; $p < 0.0001$) and on RED ($\beta = 0.259$; $p < 0.0001$). At the same time, it did not have a direct effect on SF ($\beta = -0.031$; $p = 0.504$). The results also show a significant positive effect of CPSI ($\beta = 0.148$; $p = 0.008$) on CP (Figure 3, Table 4).

Furthermore, CSI had a positive significant effect on SF ($\beta = 0.468$; $p < 0.0001$) and on PF ($\beta = 0.110$; $p = 0.023$). CSI did not have a direct effect on RED ($\beta = 0.018$; $p = 0.726$). Consequently, I could partially confirm H1 and H2, as CPSI does not increase SF, and CSI does not decrease RED. However, I confirmed the other four tested dependencies. Interesting results concern H3. Mainly, CPSI had a direct effect on CP ($\beta = 0.148$; $p = 0.008$), whereas CSI did not have a direct effect on CP ($\beta = -0.032$; $p = 0.598$). However, the indirect effect of CSI on CP was statistically significant when the mediator was SF ($\beta = 0.075$; $p < 0.05$) and the mediator was PF ($\beta = 0.029$; $p < 0.05$). The standardized indirect (mediated) effect of CSI on CP was 0.104. That is, due to the indirect (mediated) effect of CSI on CP, when CSI went by 1 standard deviation, CP went by 0.104 standard deviations. This was in addition to any direct (unmediated) effect that CSI may have had on CP (Kline, 2015, p. 52). Furthermore, the



Note(s): *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$
Source(s): Own elaboration

Figure 3.
Empirical model of the influence of supplier involvement in product development on flexibility and redundancy in relationship with suppliers and company performance

Hypothesis	Independent variables	Dependent variables	Coefficient standardised	*p*-value	Results
H1	CPSI	SF	−0.031	0.504	Not supported
	CPSI	PF	0.458	<0.0001	Supported
	CSI	SF	0.468	<0.0001	Supported
	CSI	PF	0.110	0.023	Supported
H2	PSI	RED	0.259	<0.0001	Supported
	CSI	RED	0.018	0.726	Not supported
H3	CSI	CP	−0.032	0.598	The indirect effect was confirmed when the mediator is SF and PF
	CPSI	CP	0.148	0.008	Supported
H4	SF	CP	0.159	0.004	Supported
	PF	CP	0.180	<0.0001	Supported
H5	RED	CP	0.051	0.280	Not supported

Source(s): Own elaboration

Table 4.
Hypotheses testing

bootstrap test (with a minimum of 5,000 resamples) offers clear evidence of significant mediation if the 95% confidence intervals do not include the value 0 (Nguyen *et al.*, 2020), indicating that CSI had a significant positive indirect effect on CP ($\beta = 0.104$; $p < 0.01$; 95% CI: 0.069, 0.180; excluding 0). These results suggest that SF and PF mediate the effect of CSI on CP.

Finally, the results show a significant positive effect of SF ($\beta = 0.159$; $p = 0.004$) and PF ($\beta = 0.180$; $p < 0.0001$) on CP. Thus, I fully confirmed H4.

Finally, H5 was the only hypothesis that I could not confirm, as the RED ($\beta = 0.051$; $p = 0.280$) did not have a significant positive effect on CP.

Discussion

The obtained results only partially confirmed the observations of previous qualitative studies, which state that SIPD enhances SCRES (Zsidisin & Smith, 2005; Tang *et al.*, 2009; Tang & Musa, 2011; Melnyk *et al.*, 2014). They provide much more detailed considerations in this regard, shedding light for the critical area of supplier relationship management. In general, according to the research results, the effect of SIPD on supplier relationship resilience is twofold. On the one hand, the positive impact of SIPD enhances procurement flexibility in relationship with involved supplier and the flexibility of involved supplier. On the other hand, SIPD may increase supply chain vulnerability to disruptions by encouraging companies to resign from reserve resources in relationship with key supplier involved in product development.

