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Order from chaos: A meta-analysis of supply chain complexity and firm performance

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Abstract

Increased globalization, varying customer requirements, extended product lines, uncertainty regarding supplier performance, and myriad related factors make supply chains utterly complex. While previous research indicates that supply chain complexity plays an important role in explaining performance outcomes, the accumulating evidence is ambiguous. Thus, a finer-grained analysis is required. By meta-analyzing 27,668 observations across 102 independent samples from 123 empirical studies, we examine the link between supply chain complexity and firm performance. While the preponderance of evidence from previous studies identifies supply chain complexity as detrimental to firm performance, our results illustrate that although supply chain complexity has a negative effect on operational performance, it has a positive effect on innovation performance and financial performance. Furthermore, we also distinguish among different levels of supply chain (i.e., upstream, downstream, and internal) and observe nuanced findings. Finally, our findings also reveal moderating effects of construct operationalization and study design characteristics. We discuss implications for theory and practice and provide avenues for future research.

KEYWORDS

meta-analysis, meta-regression, performance, supply chain complexity

INTRODUCTION

Supply chain complexity (SCC) is the extent to which the supply chain of an organization is made up of a large number of varying elements that interact in unpredictable ways (Aitken et al., 2016; Bode & Wagner, 2015; Bozarth et al., 2009). As companies increase product variety, adopt new technologies, and extend their supply bases globally, supply chains inevitably become more complex (Aitken et al., 2016; Dong et al., 2020; Wiengarten et al., 2017). Uncertainty arising from unreliable supplier lead times and supplier switching further contributes to this complexity (Serdarasan, 2013; Vachon & Klassen, 2002). SCC is considered one of the most pressing issues for contemporary supply chains (Bode & Wagner, 2015). Highlighting this issue, McKinsey & Company estimated that complexity in the food and beverage industry is costing manufacturers upward of $50 billion USD annually in gross profits (Adams et al., 2016). Thus, recent insights from practice illustrate that supply chain professionals associate SCC with "trouble"[1] and aim to reduce its perils[2].

However, empirical evidence regarding the performance implications of SCC is inconclusive. While some studies report a negative association between SCC and performance (e.g., Blome et al., 2014; Brandon-Jones et al., 2015;

Vachon & Klassen, 2002), others report a positive association (e.g., Lu & Shang, 2017; Sharma, Pathak, et al., 2019; Srivastava et al., 2017) or no association at all (e.g., Caniato & Größler, 2015; Chaudhuri & Boer, 2016; Liu et al., 2012). Furthermore, the definitions, conceptualizations, and operationalizations of SCC are quite diverse in the literature, making it difficult to integrate and compare findings. For instance, Choi and Krause (2006) provided a grounded definition of SCC for the upstream supply chain as "the degree of differentiation of the focal firm's suppliers, their overall number, and the degree to which they interrelate" (p. 638), whereas other studies adopt different levels of conceptualization such as complexity within internal operations and among downstream supply chain actors, together with distinct subdimensions in each (e.g., Bozarth et al., 2009; Wiengarten et al., 2017). While some sub-dimensions, such as the structural characteristics of SCC (i.e., the number of elements and the interactions between elements; Thompson, 1967) are consistently defined and studied, others such as variety, diversity, variation, and uncertainty (Fernández Campos et al., 2019; Isik, 2010) are more broadly defined and less consistently studied. Therefore, SCC remains an elusive concept (Bode & Wagner, 2015).

Accordingly, scholarly interest in understanding the content and implications of SCC has grown considerably in the past decade. To this aim, researchers have adopted various research strategies such as qualitative reviews examining drivers of SCC (e.g., Serdarasan, 2013), modeling studies aiming to measure SCC (e.g., Isik, 2010), conceptual studies formulating propositions (e.g., Skilton & Robinson, 2009), case studies focusing on specific industries (e.g., Aitken et al., 2016; Fernández Campos et al., 2019), and empirical studies testing SCC's effects on performance outcomes (e.g., Bode & Wagner, 2015; Brandon-Jones et al., 2015). Although these studies contribute to our understanding of SCC and its performance implications, the extant literature does not provide a holistic perspective of SCC. Reeves et al., (2020) suggest that complexity can enable companies to be more resilient and adaptable, but it may also negatively affect their efficiency. Thus, scrutinizing and untangling the impact of SCC on firm performance using available empirical evidence are important.

In the present research, we quantitatively synthesize previous findings about the impact of SCC on performance by adopting a meta-analytic approach. Meta-analysis is a robust analytical tool enabling researchers to not only statistically summarize empirical research findings across a large number of studies (Wowak et al., 2013; Zimmermann & Foerstl, 2014), but also to explore inconclusive findings by investigating potential moderators such as operationalization of constructs and contextual variables (Leuschner et al., 2013). By conducting a meta-analysis of the extant literature and providing a finer-grained synthesis of the relationships between subcomponents of both SCC and performance, our study not only sheds light on performance implications of SCC, but also advances theory and practice by providing avenues for further investigation.

The rest of the paper is structured as follows. First, we provide a theoretical background of SCC, discuss its dimensions, and elaborate arguments for hypotheses. Next, in the Research Method section, we discuss sample selection, coding, and the meta-analysis. Afterward, we present the results of the meta-analysis and conclude the paper by discussing theoretical and managerial implications, identifying areas for future research, and stating the conclusions and limitations.

THEORETICAL BACKGROUND

SCC was first coined as a term by Wilding (1998), who conceptualized it as a function of deterministic chaos, parallel interactions, and amplification. Although a variety of definitions and operationalizations of SCC have been proposed in the literature, the majority focus on the systems theory of Simon (1962), who defined complexity as "a system that includes a large number of varied elements that interact in a non-simple way" (p. 468). According to this perspective, SCC is classified into *detail* (or static, also referred to as structural) and *dynamic* (or operational) complexity. Detail complexity refers to the number and variety of elements defining the system (Bozarth et al., 2009; Fernández Campos et al., 2019). Dynamic complexity refers to interactions between the elements of the system which cause unpredictability, randomness, or frequent changes in a system's response to a given set of inputs (Bode & Wagner, 2015; Serdarasan, 2013).

Complexity manifests itself differently at various levels of the supply chain. The extant literature differentiates among three primary supply chain levels: upstream, internal, and downstream (Bozarth et al., 2009). While some scholars have examined all three levels (De Leeuw et al., 2013; Serdarasan, 2013), others have focused on a single level, such as upstream complexity (e.g., Brandon-Jones et al., 2015; Choi & Krause, 2006; Dong et al., 2020) or internal complexity (e.g., Chaudhuri & Boer, 2016; Wiengarten et al., 2017). Upstream complexity increases when the focal firm has many suppliers that differ in terms of geographical regions, firm size, organizational culture, or technological capabilities (Bode & Wagner, 2015; Chae et al., 2019; Gao et al., 2015). Similarly, unreliable and long supplier lead times increase upstream complexity (Brandon-Jones et al., 2015; Vachon & Klassen, 2002). Internal complexity is high when part, process, and product varieties are high, or when there are frequent manufacturing schedule changes (Blome et al., 2014; Caniato & Größler, 2015; Eckstein et al., 2015). Downstream complexity, which relates to the number and variety of customers, increases when the focal firm aims to meet a variety of changing customer needs and requirements (Caridi et al., 2010). Shorter product lifecycles further contribute to dynamic downstream complexity (Chen, 2018).

Despite complexity being perceived as "one of the most pressing problems in modern supply chains" (Bode & Wagner, 2015, p. 215), the scholarly community is still in the process of elaborating a clear conceptualization. In the present research, we intend to contribute to this development by seeking to answer a basic question: What is the impact of SCC on firm performance?

This apparently simple question requires SCC to be analyzed not only as an aggregate concept, but also in terms of its different dimensions. For this reason, in line with the literature, we examine SCC from the perspective of a focal firm via two dimensions: (1) the level of SCC (i.e., *upstream*, *internal*, and *downstream*) and (2) the type of SCC (i.e., *detail* and *dynamic*).

Further, we investigate the relationship between SCC and different performance dimensions. Although SCC is often associated with negative performance outcomes, recent studies indicate this is not always the case (e.g., Lu & Shang, 2017; Sharma, Pathak, et al., 2019). For example, SCC may affect the firm's ability to excel on its competitive priorities, that is, on some combination of quality, cost, delivery, and flexibility (Ward et al., 1998), which may affect its operational performance (Vachon & Klassen, 2002). Innovation outcomes, a performance aspect that is often considered independently from the traditional competitive priorities just listed, is another important strategic performance criterion. Indeed, some studies specifically examined the nuanced relation between SCC dimensions and focal firm innovation (e.g., Bellamy et al., 2014; Dong et al., 2020; Sharma, Pathak, et al., 2019). Finally, it is also important to examine the impact on overall business performance by focusing on the financial impact of SCC (Lu & Shang, 2017; Sharma, Kumar, et al., 2019). Thus, given the intention to understand if and to what extent SCC affects firm performance, we parsed out three primary dimensions of firm performance: (1) *operational performance*, (2) *innovation performance*, and (3) *financial performance*. Accordingly, in the next section, we formulate our hypotheses about the impact of SCC on performance.

HYPOTHESES

SCC impact on operational performance

Supply chain complexity is often associated with detrimental operational performance outcomes (Turner et al., 2018). Complex systems consisting of several varied elements generate a chaotic environment for the focal firm and increase its operational load for managing diverse actors (Choi & Krause, 2006; De Leeuw et al., 2013; Skilton & Robinson, 2009). When this effect is accompanied by high levels of uncertainty and unpredictability that come with complexity (Isik, 2010; Serdarasan, 2013), firms become more vulnerable and are exposed to a variety of operational risks such as supply chain disruptions (Birkie & Trucco, 2020; Blome et al., 2014; Bode & Wagner, 2015). Negative effects can manifest in several ways such as increased transaction costs (e.g., production, inventory, logistics, and communication), reduced efficiency, long and unreliable lead times, difficulty in schedule attainment, and inconsistent product quality (Choi & Krause, 2006; Dittfeld et al., 2018; Lorentz et al., 2012; Lu & Shang, 2017; Vachon & Klassen, 2002). These effects can stem from both external (upstream and downstream) and internal complexity (Serdarasan, 2013).

