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MANAGING INFORMATION PROCESSING NEEDS IN GLOBAL SUPPLY CHAINS: A PREREQUISITE TO SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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Sustainability is an important topic in supply chain management research and practice. For buying firms, one of the most pressing challenges associated with sustainable supply chain management is that they frequently do not possess sufficient information on what is occurring in their complex supply chains, as demonstrated by numerous incidents lacking sustainability. Using eight in-depth case studies across four industries and elaborating on information processing theory, we identify three forms of sustainability-related uncertainty that each firm is facing in its supply chain. We refer to them as task uncertainty, source uncertainty, and supply chain uncertainty. The study shows that the extent to which these uncertainties translate into information processing needs depends on a newly identified boundary condition labeled uncertainty intolerance. With respect to the management of such information processing needs, prior research has pointed primarily at matching information processing needs with fitting information processing capacity and secondly at mitigating information processing needs with corrective measures. This study illuminates how some innovative firms occasionally employ a more radical sustainability-driven supply chain modification mechanism. In doing so, this research exemplifies how sustainable supply chain management may eventually turn from an amendment to a firm's daily business to a decisive factor for shaping future supply chains. In addition, the study constitutes a nascent step to elevate information processing theory to the supply chain level.

Keywords: *sustainable supply chain management; information processing theory; uncertainty; true sustainability; sustainable business model*

INTRODUCTION

In 2007, Mattel recalled almost one million toys because of coatings that were considered hazardous to end customers (Story, 2007). Despite Mattel's rigorous supplier evaluation program that deploys independent service providers in supplier audits, the hazard had gone undetected. One manager reported that Mattel could not identify the source of the contamination because the Chinese contract manufacturer had purchased the contaminated paint from an unauthorized subsupplier (BBC, 2007). In the wake of the product recall costs of $30 million and a multimillion-dollar fine, Mattel's stock price dropped by 25% (Burke, 2007). Had Mattel gathered all coating-related information and interpreted it correctly, the hazard could have been avoided. More recently, on April 24, 2013, a factory building near Dhaka, Bangladesh, collapsed, causing the deaths of more than 1,100 garment producers (Daniel, Quadir & Ortiz, 2013). Again, a manager of a firm that had purchased textiles from the

factory and faced severe reputational damage for having done so reported that he had received no information regarding the cracks in the building nor about the poor working conditions inside (Daniel et al., 2013). The root cause of the collapse was that the building had been erected two stories higher than legally permitted (Clean Clothes Campaign, 2014; Manik & Yardley, 2013). Had the buyers gathered, interpreted, and synthesized the information on the sustainability-related conditions in the hazardous factory appropriately, they could have tried to engage in supplier development activities to enforce better standards or terminated their contracts. Many similar examples exist with respect to environmental and social issues, which demonstrate that buying firms must manage the uncertainty regarding the conditions in their supply chains as a crucial prerequisite for effective sustainable supply chain management (SSCM) and their own economic performance.

Even at firms that have integrated green and social criteria into their supply chain management processes, decision makers face uncertainty concerning the sustainability of upstream value creation (Carter, Rogers & Choi, 2015; Lee, Klassen, Furlan & Vinelli, 2014; Matten & Moon, 2008). As supply chains are becoming more complex and stakeholder expectations for sustainability within supply chains are rising, the task of resolving sustainability-related uncertainty is more important than ever (Giunipero, Hooker & Denslow, 2012; Sarkis, 2012). Thus, sustainability-related information processing has become a highly relevant and lasting challenge for buying firms that needs to be managed effectively, but has not been investigated empirically (Rauer & Kaufmann, 2015). Therefore, this research is concerned with sustainability-related information processing as a prerequisite to SSCM.