The first and the second hypotheses addressed whether SIPD influences supplier relationship resilience in terms of flexibility and redundancy elements. I verified that while collaborative practices during SIPD play a key role in increasing procurement flexibility, extensive communication is particularly important for enhancing supplier flexibility. Contrasting these observations with the results of other studies, I should evoke two things. First, such SIPD practices as sharing tangible and intangible resources, building cross-functional teams, mutual supporting (e.g. education, audits) and engagement of various levels of management may support supplier–buyer integration, shorten negotiations and decrease time and cost of placing orders (McGinnis & Vallopra, 1999; Fan, Russel & Run, 2000; Ragatz, Handfield, & Petersen, 2002; Hoegl & Wagner, 2005; McIvor, Humphreys, & Cadden, 2006; Van Echtelt *et al.*, 2008; Jayaram, 2008; Chien & Chen, 2010). Thus, they can be crucial for

achieving procurement flexibility (Swafford *et al.*, 2006; Stevenson & Spring, 2007; Tachizawa & Giménez, 2009; Park *et al.*, 2010; Supply Chain Council, 2012, p. 66). Second, frequent and intensive communication achieved by implementing various methods in SIPD (Culley *et al.*, 1999; Hoegl & Wagner, 2005; Jayaram, 2008; Najafi Tavani *et al.*, 2013) may be of particular importance for leveraging suppliers' ability to respond to time, volume, mix and product changes.

Lack of reserve resources in supply chains can be detrimental to resilience as buffers are crucial to maintaining business continuity when disruption occurs (Datta, 2017; Stecke & Kumar, 2009). The verification of the second hypothesis revealed that collaborative practices during SIPD decrease redundancy in the relationship with the involved supplier. According to previous studies, SIPD is based on close cooperation, mutual engagement and trust (Johnsen, 2009; Lai, Chen, Chiu, & Pai, 2011; Büyüközkan & Görener, 2015). Most likely, such a partnership can determine the tendency to reduce inventory stocks and spare capacity in supplier–buyer partnership cooperation. For example, lean management and just-in-time strategy encourage minimizing supply stocks while focusing on improving maximum time efficiency (Birou & Fawcett, 1994; Handfield *et al.*, 1999; Wagner & Hoegl, 2006). In turn, agile management, which is especially related to joint product development, innovative products and short product life cycles, favors make-to-order strategies and a lack of inventories of finished products (Christopher, 2000; Power, Sohal, & Rahman, 2001). Regardless of the strategy, the research results highlight that SIPD may weaken supplier relationship resilience in terms of redundancy.

Moreover, the verification of the third hypothesis provides new insights. According to the research results, supplier involvement in product development positively influences company performance. This observation reinforces previous studies exploring SIPD practice and business performance (e.g. Petersen *et al.*, 2005; Flynn, Huo, & Zhao, 2010; Najafi Tavani *et al.*, 2013). The results of this study point to a more detailed perspective, because the verified model used several sub-constructs to measure SIPD and supplier relationship resilience. Namely, while collaborative practices during supplier involvement in product development support company performance directly, communication impacts company performance only if it is mediated by flexibility in the relationship with the involved supplier, understood as supplier flexibility and procurement flexibility. The latter observation is to some extent in line with another study. Song and Liao (2019) recognized that an indirect effect of information sharing on operations capabilities is statistically significant when the mediator is market intelligence responsiveness.

Finally, the fourth and fifth hypotheses addressed the relationship between supplier relationship resilience and company performance. Each of them provides new observations. Verification of the fourth hypothesis revealed that both procurement flexibility and supplier flexibility enhanced by SIPD positively impact CP. This significantly complements previous studies on the relationship between supply chain flexibility and company performance (Sánchez & Pérez, 2005; Camison & Lopez, 2010). Nevertheless, although past studies confirmed that reduced inventory buffers have a positive effect on costs and financial performance (Xiaohong & Siying, 2012; Isaksson & Seifert, 2014), in this research, the reduced redundancy in relationship with suppliers involved in product development did impact CP. I could explain it as follows. On the one hand, the capacity and inventory buffers are considered a waste or muda for the manufacturing system (Christopher & Peck, 2004; Rüttimann & Stöckli, 2016; Helmold & Terry, 2017, pp. 103–116). On the other hand, as the current crises show, a lack of redundancy may cause critical problems with business continuity, lowering the level of customer service and translating into poorer sales and profits. Therefore, it is a very complex issue and should receive more attention in the future. I also recommend expanding CP sub-construct by including items related to the ability to anticipate risk and respond to disruptions.

Conclusions

The conducted quantitative study complements the existing research on SCRES and SIPD. The quantitative methods I used confirmed the impact of SIPD practice on two main resilience elements while providing more detailed information, which was possible thanks to the use of several sub-constructs to measure SIPD as well as resilient supplier relationship. To build supply chain resilience, the focus should be on strengthening the SCRES elements for various areas of the supply chain, including supplier relationship management. The overall conclusion is that although certain practices are considered to be those that strengthen SCRES, the impact of SIPD on supplier relationship resilience is not always unequivocal. In light of the results, it is important today to re-design and re-assess the SIPD to strengthen supplier relationship resilience.