Detrimental operational performance effects are most pronounced for upstream complexity. Transaction costs associated with managing a large supply base rise in parallel to the increase in the number of relationships and interfaces to be coordinated (Choi & Krause, 2006; Giannoccaro et al., 2018; Lu & Shang, 2017). This is partly caused by higher information processing needs of the focal firm, resulting in higher communication costs (Bode & Wagner, 2015; Lu & Shang, 2017). Moreover, suppliers that are heterogeneous from a geographical or industrial perspective further increase the focal firm's burden in coping with different organizational cultures, languages, and institutional environments (Bode & Wagner, 2015; Dong et al., 2020; Lu & Shang, 2017). Consequently, while transaction costs increase, the degree of control over the supply base diminishes with increased complexity, making the focal firm less able to address potential supplier opportunism (Choi & Krause, 2006; Giannoccaro et al., 2018; Grover & Malhotra, 2003). Additionally, loss of control can also be observed in communicating quality requirements and obtaining consistent inputs from multiple suppliers (Lu & Shang, 2017; Vachon & Klassen, 2002). As Bode and Wagner (2015) note, upstream complexity increases the probability that disruptive events will emerge along with the need for managers to control for, or prevent, disruptions. In either case, a more complex supply base is likely associated with more frequent and less manageable disruptions, due simply to the sheer numbers of suppliers. In addition to detail complexity, dynamic complexity also negatively affects operational performance. For instance, volatility in supplier lead times causes higher operational costs due to the focal firm frequently adjusting its production plans and keeping extra safety stock (Caridi et al., 2010; Lu & Shang, 2017).

Upstream complexity also makes supply base management more difficult, generating indirect effects on operational performance. Indeed, it is more difficult to select strategic partners across a numerous, heterogeneous, and uncertain supply base. As a result, the focal firm faces higher supplier search and evaluation costs and may be less likely to effectively establish collaborative relationships. The creation of social capital may be impaired or misdirected, and the focal firm may be less likely to receive preferential treatment from suppliers, which eventually threatens its performance (Autry & Griffis, 2008; Pulles et al., 2016). On the other hand, having fewer suppliers allows firms to build preferential strategic partnerships (Jacobs, 2013), which results in access to higher quality products and services and improved delivery, thus indirectly improving operational performance.

Although fewer studies investigate the link between downstream complexity and operational performance, findings still suggest a negative impact. Bozarth et al., (2009) argued that having several customers with high deviations in demand negatively affects operational efficiency due to lower production volumes and more setups. Transaction costs may also increase with more and diverse customers, thus reducing the firm's efficiency in managing its customer base. For instance, higher customer variety stemming from geographical dispersion is argued to increase inventory costs and cash-to-cash cycle times (Lorentz et al., 2012). Furthermore, with a diverse customer base consisting of various distributors, retailers, third-party logistics service providers, and end customers, the bullwhip effect stemming from a change in the downstream supply chain can have a tremendous effect on focal firm operations. Such disruptions may affect delivery performance and the level of product or service customization provided to the final customer.

Finally, the extant literature also suggests a negative relationship between internal complexity and operational performance. For instance, low-volume production with a greater number of products and parts creates capacity conflicts and increases both planning and execution costs (Caniato & Größler, 2015; Wiengarten et al., 2017). Additionally, product proliferation is often associated with higher inventory costs and lower efficiency. For example, Hu et al., (2008) stated that a high number or variety of build-combinations has a significant negative impact on quality and productivity in automotive production. Similarly, Wiengarten et al., (2017) argued that complex internal processes damage operational performance by making quality control and continuous improvement challenging as well as reducing on-time delivery. Moreover, considering the turbulent environment characterizing many industries, more uncertain production plans inhibit the matching of supply and demand, ultimately affecting operational performance.

In sum, based on the above arguments, we formulated the following hypotheses. The first hypothesis is an overall, supply chain-wide hypothesis, followed by sub-hypotheses that unravel the supply chain into upstream, internal, and downstream complexity.

Hypothesis 1 *SCC is negatively related to a firm's operational performance.*

Sub-hypotheses 1a, 1b, 1c: SCC, in the form of (a) upstream complexity, (b) downstream complexity, and (c) internal complexity, is negatively related to a firm's operational performance.

SCC impact on innovation performance

In contrast to operational performance, innovation performance may be enhanced by increased levels of SCC. Firms rely on two primary sources of knowledge for their innovation activities: internal and external knowledge (Bellamy et al., 2014; Chesbrough, 2003; Kogut & Zander, 1992). External knowledge is required to complement what the firm lacks internally (Grant & Baden-Fuller, 2004). Increasingly, firms pay more attention to the latter in line with growing interest in open innovation which suggests that firms can benefit by opening their boundaries to external parties for joint innovation (Chesbrough, 2003; Grant & Baden-Fuller, 2004; Kogut & Zander, 1992). The knowledge-based view (KBV) proposes that access to a higher number of diverse actors in a network opens the firm to more innovation (Choi & Krause, 2006). This effect is further corroborated if suppliers come from different industries with different technological capabilities which fosters creativity, the potential for useful innovations, and new product ideas (Choi & Krause, 2006; Gao et al., 2015). This effect also appears on the customer side, with Chang and Taylor (2017) showing that customer involvement leads to more new product ideas. Firms that build relationships with other firms, such as alliances and joint innovation projects, to access their unique capabilities and knowledge, achieve higher efficiency through integrating and applying that knowledge in new products and services (Grant & Baden-Fuller, 2004). Therefore, the likelihood of innovation coincides with the complexity of the firm's supply chain.

However, whether the focal firm's innovation performance is enhanced depends on the ability of the focal firm to capture those ideas and incorporate them in new products. For example, Krause and Wagner (2008) described how a focal firm used two suppliers in a forced design competition, with the winner of the competition being awarded the primary volume production contract. This is a simple illustration of how a focal firm used more, as opposed to fewer, suppliers to achieve innovation and new product goals. Strategically managing the increased complexity associated with having multiple suppliers becomes imperative to achieve innovation.

Although there have been some studies examining the link between supply network structural characteristics and innovation performance (e.g., Bellamy et al., 2014; Sharma, Pathak, et al., 2019), there are a limited number of studies that examine complexity from a focal firm's standpoint or that specifically adopt a complexity perspective. Among those few studies, Choi and Krause (2006) proposed a negative quadratic relationship between supply base complexity and supplier innovation, arguing that although complexity is beneficial for innovation, too much of it may exhibit adverse effects. In a recent study, Sharma, Pathak, et al., (2019) found that while horizontal complexity has a (diminishing) positive effect on innovation performance, spatial complexity (geographical dispersion) actually has a negative effect. While Sharma, Pathak, et al., (2019) focused on geographical distance to assess supplier heterogeneity, Gao et al., (2015) focused on technological diversity and found that, in contrast, there is a positive impact on a buying firm's new product creativity. Thus, although there are mixed effects hypothesized and reported, based on the KBV, we argue that if managed well, upstream complexity improves innovation performance via a rich knowledge base that accompanies a variety of resources.

Similar to the arguments related to upstream complexity, one can argue that access to external parties downstream in the supply chain—for example, consumers—also has a positive impact on firm innovativeness (Gambardella et al., 2016). If there is downstream complexity due to varying needs of diverse customers and frequent changes in customer expectations, firms may be forced to do both product and process innovations to survive. Indeed, inviting customers to participate in product innovation leads to higher innovation outcomes, suggesting similarly that customers possess knowledge that is relevant to the focal firm's innovativeness (Chang & Taylor, 2017).

While idiosyncratic knowledge residing within upstream or downstream supply chain entities improves the open innovation potential of firms, previous literature suggests that internal complexity in the form of product and process complexity, is also associated with higher innovation performance. For instance, Chaudhuri and Boer (2016) found that product–process complexity has both direct and indirect effects through collaborative competences on NPD performance relative to competitors. Rather than a direct effect, Vickery et al., (2016) examined the moderating role of product–process complexity and found that it attenuates the positive link between product modularity and new product introduction performance. Overall, we expect that the complexity of products, processes, and technologies within a firm can be a powerful driver of knowledge exchange and consequently of idea generation, thus creating a more fertile environment for innovation. Based on these arguments, we formulate the following hypotheses:

Hypothesis 2 *SCC is positively related to a firm's innovation performance.*

Sub-hypotheses 2a, 2b, 2c: SCC, in the form of (a) upstream complexity, (b) downstream complexity, and (c) internal complexity, is positively related to a firm's innovation performance.

SCC impact on financial performance

The extant literature focused on the impact of SCC on financial performance provides mixed results. A possible explanation for mixed results is that financial performance depends on several factors and is the long-term result of performance on other dimensions, including operational and innovation performance. Our theorizing above introduces competing effects of SCC on operational (negative) and innovation (positive) performance, which is also acknowledged in previous research. For instance, Eckstein et al., (2015) noted that studies report a trade-off between sales growth as a result of product complexity and improved operational efficiency via product rationalization. Similarly, while Bozarth et al., (2009) predicted a negative relationship between SCC and operations-based plant performance, they stated that the relationship between complexity and competitive performance is equivocal and refrained from formulating explicit hypotheses. Their research also suggested there can be varying effects based on SCC dimensions.

The base assumptions underlying transaction cost economics (TCE) theory are useful to understand and predict the effects of SCC on performance. These assumptions include bounded rationality and opportunism (Grover & Malhotra, 2003). Bounded rationality, or the assumption that managers have limits to their cognitive capabilities, may explain why SCC can negatively affect a company's financial performance. A complex supply chain means extra stress on supply chain managers to make rational decisions; complexity makes these decisions more difficult and increases the uncertainty associated with the effects of their decisions. Moreover, a more complex supply chain creates a more uncertain environment (Rindfleisch & Heide, 1997). Thus, complexity may give rise to supplier opportunism and may also decrease a focal firm's ability to detect such behavior (Rindfleisch & Heide, 1997). Bounded rationality of managers coupled with the propensity for some suppliers to behave opportunistically in the face of complexity suggests a negative correlation between complexity and firm performance.

Additional evidence of the mixed effects on performance includes Lu and Shang's (2017) work which examined five dimensions of upstream (supply base) complexity and found that only some of them have an effect, which varied in magnitude and direction. For instance, while horizontal complexity has an inverted-U-shaped relationship with financial performance, spatial complexity (geographical dispersion) has a U-shaped relationship. Chen (2018) found that demand uncertainty caused by the difficulty to predict the volume and composition of demand has a significant negative impact on financial performance. As downstream complexity increases, the focal firm may experience difficulty maintaining high levels of customer satisfaction as well as establishing collaborative relationships based on relationship-specific assets, which may reduce its market share and ultimately negatively affect its financial performance.

Product complexity is often argued to be one of the main determinants of competitiveness as differentiation of products may increase profit margins and revenues (Jacobs, 2013; Wiengarten et al., 2017). However, there are also contrasting views suggesting that product and process variety will increase the number of changeovers, inventory levels, and lengthen lead times, thereby increasing operational costs, decreasing customer satisfaction, and reducing profits (Wiengarten et al., 2017). Although the literature provides mixed evidence regarding the impact of SCC on financial performance, considering the overall preponderant detrimental effects regarding SCC, we propose the following hypotheses:

Hypothesis 3 *SCC is negatively related to a firm's financial performance.*

Hypotheses 3a, 3b, 3c: SCC, in the form of (a) upstream complexity, (b) downstream complexity, and (c) internal complexity, is negatively related to a firm's financial performance.