Because we are examining an information processing problem, we chose information processing theory (IPT) as our theoretical foundation. IPT posits that the uncertainty arising from a firm's business environment creates information processing needs which must be managed appropriately by the firm (Tushman & Nadler, 1978). Congruently, the introductory examples suggest that the sustainability-related uncertainty originates from the supply chain and that the insufficient management of sustainability-related information processing challenges may jeopardize buying firm performance. Therefore, IPT seems a promising theoretical lens to begin the study of information processing prerequisites of SSCM. However, neither the intra- (Galbraith, 1973; Tushman & Nadler, 1978) nor the interorganizational IPT framework (Bensaou & Venkatraman, 1995; Premkumar, Ramamurthy & Saunders, 2005) is directly applicable to the supply chain (i.e., network) level of analysis. Therefore, we use a theory elaboration approach (Ketokivi, 2006; Ketokivi & Choi, 2014) to accommodate the supply chain level of analysis and the sustainability context of this research.

Prior IPT research has identified multiple measures with which buying firms can manage uncertainty arising from their business environments. In particular, they can create information processing capacity (e.g., investment in information systems, creation of lateral relations, or effective process design) and engage in corrective measures aimed at the reduction of information processing needs (e.g., creation of slack resources or self-contained tasks) (Bensaou & Venkatraman, 1995; Galbraith, 1974). The sustainability reports of large and publicly visible firms highlight that firms frequently adopt these types of measures. Still, problems related to a lack of product sustainability and to supply chain sustainability risks stemming from insufficient sustainability-related conditions in production processes linger (Busse, 2016; Gmelin & Seuring, 2014; Hajmohammad & Vachon, 2016), as the introductory examples also underscore. Because prior IPT research has not been tailored to the sustainability context nor to the supply chain level of analysis, and given that the more established measures may often be insufficient, this study seeks to tackle the root of the problem by answering the following research questions: (*1) "How do sustainability-related uncertainty and information processing needs arise from buying firms' supply chains?" (2) "Are there any measures for reducing sustainability-related uncertainty directly?" If so, "How do buying firms deploy these measures?"*

To answer the research questions, we employ a multiple case study design. Case studies are particularly suitable for elaborating theory (Eisenhardt, 1989). The need to trace the rationale for specific decisions also supports this choice of method (Pratt, 2009).

The study offers fundamental theoretical contributions. First, it suggests a conceptualization and tentative operationalization for three types of sustainability-related uncertainty, which can be applied in future SSCM research, making a nascent step in elevating IPT to the supply chain level of analysis. Second, it advances the understanding of the boundary conditions of IPT by highlighting that the relationship between uncertainty and information processing needs is moderated by a firm's unique uncertainty intolerance. Third, it identifies various supply chain modification measures that buying firms can employ to decrease their sustainability-related uncertainty directly. While measures like that have been mentioned in conceptual research (Galbraith, 1977), they have previously not been investigated empirically. Fourth, the study offers a cost-benefit argumentation as to when firms decide to adopt such sustainability-driven supply chain modification. Overall, the study highlights effective information

processing as a previously under-appreciated prerequisite to SSCM. The study is also informative to managers as it fosters their understanding of the aforementioned concepts and causal relations. Because the study focused especially on those rare supply chain modification measures which only some innovative firms adopt, we dare hope that it represents a piece of research which gets "ahead of practice" and paves the way for "truly sustainable" supply chains (Pagell & Shevchenko, 2014, p. 51). As a minimum, this research informs the social debate on the responsibility of buying firms for the conditions in their supply chains by examining what firms are capable of doing.

The next section reviews theoretical foundations related to IPT and its application to SSCM. Thereafter, we present our case study method, along with data collection and coding techniques. Subsequently, we depict cross-case findings, leading to a concluding framework and testable research propositions. We amend a discussion on the theoretical and practical implications of our findings before concluding the study by discussing its limitations and opportunities for further research.

THEORETICAL FOUNDATIONS

A basic idea behind supply chain management is that optimizing value-creating activities across organizations may generate more value than the individual firms could create on their own (Ellram & Cooper, 1990). Transparency and information sharing between the supply chain partners foster such collaboration (Lamming, Caldwell, Harrison & Phillips, 2001; Zhou & Benton, 2007). Congruently, the quantum leaps in information technology development and information systems research over the last decades have facilitated the rapid progress of supply chain management (Kauremaa & Tanskanen, 2016). The environmental uncertainty (i.e., uncertainty arising from a firm's business environment) that may obstruct information sharing, transparency, and ultimately collaboration is a focus of IPT.