The study is a source of new knowledge especially for enterprises participating in international supply chains, which are particularly at risk in the VUCA world today. Therefore, supplier relationship resilience must be built carefully and with the use of varied practices. As research shows, SIPD is a practice that determines building SCRES, but in the case of supplier relationship management business process, it has both positive and negative impact. Therefore, the main suggestions for supply chain managers include the following.

First, managers should base the integration of supplier relationship management with product development and commercialization in supply chain management on a comprehensive risk assessment and mitigation through flexibility and redundancy of SCRES elements. Second, to enhance supplier relationship resilience, I recommend that managers strengthen collaborative practices during supplier involvement in product development. In this way, they will directly enhance procurement flexibility and company performance. Third, managers should extend the communication with involved suppliers to different management levels using various communication methods and tools. Frequent and intensive communication is especially important for strengthening the supplier flexibility and, consequently, company performance. Finally, although trusted, reliable and flexible suppliers are mainly involved in product development, managers must review decisions about keeping reserve resources, even if the involved supplier is located close, that is in the same country. During everyday functioning, managers perceive redundancy as additional costs. However, during a crisis, it effectively mitigates the negative effects of disruptions. Therefore, each company should individually reassess what kind of redundancy should be maintained and on what level to ensure the continuity of procurement and manufacturing processes in the relationship with the involved supplier. It is certainly a path full of compromises between the various departments of partners, but it seems to be indispensable in the light of the results of the study.

The limitation of this study may be that the sample consisted only of companies located in one country. However, enterprises involved in the international supply chains dominated the research, which changed the perspective also into the cross-country one. The study results can serve companies operating in different countries, especially those whose key supplier involved in the NPD process is located in the same country.

Future research should assess whether companies implementing SIPD coped better with ensuring supply chain business continuity than the companies that did not implement SIPD. It would also be valuable to investigate which SIPD practices are the most effective for proactive, concurrent and reactive SCRES strategies implementation. I also suggest that in addition to flexibility and redundancy other elements of SCRES be included, that is knowledge management, security or visibility. Finally, in light of contemporary global main trends and challenges, it is worth discussing the impact of SIPD on both resilient and sustainable supply chains, especially when involving suppliers in design for the environment.

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(The Appendix follows overleaf)

Appendix

Sub-construct	Item		References
Degree of supplier involvement (DSI)	Question: to what extent do you engage the supplier in product development at individual stages? Scale: 1–5 Answers: 1 – very low 5 – very high		
	DSI1*	Idea generation and screening the ideas	Hartley, Zirger, and Kamath (1997), Handfield *et al.* (1999), Parker *et al.* (2008), Klioutch and Leker (2011)
	DSI2	Technical and business assessment	Handfield *et al.* (1999), McIvor and Humphreys (2004), Danilovic (2006), Spaulding and Woods (2006), Parker *et al.* (2008), Klioutch and Leker (2011)
	DSI3*	Product concept development	Handfield *et al.* (1999), Wynstra, Weggemann and Van Weele (2001), McIvor and Humphreys (2004)
	DSI4*	Product design and engineering	Handfield *et al.* (1999), Wynstra, Weggemann, and Van Weele (2001), McIvor and Humphreys (2004), Cantarello, Nosella, Petroni, and Venturini (2011), Klioutch and Leker (2011)
	DSI5	Technological process design	Wagner (2012), Lyu and Chang (2007)
	DSI6	Planning and control of production processes	McIvor and Humphreys (2004), Kähkönen *et al.* (2015)
	DSI7	Prototype building, test and pilot	Handfield *et al.* (1999), Wynstra Weggemann and Van Weele (2001), Jayaram (2008), Wagner (2012)
	DSI8*	Supply chain design in the sense of selection of supply sources or distribution channels	Wagner (2012)
	DSI9*	Commercialization of product	Spaulding and Woods (2006), Cantarello *et al.* (2011), Najafi Tavani *et al.* (2013)
	DSI10	Full-scale production in the sense of production development and improvement	McIvor and Humphreys (2004), Sjödin and Eriksson (2010), Cagli, Kechidi, and Levy (2012)

Table A1.
Research instrument: survey questions and references

(*continued*)