Moderator analysis

Meta-analysis enables researchers to examine moderators that can impact the direction and magnitude of the associations between independent and dependent variables. Most frequently examined moderators in meta-analysis are construct operationalizations and study design characteristics (Golicic & Smith, 2013; Wang et al., 2018). In this study, we examined the impact of construct operationalization by analyzing two sub-dimensions of SCC, that is, detail and dynamic complexity. Regarding study design characteristics, we examined the following: journal ranking, data source, number of industries, number of countries, and national culture (when data were collected from a single country, assessed in terms of five Hofstede dimensions: power distance, uncertainty avoidance, individualism, feminism, and long-term orientation). The resulting conceptual model we tested through meta-analysis is shown in Figure 1.

RESEARCH METHOD

We performed a meta-analysis to quantitatively summarize empirical research findings about the link between SCC and firm performance. In this section, we describe our search to identify and filter relevant articles, the process to extract data from and code those articles, and the analytical approach to conduct meta-analysis.

Sample selection

We identified articles to be included in our review via two main approaches, as shown in Figure 2. First, we searched for articles in EBSCO Business Source Complete database in August 2020, using a comprehensive set of search terms (see Appendix A) obtained from prior literature reflecting

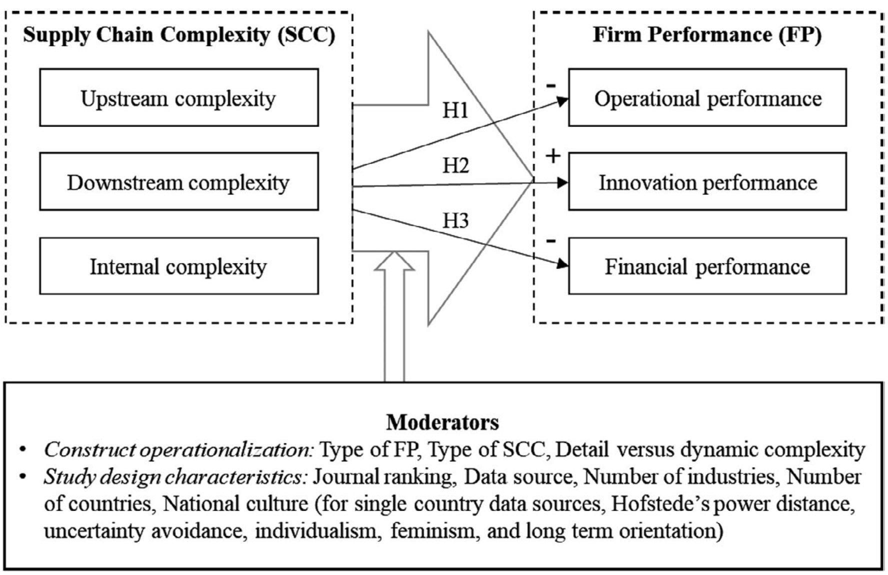

FIGURE 1 Conceptual model

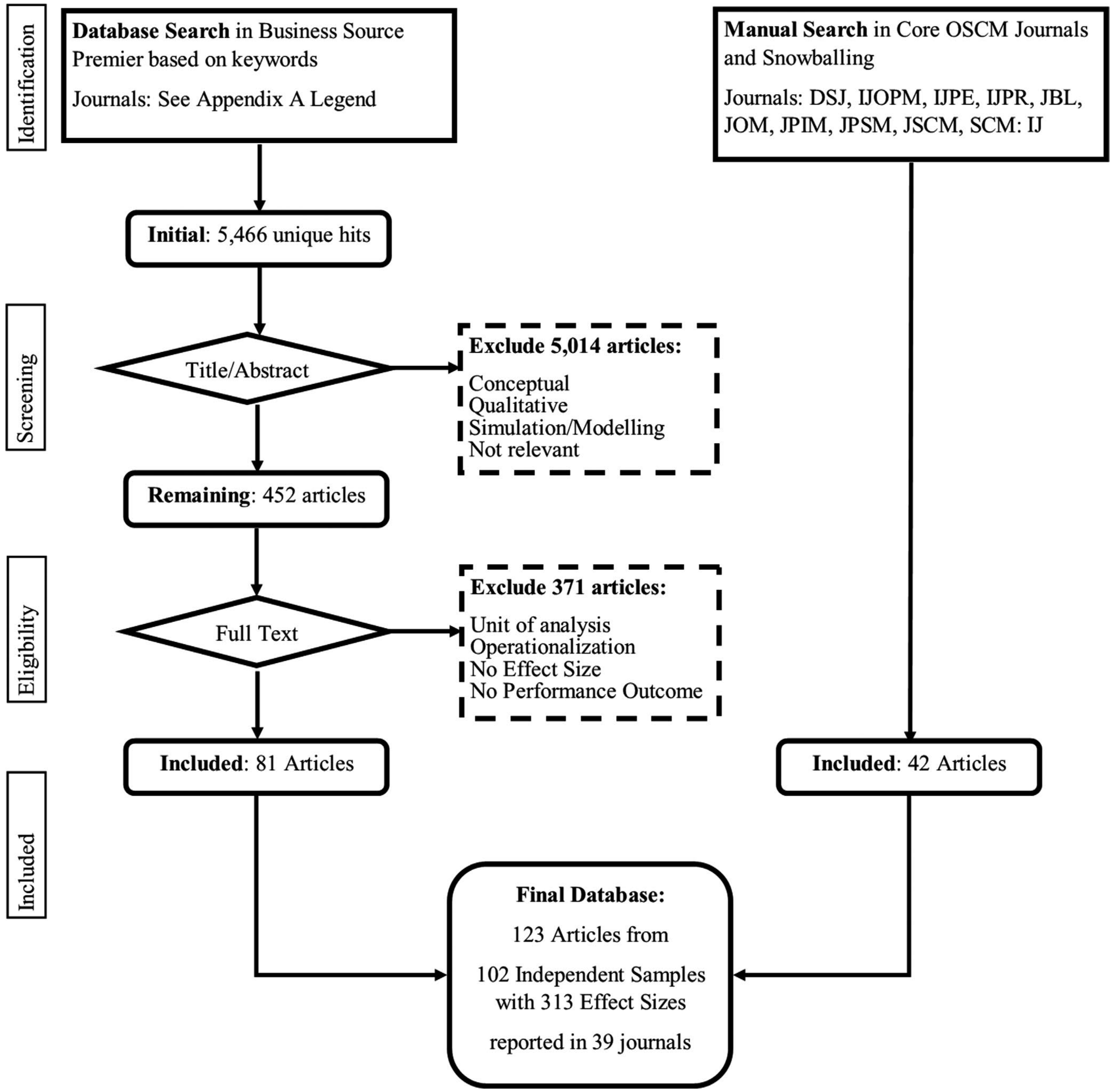

FIGURE 2 Sampling process. DSJ, Decision Sciences Journal; IJOPM, International Journal of Operations & Production Management; IJPE, International Journal of Production Economics; IJPR, International Journal of Production Research; JBL, Journal of Business Logistics; JOM, Journal of Operations Management; JPIM, Journal of Product Innovation Management; JPSM, Journal of Purchasing & Supply Management; JSCM, Journal of Supply Chain Management; SCM:IJ, Supply Chain Management: An International Journal

the different terminologies and sub-dimensions of SCC (See Table 1 and Table 2). We did not pose a restriction regarding the journals, but we limited the search to the period between 1998 and 2020, as the term SCC was first coined by Wilding in 1998. Our search resulted initially in 5,466 hits. Second and in parallel, we relied on snowballing and manually searched studies published in ten leading OSCM journals that are known to publish empirical research most frequently. We performed this additional step in order not to miss relevant studies because the literature is not clear about the definition of SCC and various terminologies are used. Hence, keywords may not suffice (Cao & Lumineau, 2015; Leuschner et al., 2013). Indeed, several studies examined SCC sub-dimensions without necessarily using the term "complexity" (e.g., demand volatility, long supplier lead time). Furthermore, several sub-dimensions of SCC are often examined as control variables (e.g., number of suppliers, demand uncertainty) making it difficult to identify those

TABLE 1 Measures of supply chain complexity

Constructs	Representative measures	Representative studies
Upstream complexity		
Detail – *numerousness*	1. The number of first-tier suppliers 2. Our firm has been relying on a small number of suppliers	Vachon and Klassen (2002), Koufteros et al., (2007), Bode and Wagner (2015), Sharma, Kumar, et al., (2019), Dong et al., (2020)
Detail—*variety*	1. The number of countries represented in supply base 2. Suppliers in this supply chain are the same size *(Reverse-coded)* 3. The degree of difference in technical capabilities, manufacturing capabilities, and R&D directions	Steven et al., (2014), Bode and Wagner (2015), Brandon-Jones et al., (2015), Gao et al., (2015), Lu and Shang (2017), Sharma, Kumar, et al., (2019), Dong et al., (2020)
Dynamic	1. Our suppliers' lead times are too long compared to our competitor's suppliers 2. We can depend on on-time delivery from suppliers in this supply chain *(Reverse-coded)* 3. The extent to which firms changed suppliers last year	Danese and Romano (2013), Brandon-Jones et al., (2015), Gao et al., (2015), Habermann et al., (2015)
Downstream complexity		
Detail—*numerousness*	1. Number of customers	Bozarth et al., (2009)
Detail—*variety*	1. Heterogeneity of customers 2. We face a high variability of customer requests (quantity, number and types of service/product features, means of delivery, etc.)	Bozarth et al., (2009), Chowdhury (2011)
Dynamic	1. The demand for our plant's products is unstable and unpredictable 2. The percentage of orders that required a customer-motivated scheduling change 3. Short product life cycle	Vachon ahd Klassen (2002), Bozarth et al., (2009), Liu et al., (2012), Chen et al., (2013), Tsai and Yang (2013)
Internal complexity		
Detail—*numerousness*	1. Number of products shipped by plant 2. Number of active parts 3. Number of services	Bozarth et al., (2009), Saldanha et al., (2013), Visnjic et al., (2016)
Detail—*variety*	1. The variety of products produced in our plant is extensive 2. Percentage of products made based on customer specifications 3. We offer our customers direct add-ons and the option of product individualization	Blome et al., (2014), Salvador et al., (2014), Wan et al., (2012), Gray and Handley (2015), Roscoe et al., (2020)
Dynamic	1. Number of items changed per redesign 2. Core production processes change 3. Variations in processing times	Merschmann and Thonemann (2011), Gray and Handley (2015), Van Assen (2018)

studies in a computerized database search as the keywords do not appear in the abstract or title (Rosenbusch et al., 2013). Including studies where SCC dimensions are control variables also enabled us to decrease the likelihood of a potential publication bias, that is, the tendency of journals to mostly publish studies with supported hypotheses (McDaniel et al., 2006; Rosenbusch et al., 2013). In sum, with the manual search, we identified 42 additional articles that fit our sample inclusion criteria.