IPT evolved in the 1970s with an intraorganizational focus, in response to organizational design problems of large firms (Galbraith, 1970, 1973). It was later extended to a dyadic, interorganizational level to assess buyer–supplier relationships (Bensaou & Venkatraman, 1995). Information processing encompasses the gathering, interpreting, and synthesizing of information (Tushman & Nadler, 1978). IPT is concerned with the link between environmental uncertainty and a firm's information processing needs, as well as with the question how firms can cope with these needs (Bensaou & Venkatraman, 1995; Galbraith, 1977). Uncertainty as the root cause of information processing needs is "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization" (Galbraith, 1973; p. 5). Uncertainty tends to be augmented by complexity (i.e., the plurality of relevant factors) and dynamism (i.e., a measure of temporal change) (Duncan, 1972). Later studies acknowledged different types (sources) of uncertainty, all of which augment information processing needs (Bensaou & Venkatraman, 1995; Premkumar et al., 2005).

Given its close tie with the very essence of supply chain management, supply chain scholars have frequently applied IPT as a theoretical lens to explain various phenomena, such as the value of internal and external supply chain integration (Flynn, Koufteros & Lu, 2016; Schoenherr & Swink, 2012; Swink, Narasimhan & Wang, 2007; Williams, Roh, Tokar & Swink, 2013; Wong, Boon-itt & Wong, 2011), responses to supply chain disruption risks (Bode, Wagner, Petersen & Ellram, 2011), the influence of information processing on the effectiveness of supply chain practices (Zhou & Benton, 2007), cycle time variance (Hult, Ketchen & Slater, 2004), buyer–supplier cooperation in new product development (Cousins, Lawson, Petersen & Handfield, 2011), the behavior of project managers (Bendoly & Swink, 2007), process integration in the outsourcing of business processes (Narayanan, Jayaraman, Luo & Swaminathan, 2011), and the influences of a culture of competitiveness and knowledge development on supply chain performance (Hult, Ketchen & Arrfelt, 2007). Literature also investigated the influence of semantics on the standardization and coordination of subunits (Wybo & Goodhue, 1995), the effect of the implementation of enterprise resource planning systems on the manufacturing–marketing interface (Gattiker, 2007; Gattiker & Goodhue, 2005), and the manufacturing environment (Flynn & Flynn, 1999) as well as the link between IT-enabled decision making and information integration (Wong, Lai, Cheng & Lun, 2015; Wong, Wong & Boon-itt, 2015). Although the importance of uncertainty and information processing has been acknowledged within SSCM research (Lee et al., 2014; Seuring & Müller, 2008; Sharfman, Shaft & Anex, 2009), we are unaware of direct applications of IPT to SSCM.

In this study, we adopt the SSCM definition of Carter and Rogers (2008, p. 368), according to whom SSCM is "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains." SSCM is currently one of the most vivid

streams of research within supply chain management and has recently been reviewed with distinct emphases (Meixell & Luoma, 2015; Touboulic & Walker, 2015; Wong, Wong et al., 2015). In the absence of prior IPT applications to SSCM, we offer conceptual arguments for why, especially in the context of sustainability and at the supply chain level of analysis, supply chain scholars should scrutinize uncertainty in more depth.

First, sustainability directs attention to both the process of how goods are produced and the products that result from these processes. For instance, child labor is a serious social problem that is in no way apparent in the supplies that a focal firm receives, but may be present at problematic points in the firm's upstream supply chain. While some types of environmental problems within production processes may harm consumer health and can thus be linked to the product, as in the introductory Mattel example, others, such as toxic wastewater emissions, do not become visible within the product. As Sharfman et al. (2009, p. 2) stated, "environmental issues (in a supply chain context) are uncertain, ambiguous, and equivocal." If firms direct their attention only to the economic dimension, considering product quality, price, and the supplier's delivery capabilities, they neglect this important process-related information, which is crucial for the buying firm's stakeholders (Hofmann, Busse, Bode & Henke, 2014).