Sub-construct	Item		References
Collaborative practices during supplier involvement in product development (CPSI)	Question: to what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	CPSI1*	Cooperation with the supplier was based on partner relations	Hoegl and Wagner (2005), Li Gu and Wang (2010), Wagner (2012)
	CPSI2*	Cooperation with the supplier was based on jointly set goals	Hoegl and Wagner (2005), Parker *et al.* (2008), Wagner (2010), Kähkönen *et al.* (2015)
	CPSI3	Cooperation with the supplier was based on mutual willingness to develop a long-term relationship	Primo and Amundson (2002), Song, Song, and Di Benedetto (2011)
	CPSI4*	Cooperation with the supplier was based on equitable risk and reward sharing	McGinnis and Vallopra (1999)
	CPSI5	Cooperation with the supplier was based on sharing such knowledge as technical/technological	McGinnis and Vallopra (1999), Hoegl and Wagner (2005), Jayaram (2008), Chien and Chen (2010)
	CPSI6	Cooperation with the supplier was based on sharing cost information	McGinnis and Vallopra (1999), Hoegl and Wagner (2005), Jayaram (2008), Chien and Chen (2010)
	CPSI7*	Cooperation with the supplier was based on the sharing physical assets, for example plant or only equipment	Birou and Fawcett (1994), Bozdogan, Deyst, Hoult, and Lucas (1998), McGinnis and Vallopra (1999), Parker *et al.* (2008)
	CPSI8	Cooperation between the company's employees and the supplier's employees was very close. For example, product development cross functional team consisted of employees of the company and the supplier	Fan, Russel, and Run (2000), Primo and Amundson (2002)
	CPSI9	Cooperation with the supplier was based on mutual supporting in the improvement of, e.g. quality, production capacity, through the specific activities: education and training programs, evaluations, audits	Birou and Fawcett (1994), Ragatz Handfield and Petersen (2002)
	CPSI10	Cooperation with the supplier involved various levels of management, e.g. strategic and operational	McGinnis and Vallopra (1999), McIvor *et al.* (2006), Van Echtelt *et al.* (2007, 2008)

(*continued*)

Table A1.

Sub-construct	Item		References
Communication during supplier involvement in product development (CSI)	Question: to what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	CSI1	Communication was frequent	Hartley *et al.* (1997), Culley *et al.* (1999) Hoegl and Wagner (2005), Jayaram (2008)
	CSI2	Communication was intensive	Najafi Tavani *et al.* (2013), Hoegl and Wagner (2005)
	CSI3	Communication was in friendly atmosphere	Wagner and Hoegl (2006)
	CSI4*	Communication involved employees from various departments of the company and employees from various departments of the supplier	Birou and Fawcett (1994), Dowlatshahi (1998), Swink (1999), Maffin and Braiden (2001), Lakemond, Berggren, and Van Weele (2006), Parker *et al.* (2008)
	CSI5	Cooperation with the supplier was based on communication using traditional methods, which can be a telephone, fax or direct meetings	Birou and Fawcett (1994), Hartley *et al.* (1997), Culley *et al.* (1999)
	CSI6*	Cooperation with the supplier was based on communication with the use of advanced information and communication tools	Tang, Eversheim, and Schuh (2004), Huang *et al.* (2003)

Table A1. (*continued*)

Sub-construct	Item		References
Supplier flexibility (SF)	Question: To what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	SF1*	SIPD positively influenced the supplier's ability to respond to volume changes	Chang, Yang, Cheng, and Sheu (2003), Swafford *et al.* (2006), Tachizawa and Thomsen (2009), Chu *et al.* (2012)
	SF2*	SIPD positively influenced the supplier's ability to offer small minimum order quantity	Pujawan (2004)
	SF3	SIPD positively influenced the supplier's ability to respond to delivery time changes	Chang *et al.* (2003), Swafford *et al.* (2006), Tachizawa and Thomsen (2009), Chu *et al.* (2012)
	SF4	SIPD positively influenced the supplier's ability to produce a large volume in a short time	Swafford *et al.* (2006), Tachizawa and Thomsen (2009), Chowdhury and Quaddus (2016), Stone and Rahimifard (2018)
	SF5*	SIPD positively influenced the supplier's ability to respond to changes in the type of ordered items	Chang *et al.* (2003), Pujawan (2004), Swafford *et al.* (2006), Tachizawa and Thomsen (2009), Chiang, Kocabasoglu-Hillmer, and Suresh (2012), Chu *et al.* (2012)
	SF6	SIPD positively influenced the supplier's ability to develop new products	Chang *et al.* (2003), Chiang *et al.* (2012), Chu *et al.* (2012)
	SF7	SIPD positively influenced the supplier's ability to implement engineering changes to orders	Chang *et al.* (2003), Swafford *et al.* (2006), Tachizawa and Thomsen (2009), Chiang *et al.* (2012), Chu *et al.* (2012)
	SF8	SIPD positively influenced the supplier's ability to offer various pre- and after services	Chang *et al.* (2003)

(*continued*)

Table A1.