For a study to be included in our review, it had to meet four main criteria in line with the scope of this research. First, the selected studies must have been empirical and report at least one of the following effect sizes for at least one of our hypotheses: correlation coefficient (r), regression coefficient (B), or path coefficient (γ). Therefore, we excluded conceptual, case study, modeling, and simulation papers as well as those that were not about SCC, resulting in 452 articles remaining. Second, the unit of analysis must be the focal firm. Therefore, studies that examine complexity at the industry, purchased item, NPD project, or dyadic buyer–supplier relationship levels were not included in our sample. Third, the variables of interest must match our conceptualization of the independent and dependent variables (for details, see "Coding" section). Finally, the samples have to be independent. Therefore, we included articles that relied on the same data set or sample as clusters in the meta-analysis rather than

TABLE 2 Measures of firm performance

Constructs	Representative measures	Representative studies
Operational performance		
Cost	1. Unit manufacturing cost, manufacturing overhead cost 2. Administration/warehousing/distribution/ inventory cost	Bozarth et al., (2009), Lorentz et al., (2012), Eckstein et al., (2015), Um et al., (2018)
Quality	1. Quality conformance/product reliability 2. Number of product features 3. Percentage of internal scrap and rework 4. Perceived quality	Caniato and Größler (2015), Gray and Handley (2015), Cheng et al., (2016), Peng et al., (2020)
Delivery	1. Delivery speed, late delivery 2. Delivery reliability 3. Schedule attainment	Vachon and Klassen (2002), Bozarth et al., (2009), Caniato and Größler (2015)
Flexibility	1. Volume flexibility 2. Mix flexibility 3. Adjusting of deliveries to customer changes	Kim and Park (2013), Blome et al., (2014), Cheng et al., (2016), Thome and Sousa (2016), Chaudhuri et al., (2018)
Innovation performance	1. Number of new product/process innovations 2. The speed of new product development 3. On-time product launch 4. Percentage of sales generated by new products or services relative to major competitors	Koufteros et al., (2007), Heim and Peng (2010), Sheng et al., (2013), Caniato and Größler (2015), Delbufalo (2015), Baker et al., (2016), Vickery et al., (2016), Zhou et al., (2019)
Financial performance	1. Return on assets/equity/investment 2. Gross margin 3. Profitability as percentage of sales 4. Tobin's Q	Setia and Patel (2013), Lu and Shang (2017), Srivastava et al., (2017), Chen (2018), Sharma, Kumar, et al., (2019), Dong et al., (2020)

individually. This process resulted in a final data set of 123 articles with 102 independent samples from 39 different journals (See Appendix B).

Coding

We developed a coding protocol to record information regarding the publication details (e.g., authors, journal, year) and meta-analytic analysis inputs (e.g., constructs, operationalizations, effect sizes). Based on this protocol, the first author coded and a graduate student assistant checked all calculation-based information (e.g., effect size, sample size) to reduce the threat of subjectivity (Cao & Lumineau, 2015). Next, for non-calculation-based information (e.g., identifying SCC sub-dimensions, operationalization), two authors double-coded a sample of ten studies. Most of the coding was consistent, and the few remaining differences were resolved via discussion. Based on this coding strategy, double-coding was performed by one of the authors and a graduate student assistant. Initial inter-rater reliability was 90.5% and all differences were resolved via discussion.

Given our intention to explore the potential moderating effects of construct operationalization, we split the three main SCC dimensions (i.e., upstream, internal, and downstream) into two further sub-dimensions as detail and dynamic complexity, in line with the previous conceptualizations (Aitken et al., 2016; Vachon & Klassen, 2002; Wilding, 1998). We defined *detail complexity* as “the distinct number of components or parts that make up a system,” and *dynamic complexity* as “the unpredictability of a system's response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system” (Bozarth et al., 2009, p. 79). Detail upstream complexity refers to the number and heterogeneity of suppliers whereas dynamic upstream complexity refers to long and unreliable supplier lead times and supplier volatility (Bode & Wagner, 2015; Brandon-Jones et al., 2015; Gao et al., 2015). At the downstream level, detail complexity refers to the number and heterogeneity of customers, whereas dynamic complexity refers to demand fluctuations, scheduling changes motivated by customers, and unpredictability of customer needs (e.g., Gao et al., 2015; Vachon & Klassen, 2002). At the internal level, detail complexity refers to the number of SKUs and final product configurations (e.g., Heim & Peng, 2010; Malhotra & Mackelprang, 2012) whereas dynamic complexity refers to process changes and un-level MPS (Gray & Handley, 2015). At the SCC dimension level, we were only able to distinguish between detail and dynamic complexity for investigating the effect of SCC on operational performance, as the number of observations for the sub-groups was not sufficient for investigating innovation performance and financial performance for detail and dynamic complexity separately. However, we relied on the whole set to investigate the overall moderating effect of detail versus dynamic complexity on the relationship between SCC and firm performance.

Table 1 illustrates the representative measures for all SCC sub-dimensions. In a few cases, an overall SCC construct composed of several sub-dimensions was examined (e.g., Birkie et al., 2017; Lam, 2018). Such cases were not part of the sub-group analysis but were included in assessing the performance of effects of overall SCC—as in the main hypotheses.

Regarding performance outcomes, we focused on three categories that are most frequently utilized in SCM research: *operational performance*, *innovation performance*, and *financial performance* (Sharma, Pathak, et al., 2019; Wowak et al., 2013; Zimmerman & Foerstl, 2014). In line with the OM literature, operational performance was further split into four key competitive priorities in post hoc analyses: cost, quality, delivery, and flexibility. In some studies, several operational performance dimensions were included in a single construct operationalization (e.g., Wong et al., 2015). These studies were not included in the sub-group analysis but were part of the overall operations performance analyses. Table 2 illustrates the representative measures for each firm performance dimension.

For both SCC and performance constructs, we required that 75% of the measurement items in a given scale closely match our definitions (Suurmond et al., 2020; Zimmerman & Foerstl, 2014). Finally, we coded study design characteristics as follows: (i) journal ranking—ABS4 or higher vs. lower, (ii) data source—primary or secondary data, (iii) number of industries—single vs. multiple, (iv) number of countries—single vs. multiple, and national culture—Hofstede dimensions (when data were collected from a single country).

Meta-analytic approach

We conducted multivariate and multilevel meta-regression analysis to analyze the effects of SCC on performance (Combs et al., 2019). Similar to most meta-analyses in our field and the social sciences generally, we employed random effects meta-analysis to account for heterogeneity in effect sizes. Before running the analysis, the variance-stabilizing Fisher r-to-z transformation was employed to produce accurate findings even with very large correlation coefficients (close to +1 or −1) and back-transformed into r before reporting (Geyskens et al., 2009). For studies or samples that reported multiple effect sizes, we modeled the interdependency between effects using clustering in the random effects models using a multilevel model (Viechtbauer, 2010). Effects from the same sample were first clustered into a composite effect before running the meta-analysis, but only those individual effects were clustered that are relevant for the specific (sub)hypothesis to be tested. See Supplementary Materials Table S1 for details of our analytical approach.

Based on the analysis of the total set, we performed sub-group analyses to test each hypothesis, using only those effects (clustered into composites when needed) that applied to a specific dimension of SCC, for example, upstream detail complexity (numerousness), and specific dimension of performance, for example, financial performance. While these sub-group analyses provided a preliminary understanding of the heterogeneous nature of the relationship between SCC and performance, a further search for contingency factors using meta-regression was warranted.

Therefore, we performed multivariate meta-regression to uncover moderating effects in our main relationship that single studies cannot adequately detect (cf. Bockstedt et al., 2015; Storey et al., 2016). In particular, the effect sizes (correlation coefficients) are included as a dependent variable in a weighted-least-squares (WLS) regression. The moderating factors were included as independent variables (i.e., explaining variance in effects) and characterize construct operationalizations and study designs.

Publication bias analysis

We assessed the threat of publication bias on the validity of our results from the visual and statistical inspection of a funnel plot. Given that most of our results are centered around zero and include many statistically non-significant effect sizes, no asymmetry appeared in the funnel plot, as shown in Figure 3. An Egger-style analysis was performed (Egger et al., 1997) by running sample size as a predictor of effect size in a meta-regression. If publication bias affected the results of this meta-analysis, a significant negative coefficient would be expected, showing that a small number of studies tend to report larger effects. We found no evidence of publication bias using this analysis, with the reported effect of sample size on effect size very close to zero and insignificant

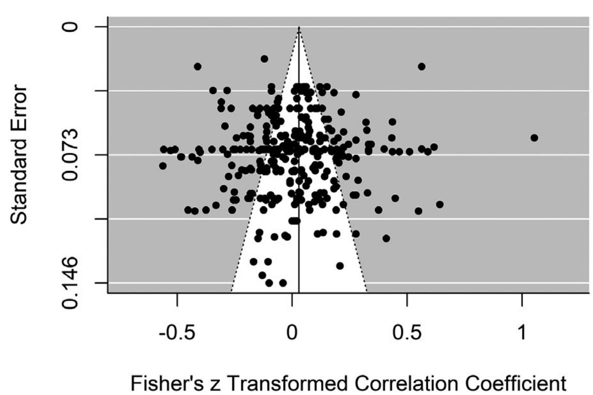

FIGURE 3 Funnel plot

(β = −0.000, p = 0.7995). Other, more traditional, publication bias analyses, such as Rosenthal's failsafe number are not applicable to a multilevel multivariate meta-regression model. In conclusion, we did not find evidence that publication bias affects the validity of our findings.

RESULTS

To probe the association between SCC and firm performance, we conducted a meta-analysis on the total set of 313 effects from 102 independent samples, for a total of 27,668 observations accumulated from prior research. The results are presented in Table 3. The meta-analytic correlation coefficient for a given hypothesis is shown as r with its 95% confidence interval (used for testing the hypotheses on the average effect) and 95% credibility interval (used for predicting the range of true effect sizes among the studies). Table 3 further illustrates the number of effect sizes (s), the number of independent samples (k), and the total number of observations (N) for each hypothesis. Finally, a test of heterogeneity (Q) for each relationship is presented, where a significant result indicates the need to search for moderators and other explanations of differences between studies. Supplementary Materials Figure S1 presents a Forest Plot of the overall analysis.[3]

In line with our main hypotheses, we first tested the effect of SCC on three performance dimensions—operational performance, innovation performance, and financial performance. Next, we tested the sub-hypotheses to investigate distinctive effects of different dimensions of SCC.

SCC and operational performance

The results indicate a significant negative relationship between SCC and operational performance (r = −0.083), supporting H1. As a post hoc analysis, we assessed four subdimensions of operational performance, that is, cost, quality, delivery, and flexibility and found significant negative effects for *cost* (r = −0.141) and *delivery* (r = −0.135). These findings reinforce the view that complexity in the supply chain increases firms' operational burdens (Brandon-Jones et al., 2015; Choi & Krause, 2006).