Second, sustainability involves numerous issues that require the simultaneous attention from the buying firm; not only is sustainability defined by the economic, environmental, and social dimensions of the triple-bottom line (Elkington, 1998), but it also comprises many subcategories and topics within each of the three dimensions. Schleper and Busse (2013, p. 197) identified 29 sustainability-related topics for which general principles are explicitly stated in important supplier codes of conduct.

Third, the supply chain level of analysis contributes to the sustainability-related uncertainty; firms must consider the sustainability-related information from potentially anywhere in their supply chains, but cannot control them entirely (Carter et al., 2015; Rauer & Kaufmann, 2015). Hartmann and Moeller (2014) found evidence that supplier misconduct can also endanger firm reputation when it occurs beyond tier-1 suppliers. Consequently, firms are exposed to the sustainability-related uncertainty from their entire supply chain, which is complex in numerous ways (Choi & Hong, 2002). Therefore, this study investigates the emergence of sustainability-related information processing needs from buying firms' complex supply chains.

IPT posits that firms must achieve fit between information processing needs and their own information processing capacity to foster performance, whereas misfit jeopardizes performance (Galbraith, 1977). In striving for fit, "the organization must adopt a strategy to either (1) reduce the information necessary to coordinate its activities, (2) increase its capacity to process more information" (Galbraith, 1973; p. 14) or (3) apply a combination of both strategies (Gattiker, 2007). As a contingency theory, IPT assumes that the external business environment is rather inert, whereas the internal firm processes are relatively more adaptable (Sousa & Voss, 2008; Venkatraman, 1989). Accordingly, IPT refers to information processing mechanisms aimed at the creation of additional information processing capacity, such as investments in suitable information systems, as well as at firm-internal coordination mechanisms supposed to mitigate the effects of uncertainty on information processing needs, such as the creation of self-contained tasks (see Table 1 for additional details). However, Galbraith (1977, p. 50) conjectured that "instead of modifying its own structure and processes, the organization can attempt to modify its environment." Such strategies have hitherto not been analyzed empirically, neither within IPT-related scholarship nor within SSCM research.

It is important to investigate whether firms adapt their business environments to their sustainability-related need in order to facilitate the further evolution of IPT, but also to foster the impact of SSCM research on corporate practice. Despite decades of scholarly attention to SSCM, modern supply chains still tend to be mostly unsustainable (Pagell & Shevchenko, 2014). A possible explanation to this nuisance might be that many SSCM practices are additive, corrective, and ultimately symbolic measures which do not change the rules of the games that firms tend to play. In contrast, sustainability-driven modification to buying firms' environments would have to be qualified as truly substantial changes. Per the previous considerations, this study also investigates whether measures for decreasing sustainability-related uncertainty directly exist and under which conditions buying firms implement these measures. We should concede at this point that we found only some innovative firms to apply such measures, and we found them to adopt them only under certain circumstances. Still, given that these measures are most insightful for understanding what firms are capable of doing, this study focuses on the sustainability-related supply chain modification measures.

Table 1 summarizes and details the intersection between IPT studies and SSCM research at different levels of analysis. In doing so, it also elaborates the relevance of supply chain level studies of the information processing prerequisites to SSCM.