Sub-construct	Item		References
Procurement flexibility (PF)	Question: to what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	PF1	SIPD positively influenced planning and information sharing intensity with the suppliers (e.g. forecasts, production plans, inventory levels)	Stevenson and Spring (2007), Tachizawa and Thomsen (2009), Park *et al.* (2010)
	PF2*	SIPD positively influenced developing long-term relationship with suppliers	Tachizawa and Giménez (2009)
	PF3*	SIPD increased the degree of using IT planning tools and/or Electronic Data Interchange (EDI) in relationships with suppliers	Skipper and Hanna (2009), Tachizawa and Giménez (2009)
	PF4	SIPD shortened time required in negotiating new source/volume contracts/terms	Tachizawa and Giménez (2009), Supply Chain Council (2012, p. 66)
	PF5	SIPD increased using flexible contracts	Rice and Caniato (2003), Stevenson and Spring (2007), Tachizawa and Giménez (2009), Pettit, Croxton, and Fiksel (2013), Tukamuhabwa *et al.* (2015), Chowdhury and Quaddus (2016)
	PF6	SIPD determined integrating various areas within the firm	Swafford *et al.* (2006), Tachizawa and Giménez (2009)
	PF7	SIPD lowered costs of placing orders	Swafford *et al.* (2006), Tachizawa and Giménez (2009)
	PF8	SIPD shortened time of placing orders	Swafford *et al.* (2006), Tachizawa and Giménez (2009)
Logistics flexibility (LF)	Question: to what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	LF1	SIPD increased using multiple transportation modes	Pujawan (2004), Tachizawa and Giménez (2009), Ishfaq (2012), Kamalahmadi and Parast (2016), Zhao, Liu, and Lopez (2017)
	LF2	SIPD make it possible to choose a faster mode of transportation in case of emergency needs	Pujawan (2004)
	LF3	SIPD make it possible to transport small deliveries, with a volume smaller than the load capacity of the delivery vehicle/container	Pujawan (2004)
	LF4	SIPD make it possible to mix different products into a delivery load	Pujawan (2004)
	LF5	SIPD enhanced collaborating with logistics providers	Tachizawa and Giménez (2009)

Table A1. (*continued*)

Sub-construct	Item		References
Redundancy in relationship with involved suppliers (RRS)	Question: to what extent do you agree with the below statement? Scale: 1–5 Answers: 1 – very low 5 – very high		
	RED1*	SIPD resulted in the resignation from having backup suppliers	Yi, Ngai, and Moon (2011), Ivanov, Sokolov, and Dolgui (2014), Hohenstein *et al.* (2015), Chowdhury and Quaddus (2016), Kamalahmadi and Parast (2016), Ali *et al.* (2017)
	RED2*	SIPD resulted in the resignation from reserving slack capacity with supplier	Rice and Caniato (2003), Park *et al.* (2010), Chowdhury and Quaddus (2016)
	RED3	SIPD resulted in the resignation from keeping safety stocks by supplier	Rice and Caniato (2003), Christopher and Peck (2004), Tachizawa and Giménez (2009), Zsidisin and Wagner (2010), Tukamuhabwa *et al.* (2015), Ali *et al.* (2017)
	RED4	SIPD resulted in the resignation from keeping safety stocks by company	Yi *et al.* (2011), Ivanov *et al.* (2014), Hohenstein *et al.* (2015), Chowdhury and Quaddus (2016), Kamalahmadi and Parast (2016), Ali *et al.* (2017)
	RED5	SIPD resulted in resignation from sending orders to the supplier in advance (in order to protect against time uncertainty, e.g. delayed delivery)	Rice and Caniato (2003), Park *et al.* (2010), Chowdhury and Quaddus (2016)
Company performance (CP)	Question: how well does your organisation perform relative to major competitors in terms of. . .? Scale: 1–5 Answers: 1 – very badly; 5 – very well		
	CP1	Net profit	Petersen *et al.* (2005), Flynn *et al.* (2010), Tipu and Fantazy (2014)
	CP2	Sales growth	Petersen *et al.* (2005) Tipu and Fantazy (2014)
	CP3	Lead time for fulfilling customers' orders	Flynn *et al.* (2010), Tipu and Fantazy (2014)
	CP4	Customer satisfaction	Flynn *et al.* (2010), Najafi Tavani *et al.* (2013), Tipu and Fantazy (2014)

Note(s): * Item dropped after CFA
Source(s): Own elaboration

Table A1.

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