TABLE 3 Meta-analysis results

	s	(*k*)	*N*	*r*	Confidence interval		Credibility interval		Q
H1: Operational performance	163	(48)	13,621	−0.083	−0.131	−0.034	−0.381	0.232	1134.06*
Cost	25	(11)	2,947	−0.141	−0.258	−0.019	−0.497	0.256	127.98*
Quality	18	(9)	2,428	−0.061	−0.138	0.017	−0.270	0.153	64.96*
Delivery	42	(9)	2,740	−0.135	−0.254	−0.012	−0.473	0.237	403.31*
Flexibility	11	(7)	1,925	0.034	−0.058	0.125	−0.197	0.261	78.23*
H1a: Upstream complexity	48	(16)	4,397	−0.149	−0.202	−0.095	−0.340	0.053	303.91*
Detail complexity	32	(14)	4,051	−0.128	−0.180	−0.076	−0.300	0.051	123.04*
Dynamic complexity	13	(3)	581	−0.248	−0.379	−0.107	−0.482	0.020	56.39*
H1b: Downstream complexity	32	(13)	6,340	−0.058	−0.143	0.028	−0.339	0.232	227.41*
Detail complexity	9	(4)	562	0.063	−0.080	0.203	−0.209	0.326	17.98*
Dynamic complexity	23	(10)	5,987	−0.090	−0.174	−0.005	−0.340	0.171	156.50*
H1c: Internal complexity	70	(25)	5,273	−0.061	−0.143	0.022	−0.429	0.325	422.29*
Detail complexity	43	(16)	3,170	−0.066	−0.151	0.020	−0.374	0.255	188.49*
Dynamic complexity	17	(8)	2,366	−0.033	−0.170	0.106	−0.406	0.349	159.80*
H2: Innovation performance	44	(25)	7,478	0.171	0.105	0.234	−0.144	0.454	1249.82*
H2a: Upstream complexity	13	(4)	770	0.113	−0.089	0.307	−0.318	0.505	112.44*
H2b: Downstream complexity	18	(15)	5,394	0.187	0.071	0.299	−0.262	0.562	644.87*
H2c: Internal complexity	10	(7)	3,247	0.138	−0.036	0.303	−0.327	0.548	271.06*
H3: Financial performance	106	(55)	12,354	0.078	0.033	0.122	−0.226	0.368	939.92*
H3a: Upstream complexity	16	(8)	2,630	0.063	−0.110	0.232	−0.416	0.515	167.47*
H3b: Downstream complexity	46	(32)	7,682	0.050	−0.003	0.103	−0.218	0.311	265.74*
H3c: Internal complexity	40	(22)	4,176	0.098	0.032	0.165	−0.185	0.367	390.09*

s = number of effect sizes; k = number of independent samples; N = total sample size (sum over independent samples); r = meta-analytic correlation coefficient; confidence interval is the 95% probability range for observing this meta-analytic correlation coefficient; credibility interval = 95% probability range for observing an individual effect size; Q = Chi-square heterogeneity statistics with * indicating statistical significance of this parameter at $\alpha < 0.05$.

At the SCC dimension level, the results indicate a significant negative relationship between upstream complexity and operational performance ($r = -0.149$), supporting H1a. Significant negative effects were observed for both detail complexity ($r = -0.128$) and dynamic complexity ($r = -0.248$). While the extant literature reports mixed results about the effect of detail upstream complexity, our findings illustrate a dominant negative effect. A large number of suppliers might provide flexibility to the firm in case of shortages or disruptions (Birkie & Trucco, 2020), but transaction costs associated with managing a large and varied supply base increase outweigh these benefits.

Regarding downstream complexity, we found a significant, negative effect on operational performance only for dynamic complexity ($r = -0.090$), thus providing partial support for H1b. These results illustrate that having a large and varied customer base does not deteriorate operational performance per se. Rather, unstable and unpredictable demand brings operational challenges. Increased demand uncertainty necessitates frequent scheduling changes and adjusting production to short product life cycles (Bozarth et al., 2009), which may hamper operational performance.

Contrarily, although we observed a negative effect of internal complexity, this effect was not significant, and thus H1c was not supported. Overall, these findings suggest that firms cope with operational challenges of internal complexity better than external complexity. In many cases, internal complexity is the direct result of deliberate product-specific goals (e.g., having a large variety of products to penetrate a market). However, firms are more vulnerable to external complexity where they have less control.

SCC and innovation performance

Our findings also reveal an overall significant, positive relationship between SCC and innovation performance ($r = 0.171$), supporting H2. This result aligns with the knowledge-based view (KBV) which suggests that access to a large number of varied knowledge resources increases the likelihood of generating innovative outputs (Choi & Krause, 2006).

At the SCC dimension level, while all effects were positive, only the effect of downstream complexity was significant ($r = 0.187$), which supports H2b. The effect sizes for upstream complexity and internal complexity were not negligible ($r = 0.113$ and $r = 0.138$, respectively). Therefore, the lack of significant results may be partly explained by the low number of observations. Nonetheless, the results suggest that a large, varied, and dynamic customer base can be a source of innovation for the firm, for instance by soliciting a diverse set of customer inputs in an NPD project (Chang & Taylor, 2017), or by promoting to address the needs of a diverse set of customers.

SCC and financial performance

In contrast to the negative relationship stipulated in Hypothesis 3, we found a significant, positive relationship between SCC and financial performance ($r = 0.078$). Although previous studies highlight both negative and positive effects of SCC on financial performance (e.g., Lu & Shang, 2017), our findings suggest that the preponderance of evidence supports the latter view. While SCC can pose operational challenges and hence increase costs, financial gains —such as the ones accrued from increased innovation— may offset these negative effects. At the SCC dimension level, while all effects were positive, only the effect of internal complexity was significant ($r = 0.098$). These findings further support the view that product variety increases complexity, but also fosters sales growth (Eckstein et al., 2015). However, having a diverse set of suppliers and customers operating in a dynamic environment does not appear to be associated with an increase in financial performance. This result may stem from the more pronounced detrimental effects of external complexity on operational performance, which increases coordination costs extensively and reduces financial gain.

Additional analyses

Table 4 presents the meta-regression results, which provides additional evidence for our meta-analysis findings. Specifically, meta-regression was employed (i) as a robustness check, to test the relationship between SCC and performance and to compare effect sizes, and (ii) to provide exploratory evidence for potential contingency effects of theoretical (construct operationalizations) and methodological (study design characteristics) moderators. The intercept in the meta-regression represents the "baseline" effect, that is, the average correlation coefficients with moderators held constant, while the remaining coefficients indicate the change in correlation coefficient compared to this baseline. A significant regression coefficient indicates a significant departure from the baseline—not a statistically significant correlation coefficient for a particular level of the moderator in and of itself (those are reported in Table 3). The baseline represented by the intercept applies to the relationship between upstream complexity and operational performance, with all other moderators included in the models held at zero. Continuous moderators, for example, cultural dimensions, were standardized (scaled and centered) before inclusion. We conducted three meta-regressions, as follows.

TABLE 4 Meta-regression results

	Model 1	Model 2	Model 3
	All data	**Research design**	**National culture**
Intercept	−0.323 (−0.386; −0.261)	−0.336 (−0.501; −0.170)	−0.339 (−0.448; −0.230)
Performance (vs. Operational)			
Financial	0.232 (0.149; 0.315)	0.285 (0.179; 0.391)	0.278 (0.158; 0.398)
Innovation	0.325 (0.213; 0.437)	0.342 (0.195; 0.489)	0.366 (0.217; 0.516)
SCC main dimensions (vs. Upstream)			
Downstream complexity	0.051 (0.022; 0.080)	0.024 (−0.007; 0.055)	−0.065 (−0.110; −0.021)
Internal complexity	0.142 (0.115; 0.169)	0.123 (0.094; 0.153)	0.202 (0.157; 0.247)
SCC sub-dimensions (vs. Dynamic)			
Detail complexity	0.216 (0.192; 0.241)	0.247 (0.220; 0.273)	0.273 (0.223; 0.323)
Research design			
ABS4 and up vs. lower		−0.061 (−0.099; −0.024)	
Data: Primary vs. secondary		−0.001 (−0.137; 0.136)	
Data: Single vs. multiple countries		0.018 (−0.096; 0.131)	
Data: Single vs. multiple industries		0.005 (−0.151; 0.162)	
National culture			
Power distance			−0.092 (−0.193; 0.010)
Uncertainty avoidance			−0.089 (−0.181; 0.002)
Individualism			−0.294 (−0.479; −0.109)
Masculinity			0.047 (−0.021; 0.115)
Long-term orientation			−0.156 (−0.308; −0.005)
Number of effects (samples)	272 (89)	220 (70)	168 (65)
Residual heterogeneity (Q_e)	2601.07 ($p < 0.001$)	2013.03 ($p < 0.001$)	1495.42 ($p < 0.001$)
Test of moderators (Q_r)	619.50 ($p < 0.001$)	613.19 ($p < 0.001$)	676.34 ($p < 0.001$)

Model 1 provides further evidence of the heterogeneous nature of the relationship between SCC and performance. First, we found significant differences between the dimensions of performance, with innovation performance and financial performance exhibiting more positive effect sizes than operational performance. Second, we found significant differences between SCC dimensions, with downstream and internal complexity having significantly more positive effect sizes than upstream complexity (which is negatively related to performance). Finally, we confirmed a significant difference between sub-dimensions of SCC, with detail complexity exhibiting a more positive effect (i.e., a smaller negative effect) than dynamic complexity, suggesting that firms should prioritize managing the detrimental effects of dynamic complexity. Overall, these findings highlight the need to have a comprehensive conceptualization of both SCC and performance to disentangle varying effects.

Model 2 includes explanatory variables related to research design. We found that effect sizes of research published in journals with an "ABS4 and higher" ranking were significantly larger (i.e., larger negative effects, as the intercept is already negative) than effects reported in lower tier journals. This result is surprising, as more reputable journals are generally considered to report smaller effects (Heugens & Lander, 2009; Suurmond et al., 2020). We did not find any differences in effects between primary and secondary data, single or multiple countries of data collection, or single or multiple industries for data collection.

Finally, Model 3 includes five Hofstede dimensions in the subset of studies where data were collected from a single country. We found that SCC has a more detrimental impact on performance in cultures that are more individualistic and more long-term oriented. Cultures with a long-term orientation might have difficulties in coping with uncertainty over a long period whereas collaborative cultures might be better in managing complexity by adopting cooperative and team-based efforts across the supply chain. While we did not have a priori expectations regarding the role of national culture, our results illustrate the need to consider contextual contingencies.

DISCUSSION

As supply chains become increasingly complex, researchers and practitioners seek to understand SCC and its performance implications (Bode & Wagner, 2015; Huaccho Huatuco et al., 2020). In the present research, we sought to answer a fundamental question: *What is the impact of SCC on firm performance?* The extant empirical evidence on this question is scattered and equivocal. To address this gap, we adopted a meta-analytic approach to derive the most recent and complete evidence-based picture of SCC's impact on firm performance.

The contributions of this study are two-fold. First, we found that SCC is not always detrimental and its effects vary by the type of performance. While previous research mainly theorized a negative impact of SCC on firm performance, our findings suggest SCC can be both dysfunctional and strategic (e.g., Aitken et al., 2016; Serdarasan, 2013; Turner et al., 2018). Specifically, we found that while SCC has a negative effect on operational performance, it can also have positive effects on both innovation and financial performance. These results indicate an inherent trade-off across performance dimensions that researchers and practitioners need to deliberately take into account. Second, by investigating the dimensions of SCC—upstream, downstream, and internal—as well as moderators (i.e., construct operationalization and study design characteristics), we contribute to the literature by disentangling distinct effects and highlighting boundary conditions. In the next sections, we elaborate on these nuanced findings, discuss the implications for theory and practice, state the limitations, and propose a research agenda.

Theoretical implications

A summary of the findings from this research is provided in Table 5. We found SCC to negatively affect operational performance, primarily in terms of cost and delivery. This effect was more evident for upstream complexity, observed for both detail and dynamic complexity, whereas at the downstream level only dynamic complexity had a negative effect. In contrast, internal complexity was not associated with lower operational performance. Thus, firms have more difficulty coping with external sources of complexity than internal complexity.

These results are in line with the predictions of TCE. Large and heterogeneous supply bases create higher coordination needs with and between suppliers, cause greater operational loads, and increase the severity of supply disruptions (Bode & Wagner, 2015; Choi & Krause, 2006; Wiedmer *et al*., 2021). In turn, these factors create higher transaction costs for the firm. Additionally, the uncertainty and volatility originating from suppliers and/or customers further increase coordination costs and worsen control. In such cases, firms might aim for mitigating the detrimental effects, for instance by trying to improve supply chain visibility (Brandon-Jones et al., 2015).

In contrast to operational performance, we found that SCC is positively associated with innovation performance. This finding is in line with the core tenets of KBV, which proposes that access to each additional and varied actor in the network (i.e., high detail complexity) increases the likelihood of generating innovation (Bellamy et al., 2014; Choi & Krause, 2006). Although our results indicate a significant effect only for downstream complexity, the effects for upstream complexity and internal complexity were also positive, albeit not significant, possibly due to low sample size.

Downstream complexity can increase innovation performance in two ways. First, in a B2B context, access to a large and varied customer base with unique assets and skills increases the likelihood of finding capable customers to provide innovative ideas. Second, in both B2B and B2C contexts, varying needs and requirements of customers (i.e., high dynamic complexity) triggers the firm to be more innovative. The significant positive effect of downstream complexity matches Chesbrough's (2011) open innovation-based observation that value creation is an iterative process. Through customer engagement, tacit knowledge is exchanged both outside-in and inside-out, a process of value co-creation and innovation generation.

It is interesting to note that we did not observe a similar effect for upstream complexity. While the involvement of suppliers in NPD is an established research stream (Luzzini et al., 2015; Suurmond et al., 2020), SCM literature mostly focuses on NPD projects or specific (strategic) buyer–supplier relationships as units of analysis. Therefore, our understanding regarding the impact of the overall supply base as a source of innovation is rather limited. A possible explanation for the non-significant effect of upstream complexity on innovation

TABLE 5 Summary of findings

	Operational performance	Innovation performance	Financial performance
Overall SCC	**Negative effect** (*Cost*, *Delivery*)	Positive effect	Positive effect
Upstream	**Negative effect** (*Detail* and *Dynamic* complexity)	Not significant	Not significant
Downstream	Negative effect (*Dynamic* complexity)	**Positive effect**	Not significant
Internal	Not significant	Not significant	**Positive effect**

performance is that operational challenges may offset the benefits. For instance, a large supply base might make it more difficult to sufficiently allocate limited resources across several NPD projects with suppliers. Furthermore, a highly volatile supply base can pose operational challenges that negate the benefits from joint innovation, leading to a null net effect. Recent evidence supports this observation and warns against the detrimental effects of excessive levels of upstream complexity for innovation (Sharma, Pathak, et al., 2019). In addition, the scarcity of studies at the supply base level limits the power of statistical tests.

In contrast to operational performance, we found that SCC is positively associated with financial performance, primarily stemming from internal complexity. These findings corroborate Aitken et al., and's (2016) assertion that SCC is not always dysfunctional but can be strategic. That is, firms may need to absorb the negative operational consequences of SCC to deploy more sophisticated business strategies. For instance, firms with high product variety may satisfy a variety of customers with different preferences, hence increasing sales and profits (Wan et al., 2012). Positive, albeit not significant, effects were observed for upstream and downstream complexity, suggesting that costs stemming from operational load and control may outweigh the benefits, resulting in lower financial gains. Previous research often reports mixed findings regarding the effect of SCC on financial performance; yet, our meta-analysis suggests that the overall evidence seems to favor the positive effect view.

Finally, the results of the meta-regression confirmed that construct operationalization and study design characteristics moderate the relationship between SCC and performance. For instance, we found that dynamic complexity is more detrimental than detail complexity. While we did not find any differences between single versus multiple country/industry studies, our results suggest that national culture impacts the effect of SCC on performance. This result may be due to differences regarding how SCC is perceived or the types of SCC management practices (i.e., reactive vs. proactive) adopted across countries. All in all, these results suggest the need to take into account the contingencies in the SCC–performance relationship.

In sum, our meta-analysis distinguishes between types of both SCC and performance as well as contingency factors. SCC is not always detrimental and there are trade-offs across performance dimensions.

Managerial implications

This study holds several essential implications for supply chain managers regarding SCC. First, our results indicate that SCC has varying effects on firm performance, and hence it deserves managers' deliberate attention. Although the importance of SCC is widely acknowledged, strategies and practices regarding how to effectively manage SCC are seldom integrated in corporate agendas (Aitken et al., 2016; Turner et al., 2018). At best, a fragmented approach is adopted where only some sub-dimensions of SCC (e.g., demand volatility or number of suppliers) are assessed and managed separately without an overall evaluation of SCC. For example, supply base reduction has been a go-to approach for addressing complexity for decades, even though the articulated goal has typically been cost reduction (Tully, 1995). However, managers should realize that SCC is a multidimensional concept affecting several business functions (i.e., production, supply chain, sales, R&D). Thus, while individual managers may have limited ability to directly influence SCC, especially in the short-term, managers should be cognizant of the trade-offs between SCC levels and different aspects of performance. These trade-offs suggest the need for a comprehensive and cross-functional approach to managing SCC.

Second, our study contributes to a better understanding of which SCC sources need to be absorbed versus reduced (Aitken et al., 2016). Supply chain managers should be conscious of the detrimental operational performance effects of SCC and implement systems that extend their operational control beyond the focal firm's boundaries (Maestrini et al., 2017) to minimize disruptions and maintain customer service. Within an increasingly globalized business environment, the temptation to work with a larger and more diverse supply base increases, especially under competitive pressures for cost reduction. Similar issues may surround the search for new customers and the activation of multiple sales channels, that is, downstream complexity. However, our results suggest that in order to preserve operational performance, supply chain managers should take specific actions when the number and variety of suppliers increases, as well as when more uncertainty and volatility characterize upstream and downstream relationships. These situations are further exacerbated by environmental conditions, such as the recent outbreak of the coronavirus. In this regard, SCM literature is clear about the need to focus on relation-specific investments and to collaborate with a few strategic suppliers (Wynstra & Ten Pierick, 2000). However, this approach should incorporate knowledge of each firm's complexity sub-dimensions. For example, is supplier diversity a primary cause? If so, is the diversity a factor of variability in size of suppliers, geographical dispersion, language or cultural differences, or other factors? For supply chain managers, identifying what drives complexity is an important prerequisite to effectively manage complexity.

Despite the negative effects on operational performance, supply chain managers should not lose sight of the fact that SCC can have a strategic effect on the firm by improving innovation and financial performance. Complex supply chains with more diverse sources of knowledge are favored in an open innovation paradigm (Chesbrough, 2020), which leverages the knowledge of supply chain members to create new products and services (Bogers et al., 2019). Examples include Lego's Mindstorms project (Afari & Khine, 2017) and DHL's Parcelcopter project (DHL, 2020).

Similarly, since we illustrate that SCC improves financial performance, supply chain managers should not, for example, aim to reduce product variety or the number of suppliers purely for operational reasons. These decisions should be guided by the firm's business strategy. If firms emphasize a cost leadership strategy, reducing SCC might be preferred. Contrarily, pursuing an innovation strategy might necessitate absorbing SCC to benefit from the knowledge emanating from a diverse set of actors and require firms to reduce transactions costs with appropriate governance mechanisms such as supply chain integration (Leuschner et al., 2013).

Finally, our study sheds light on the importance of adjusting SCC management strategies to different country contexts. Supply chain managers in countries with more individualistic or long-term-oriented cultures might pay more attention to mitigating the negative effects of SCC, as our results indicate a higher negative impact in such countries.

Limitations

As with any other research, this study has limitations. First, despite adopting a broad set of search terms that took into account related terminologies and sub-dimensions of SCC, we may not have identified all relevant articles. However, publication bias analysis illustrates that it is unlikely the results would change. Second, meta-analysis enables us to only examine linear effects; therefore, there is a need for further investigation of non-linear effects. Third, although we were able to examine heterogeneity by investigating several moderators, we did not have enough observations for some subgroups, such as the link between downstream complexity and sub-dimensions of operations performance, which prevented us from drawing further conclusions. Notwithstanding these limitations, this study paves the way for further research about SCC by quantitatively synthesizing a large number of studies, highlighting the need to investigate dimensions of SCC and performance, and illustrating both negative and positive effects.

A research agenda for supply chain complexity

Meta-analysis enables researchers to identify gaps in the extant literature and provide avenues for future research (Wowak et al., 2013). Based on our meta-analysis of the current state of science, we provide a research agenda for future SCC research. We group our suggestions in terms of *under-investigated relationships and extensions*, *theoretical development*, *data*, and *the nature of complexity*. We hope this overview will inspire fellow researchers to fill these gaps.

Under-investigated relationships and extensions

Despite the growing interest in SCC, we observed that some SCC–performance relationships remain rather an untouched territory. These include the effects of upstream dynamic complexity, downstream detail complexity, and internal dynamic complexity on performance. Furthermore, during our database search, we identified only a few studies focusing on more contemporary aspects of performance such as sustainability and resilience. Clearly, sustainability and resilience are top-of-mind concerns given climate change and the COVID pandemic. Empirical research on these relationships can provide a more comprehensive picture of the performance implications of SCC. Additionally, we identified some potential extensions that may add further insights on the link between SCC and performance. First, scholars may focus on the mechanisms that create the effect (i.e., intervening variables). Obviously, our meta-analysis only illustrates the direction and magnitude of the effect; yet, it is not capable of answering why and how these effects take place. Second, as we observe both positive and negative effects, future research should investigate how firms might balance extant trade-offs. This links to a third important issue: how SCC is managed. The heterogeneity observed in performance effects might also stem from the different approaches to managing complexity (e.g., proactive vs. reactive). Fourth, studies adopting more complex conceptual models that investigate not only the direct effects but also the interactions between SCC dimensions would enrich our understanding of the overall effects of SCC. Finally, the role of contingencies such as national culture, firm size, or product characteristics need to be investigated. Table 6 provides specific research questions in each of the areas discussed above.

Theoretical development

We observed that most SCC studies increasingly rely on sophisticated data analysis. However, these developments have not been accompanied by a parallel development of theory. In fact, most studies either do not refer to any specific theory or just adapt grand theories such as TCE or generic social network arguments. Our results reinforce SCC as an umbrella construct with important sub-constructs. Future SCC studies could advance theory by focusing on specific levels or dimensions of SCC and their relationships to specific

TABLE 6 Directions for future SCC research

Area of investigation	Explanation	Future research questions
Under-researched SCC–performance relationships	We found a limited number of studies examining specific SCC–performance relationships (e.g., upstream dynamic, downstream detail and internal dynamic complexity). We also found a limited breadth of dependent variables.	What is the effect of SCC on performance? For example: • What is the impact of number and variety of customers on operational performance? • What is the impact of process variety on financial performance? • Does supplier volatility harm innovation performance? • Is a large and varied supply base a threat or an asset for sustainability?
Mechanisms explaining SCC effects	Although our meta-analysis enabled us to identify the direct effects of SCC, we are not able to illustrate the intervening mechanisms.	• How does SCC improve or hinder performance? • What are the intervening variables in the SCC–performance relationships?
Balancing positive and negative effects of SCC	Our results suggest that SCC is not always detrimental.	• How can firms balance the negative (i.e., operational) and positive (i.e., innovation) effects of SCC? • What kind of practices and capabilities can help solving the trade-offs related to SCC?
Managing SCC	The heterogeneity of results across studies suggests that firms might have different approaches to manage SCC. Overall, the literature suggests that very few firms integrate a complexity perspective in their supply chain planning.	• What type of proactive or reactive practices are used to manage SCC? • What are the moderating factors that enable exploiting the positive effects and mitigating the negative effects of SCC?
Interactions between SCC dimensions	There are very few studies that empirically test the interaction between SCC dimensions.	• Do interactions between upstream, downstream and internal complexity reduce or increase overall SCC? • Does dynamic complexity amplify the effects of detail complexity?
SCC in different contexts	Although we found no differences between single vs. multiple country/industry contexts, we found that national culture plays a role. Other contingencies might also be taken into account, such as firm size or product characteristics.	• Do collectivist cultures cope with SCC more effectively than individualistic cultures? • Do cultures with a long-term orientation adopt more proactive approaches to manage SCC? • Are large firms affected more by SCC compared to SMEs? • Do product characteristics interact with SCC and its outcomes?

aspects of performance. For example, a firm may have a very complex supply base and a much less complex customer base, or vice versa. The salient sub-dimensions of complexity may differ between a company's supply base and its customer base. Theoretical frameworks that distinguish among these constructs and better define their inter-relationships can increase our understanding of SCC. Therefore, we call for more theorizing around the specific dimensions/levels of SCC to develop a better understanding about its antecedents, consequences, mechanisms, and contingencies. On a much-related note, complexity is often used as a control variable in empirical studies because it is presumed to explain differences in performance (Brandon-Jones, Squire, & van Rosenberg, 2015). Our meta-analysis illustrates that rather than approaching SCC as a default control variable, scholars need to further distinguish between types of SCC for more meaningful analyses and theorize accordingly.

Data

Despite being surrounded by "big data" and having sophisticated econometric models that allow researchers to analyze supply chain variables using a variety of proxies from large archival data sets, SCC studies still suffer—as admitted by the researchers—from lack of reliable data. Getting direct information about companies' supply chains is not easy. Partial data allowing researchers to reconstruct supply chains and networks are available, but they require expensive licenses and have limitations such as representativeness and missing data. Our meta-analysis article set illustrates an upsurge in recent years regarding the use of secondary data[4]; however, the meta-regression results did not reveal any differences between studies using primary versus secondary data (see Table 4). Accordingly, we suggest that researchers carefully assess the pros and cons of primary versus secondary data for investigating performance implications of SCC, while we emphasize the need for reliable and valid measures of the constructs of interest.

The nature of complexity

Despite the fact that we have long-known supply chains are networks (Choi et al., 2001), scholars have recently begun to empirically examine structural supply chain characteristics through network analysis (Sharma, Kumar, et al., 2019). For the purposes of a meta-analysis, the limited number of studies at the network level do not yet suffice; however, it is plausible to expect more network studies in the near future. While the term "supply chain" will probably remain dominant, the conceptualization of supply chains has evolved in the last decades from primarily focusing on focal firms, then on dyadic buyer–supplier relationships, multi-tier chains, and finally on complex networks. Contemporary supply chains are embedded in networks made of vertical and horizontal relationships, up to the point that is not always easy to decouple a single focal firm's supply chain, due to the high degree of connectedness, dependence, and influence of network relationships across different supply chains. Distinguishing upstream, downstream, and internal complexity still makes sense, as these units of observation maintain peculiar characteristics. Nonetheless, we believe it would be worthwhile to provide an integrative view that acknowledges network-based conceptualizations and measures of complexity.

CONCLUSION

Supply chain complexity is considered one of the most pressing issues for contemporary supply chains. Reviewing and analyzing prior empirical research, this study finds that SCC is not always detrimental. While supply chain managers have perhaps unintentionally addressed SCC in recent decades by rationalizing their supply chains to reduce transaction costs, our results suggest that managers should adopt a holistic view and consider the varying effects of SCC dimensions on different performance outcomes. Companies that seek to measure, monitor, and manage SCC may find that such efforts enhance their ability to compete. We hope the results of our meta-analysis motivate new research in this area.

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ENDNOTES

[1] https://www.ft.com/content/2cf5bebe-9773-11e5-9228-87e603d47bdc

[2] https://www.forbes.com/sites/benjaminlaker/2020/09/07/why-organizations-need-to-manage-supply-chain-risk-today/#2fae6edc3b74

[3] Supplementary Materials files are available on http://dx.doi.org/10.17605/OSF.IO/73ZGC

[4] In 2002, 18 out of 19 effect sizes stem from primary data collection. In 2020, instead, 12 out of 18 used secondary data for the results.

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APPENDIX A

Meta-analysis Search String

“Supply chain complexity” OR “Supply network complexity” OR “Supply base complexity” OR “Supply network structure” OR “Supply complexity” OR "Dynamic complexity" OR "Structural complexity" OR “Upstream complexity” OR “Sourcing complexity” OR “Number of suppliers” OR “Horizontal complexity” OR “Supply base rationalization” OR “Supply base reduction” OR “Supply base size” OR “Supply network size” OR “supply chain size” OR “Spatial complexity” OR “Supplier geographical dispersion” OR “Geographical dispersion” OR “Supplier differentiation” OR “Supplier heterogeneity” OR “Delivery complexity” OR “Delivery reliability” OR “Delivery uncertainty” OR “Supplier lead time” OR “Downstream complexity” OR “Number of customers” OR “Customer heterogeneity” OR “Demand variability” OR “Demand uncertainty” OR “Customer variability” OR “Demand heterogeneity” OR “Demand fluctuation” OR “Demand variation” OR “Demand volatility” OR “Environmental complexity” OR “Environmental dynamism” OR "Demand risk" OR “Market turbulence” OR “Internal complexity” OR “Manufacturing complexity” OR “Manufacturing heterogeneity” OR “Number of parts” OR “Number of products” OR “Number of processes” OR “Product complexity” OR “Process complexity” OR “Product standardization” OR “Process standardization” OR “Product variety” OR “Process variety” OR “Product customization” OR “Process customization”

APPENDIX B

Articles in Meta-analysis

A_ID	S_ID	J	Authors/Year	N	Relations	Country	Industry	Data
A001	S001	J12	Akgün and Keskin (2014)	112	BIJ	Turkey	BOTH	PRIM
A002	S001	J27	Akgün et al., (2008)	112	BJ	Turkey	BOTH	PRIM
A003	S002	J28	Akgün et al., (2012)	153	BI	Turkey	BOTH	PRIM
A004	S003	J26	Azadegan et al., (2013)	124	DJ	USA	MANF	BOTH
A005	S004	J28	Baker et al., (2016)	1978	BCI	USA	BOTH	PRIM
A006	S005	J23	Bevilacqua et al., (2017)	254	ACJ	Italy	MANF	PRIM
A007	S006	J11	Blome et al., (2014)	141	ACH	Germany	BOTH	PRIM
A008	S007	J05	Bode and Macdonald (2017)	438	ACK	Multiple	MANF	PRIM
A009	S008	J26	Bode and Wagner (2015)	396	ADK	Multiple	MANF	PRIM
A010	S009	J26	Bozarth et al., (2009)	209	ABCEGK	Multiple	MANF	PRIM
A011	S010	J12	Brandon-Jones et al., (2015)	264	AK	UK	MANF	PRIM
A012	S011	J36	Caniato and Größler (2015)	725	CEFGHI	Multiple	MANF	PRIM
A013	S012	J19	Chaudhuri and Boer (2016)	343	CK	Multiple	MANF	PRIM
A014	S012	J10	Chaudhuri et al., (2018)	343	DH	Multiple	MANF	PRIM
A015	S013	J10	Chen (2018)	106	BJ	Taiwan	BOTH	PRIM
A016	S014	J26	Chen et al., (2004)	221	AJ	USA	MANF	PRIM
A017	S015	J12	Chen et al., (2013)	203	BK	Not reported	MANF	PRIM
A018	S016	J11	Chen et al., (2016)	170	BI	Taiwan	SERV	PRIM
A019	S017	J07	Chen et al., (2018)	176	BJ	China	MANF	PRIM
A020	S018	J17	Chen et al., (2019)	288	BIJ	China	BOTH	PRIM
A021	S012	J38	Cheng et al., (2016)	606	DFGH	Multiple	MANF	PRIM
A022	S019	J18	Chowdhury (2011)	134	BJ	USA	BOTH	BOTH
A023	S009	J34	Danese (2013)	186	AGHK	Multiple	MANF	PRIM
A024	S009	J06	Danese and Filippini (2012)	201	BI	Multiple	MANF	PRIM
A025	S009	J10	Danese and Romano (2013)	200	AK	Multiple	MANF	PRIM
A026	S020	J31	Delbufalo (2015)	210	AI	Italy	MANF	BOTH
A027	S021	J10	Doll et al., (2010)	205	CE	Multiple	MANF	PRIM
A028	S022	J26	Dong et al., (2020)	753	AJK	USA	MANF	SECN
A029	S023	J37	Dowell (2006)	184	CJ	USA	MANF	SECN
A030	S024	J02	Dubey et al., (2020)	312	CE	India	MANF	PRIM
A031	S006	J12	Eckstein et al., (2015)	116	CEK	Germany	BOTH	PRIM
A032	S025	J12	Flynn and Flynn (2005)	164	AG	Multiple	MANF	PRIM
A033	S026	J26	Gao et al., (2015)	202	ABI	China	MANF	PRIM
A034	S027	J12	González-Zapatero et al., (2020)	106	AK	Portugal	NREP	PRIM
A035	S028	J26	Gray and Handley (2015)	106	CF	Not reported	MANF	PRIM
A036	S029	J39	Gupta et al., (2018)	154	AJ	India	SERV	PRIM
A037	S030	J05	Habermann et al., (2015)	108	AK	Not reported	MANF	PRIM
A038	S031	J38	Hallavo (2015)	769	BJK	Russia	MANF	PRIM
A039	S028	J05	Handley and Gray (2015)	106	CF	Not reported	MANF	PRIM
A040	S009	J26	Heim and Peng (2010)	238	CFHI	Multiple	MANF	PRIM
A041	S032	J10	Helkiö and Tenhiälä (2013)	151	CEFG	Finland	MANF	PRIM
A042	S011	J36	Hong and Lefakis (2017)	382	BCK	Multiple	MANF	PRIM

A_ID	S_ID	J	Authors/Year	N	Relations	Country	Industry	Data
A043	S033	J11	Hsiao et al., (2010)	114	BDK	Multiple	MANF	PRIM
A044	S034	J31	Huang et al., (2018)	217	BI	China	MANF	PRIM
A045	S035	J15	Iyer (2014)	115	CK	Not reported	MANF	PRIM
A046	S036	J08	Iyer et al., (2009)	152	BJK	USA	MANF	PRIM
A047	S035	J25	Iyer et al., (2014)	115	CK	USA	MANF	PRIM
A048	S037	J39	Jeble et al., (2018)	205	AE	India	MANF	PRIM
A049	S038	J29	Kim (2017)	717	BJ	USA	BOTH	SECN
A050	S039	J12	Kim and Park (2013)	193	DFHIJ	Korea	MANF	PRIM
A051	S040	J26	Koufteros et al., (2007)	157	AFI	USA	MANF	PRIM
A052	S041	J26	Kovach et al., (2015)	165	CJ	USA	MANF	PRIM
A053	S042	J26	Kristal et al., (2010)	174	BJ	USA	MANF	PRIM
A054	S043	J10	Lam (2018)	57	DK	Netherlands	BOTH	SECN
A055	S044	J26	Lampel and Giachetti (2013)	260	CJ	Multiple	MANF	BOTH
A056	S045	J07	Land et al., (2012)	675	BI	Multiple	BOTH	PRIM
A057	S046	J07	Li and Sheng (2011)	289	BJ	China	MANF	BOTH
A058	S047	J11	Li et al., (2013)	290	CI	China	MANF	PRIM
A059	S048	J10	Li et al., (2015)	76	BDJ	USA	MANF	PRIM
A060	S049	J20	Lin and Germain (2004)	205	BCJ	China	MANF	PRIM
A061	S009	J05	Liu et al., (2012)	266	BDF	Multiple	MANF	PRIM
A062	S050	J15	Liu et al., (2019)	201	BI	China	NREP	PRIM
A063	S051	J20	Lorentz et al., (2012)	95	AEGJ	Finland	MANF	PRIM
A064	S052	J09	Lorentz et al., (2016)	551	AK	Finland	BOTH	PRIM
A065	S053	J26	Lu and Shang (2017)	867	ABCJ	USA	BOTH	SECN
A066	S054	J26	Malhotra and Mackelprang (2012)	158	CG	USA	MANF	PRIM
A067	S055	J33	Masini and Van Wassenhove (2009)	75	CDI	Multiple	MANF	PRIM
A068	S056	J10	McDermott and Prajogo (2012)	180	BJ	Australia	SERV	PRIM
A069	S057	J28	Menguc et al., (2014)	216	BI	Canada	BOTH	PRIM
A070	S058	J11	Merschmann and Thonemann (2011)	85	ABCJ	Germany	MANF	PRIM
A071	S059	J21	Nobeoka et al., (2002)	125	BJ	Japan	MANF	SECN
A072	S060	J26	O'leary-Kelly and Flores (2002)	121	BCJ	USA	MANF	PRIM
A073	S061	J14	Panagopoulos and Avlonitis (2010)	129	BJ	Greece	BOTH	PRIM
A074	S062	J26	Patel and Jayaram (2014)	141	CK	Not reported	MANF	PRIM
A075	S063	J05	Peng et al., (2020)	59	BCF	USA	SERV	SECN
A076	S064	J11	Prajogo (2016)	207	BIJ	Australia	MANF	PRIM
A077	S056	J10	Prajogo and Oke (2016)	228	BJ	Australia	SERV	PRIM
A078	S065	J33	Rajagopalan (2013)	104	BCJ	USA	SERV	SECN
A079	S066	J32	Randall et al., (2006)	53	CJ	Not reported	SERV	BOTH
A080	S006	J36	Roscoe et al., (2020)	143	ACK	Germany	BOTH	PRIM
A081	S067	J26	Rosenzweig (2009)	50	CJK	USA	MANF	PRIM
A082	S068	J26	Saldanha et al., (2013)	3032	BK	USA	MANF	SECN
A083	S069	J26	Salvador et al., (2014)	108	CJ	Italy	MANF	BOTH

A_ID	S_ID	J	Authors/Year	N	Relations	Country	Industry	Data
A084	S070	J07	Sánchez et al., (2011)	181	BJ	Spain	MANF	PRIM
A085	S071	J26	Sawhney (2013)	74	CK	USA	MANF	PRIM
A086	S072	J29	Sengupta et al., (2006)	73	CJK	USA	MANF	PRIM
A086	S073	J29	Sengupta et al., (2006)	72	CJK	USA	SERV	PRIM
A087	S074	J26	Setia and Patel (2013)	153	CJK	Not reported	MANF	BOTH
A088	S075	J26	Sharma, Kumar, et al., (2019)	201	AIJ	Multiple	BOTH	SECN
A089	S076	J17	Sheng et al., (2013)	244	BIJ	China	MANF	PRIM
A090	S077	J28	Song et al., (2011)	227	BIJ	Not reported	MANF	PRIM
A091	S078	J22	Soto-Acosta et al., (2018)	429	BJ	Spain	MANF	PRIM
A092	S035	J10	Srivastava et al., (2017)	115	CJK	USA	MANF	PRIM
A093	S079	J26	Steven et al., (2014)	165	AF	USA	MANF	SECN
A094	S080	J30	Su et al., (2013)	212	BJ	China	MANF	PRIM
A095	S027	J05	Syed et al., (2020)	292	DI	UK	BOTH	PRIM
A096	S032	J26	Tenhiälä and Helkiö (2015)	151	CEGH	Finland	MANF	PRIM
A097	S081	J05	Tenhiälä et al., (2018)	163	CG	Multiple	MANF	PRIM
A097	S082	J05	Terjesen et al., (2012)	261	CK	Not reported	MANF	PRIM
A099	S011	J10	Thome and Sousa (2016)	725	CFGH	Multiple	MANF	PRIM
A100	S083	J07	Tsai and Yang (2013)	154	BJ	Taiwan	NREP	PRIM
A101	S084	J10	Tsinopoulos and Al-Zu'bi (2012)	421	CI	Multiple	MANF	PRIM
A102	S085	J13	Um et al., (2018)	364	CEKJ	Multiple	MANF	PRIM
A103	S086	J06	Vachon and Klassen (2002)	469	ABCG	Multiple	MANF	PRIM
A104	S087	J03	Van Assen (2018)	100	CK	Netherlands	BOTH	PRIM
A105	S088	J28	Van Doorn et al., (2013)	346	DJ	Netherlands	BOTH	BOTH
A106	S089	J35	Vickery et al., (2016)	112	CI	Not reported	MANF	PRIM
A107	S090	J28	Visnjic et al., (2016)	133	CIJ	Not reported	MANF	SECN
A108	S091	J05	Wan and Dresner (2015)	94	CEJ	USA	MANF	SECN
A109	S092	J11	Wan and Sanders (2017)	283	CEJ	USA	MANF	SECN
A110	S093	J26	Wan et al., (2012)	108	CJK	USA	MANF	SECN
A111	S091	J16	Wan et al., (2014)	108	CJK	USA	MANF	SECN
A112	S091	J05	Wan et al., (2018)	108	BCJK	USA	MANF	SECN
A113	S093	J11	Wan et al., (2020)	101	BCJ	USA	MANF	SECN
A114	S094	J11	Wei et al., (2017)	186	BJH	China	MANF	PRIM
A115	S095	J10	Wiengarten et al., (2017)	318	CJ	Multiple	MANF	PRIM
A116	S096	J11	Wong et al., (2015)	188	DEK	Hong Kong	SERV	PRIM
A117	S097	J26	Zepeda et al., (2016)	307	BK	USA	SERV	SECN
A118	S098	J15	Zhang et al., (2020)	239	BJ	China	MANF	PRIM
A119	S009	J38	Zhao et al., (2013)	317	BGK	Multiple	MANF	PRIM
A120	S099	J24	Zhou et al., (2005)	350	BJK	China	MANF	PRIM
A121	S100	J04	Zhou et al., (2019)	303	BI	China	MANF	PRIM
A122	S101	J17	Zhu et al., (2017)	187	BJ	China	SERV	PRIM
A123	S102	J07	Ziggers and Henseler (2016)	176	AK	Netherlands	BOTH	PRIM

A_ID: Article ID; S_ID: Sample ID; J: Journal - J01. Academy of Management Journal, J02. Annals of Operations Research, J03. Business Process Management Journal, J04. Business Strategy and the Environment, J05. Decision Sciences, J06. IEEE Transactions on Engineering Management, J07. Industrial Marketing Management, J08.

Information & Management, J09. International Business Review, J10. International Journal of Operations & Production Management, J11. International Journal of Production Economics, J12. International Journal of Production Research, J13. International Journal of Productivity and Performance Management, J14. International Journal of Research in Marketing, J15. Journal of Business & Industrial Marketing, J16. Journal of Business Logistics, J17. Journal of Business Research, J18. Journal of Business Venturing, J19. Journal of Engineering and Technology Management, J20. Journal of Global Marketing, J21. Journal of International Business Studies, J22. Journal of Knowledge Management, J23. Journal of Manufacturing Technology Management, J24. Journal of Marketing, J25. Journal of Marketing Theory and Practice, J26. Journal of Operations Management, J27. Journal of Organizational Change Management, J28. Journal of Product Innovation Management, J29. Journal of Supply Chain Management, J30. Management and Organization Review, J31. Management Decision, J32. Management Science, J33. Manufacturing & Service Operations Management, J34. Omega, J35. Production and Operations Management, J36. Production Planning & Control, J37. Strategic Management Journal, J38. Supply Chain Management: An International Journal, J39. The International Journal of Logistics Management; N: Sample size; Relationships—A. Upstream complexity, B. Downstream complexity, C. Internal complexity, D. Overall supply chain complexity, E. Cost performance, F. Quality performance, G. Delivery performance, H. Flexibility performance, I. Innovation performance, J. Financial performance, K. Overall operational performance; Country—Single (name of the country) or Multiple; Industry – MANF: Manufacturing, SERV: Service, BOTH: Both manufacturing and service; Data—PRIM: Primary, SECN: Secondary, BOTH: Both primary and secondary.