TABLE 1

Viewing SSCM Research from an IPT Lens

Level of Analysis	Select Studies That Contributed to Information Processing Theory	Select Findings from the (Sustainable) Supply Chain Management Discourse
Any	• Information processing is the gathering, interpreting, and synthesizing of information (Tushman & Nadler, 1978). • "Information" goes beyond "data"—IPT encompasses the wider study of the interrelationship between information, people, and knowledge (e.g., Newell & Simon, 1972). • Fit between information processing needs and capacity is required and can be achieved through suitable mechanisms (Bensaou & Venkatraman, 1995; Galbraith, 1974, 1977). • Firms choose information processing mechanisms based on cost-benefit evaluations (Galbraith, 1970). • "Instead of modifying its own structure and processes, the organization can attempt to modify its environment" (Galbraith, 1977, p. 50).	• Information unavailability and opaqueness are major obstacles to SSCM (Sharfman et al., 2009). • Managing sustainability-related uncertainty represents a crucial precondition for successful SSCM (Lee et al., 2014; Seuring & Müller, 2008). • Information processing has been facilitated by the development of information systems (e.g., Gunasekaran & Ngai, 2004); thus, supply chain management has witnessed substantial improvements in fostering supply transparency, control, and information sharing over the last decades (e.g., Lamming et al., 2001; Zhou & Benton, 2007).
Intraorganizational	• In classical IPT, the amount of uncertainty is decisive for the choice of information processing mechanisms (Galbraith, 1974). • Available information processing mechanisms for low uncertainty: rules and programs, hierarchical referral, and goal setting (Galbraith, 1974, 1977). • Available information processing mechanisms for high uncertainty: vertical information systems, lateral relations, slack resources, and self-contained tasks (Galbraith, 1974, 1977). • Later studies also distinguish between different types of uncertainty (e.g., Daft & Lengel, 1986).	• Firms use operating principles (i.e., general rules to guide decision making) and technical standards (i.e., specific rules for task-based decisions) in their SSCM decision making (Wu & Pagell, 2011).
Interorganizational (dyadic)	• Amount and type (source) of uncertainty determine the suitable information processing mechanisms (Bensaou & Venkatraman, 1995; Premkumar et al., 2005). • IPNs arise from three types of uncertainty: environmental,	• Cross-firm communication and information sharing foster information processing (Beske, Land & Seuring, 2014; Cantor & Macdonald, 2009; De Bakker & Nijhof, 2002; Grover, Jeong, Kettinger & Teng, 1995; Paulraj, Jayaraman & Blome, 2014).

(continued)

TABLE 1 (continued)

Level of Analysis	Select Studies That Contributed to Information Processing Theory	Select Findings from the (Sustainable) Supply Chain Management Discourse
	partnership, and task uncertainty (Bensaou & Venkatraman, 1995). • Interorganizational information processing mechanisms relate to structure, process, and information technology (Bensaou & Venkatraman, 1995).	• However, processing too much information can overwhelm the decision maker (Glazer, Steckel & Winer, 1992; Steckel, Gupta & Banerji, 2004). • Green information sharing among supply chain partners enhances the environmental adaptability and the focal firm performance (Wong, 2013). • Sustainability-related uncertainty cannot only be addressed by the creation of information processing capacity, but also by the lowering of information processing needs (Hollos, Blome & Foerstl, 2012; Paulraj, 2011).
Interorganizational (supply chain)	• No direct transferability of IPT studies from other levels of analysis • Types (sources) of uncertainty unknown • Specificity of sustainability-related uncertainty to be expected • Inherent uncontrollability of sustainability-related uncertainty seems plausible • Galbraith's (1977, p. 50) conjecture of adaptations to the business environment of a firm is of particular relevance for modern supply chains in which "true sustainability remains an aspiration" (Pagell & Shevchenko, 2014, p. 45).	• Sustainability-related uncertainty can be attributed to the numbers of purchased items (Klassen & Vachon, 2003), to institutional distance between business partners' legitimacy contexts (Busse, Kach & Bode, 2016), to frequent changes in suppliers (Sarkis, 2012), and to supply chain complexity (Tachizawa & Wong, 2015). • The resulting uncertainty increases substantially beyond the first-tier level (Grimm, Hofstetter & Sarkis, 2014; Rauer & Kaufmann, 2015). • Supply chains are becoming more complex (Choi & Hong, 2002; Choi et al., 2001). • Stakeholder pressure for supply chain sustainability keeps increasing (Meixell & Luoma, 2015); it is directed not only at products (outputs), but also at processes (Hofmann et al., 2014). • Sustainability comprises numerous sublevel indicators (Kirchoff et al., 2011; Schleper & Busse, 2013).

METHODOLOGY

Research Design

Our research concerns the sustainability-related uncertainty arising from a buying firm's supply chain, the resulting information processing needs, and the firm's efforts at reducing uncertainty. The buying firm is thus our prime observational unit of analysis, while the buying firm embedded in its supply chain is the explanatory unit of analysis (Wilhelm, 2011).

The design of this research can best be described as abductive theory elaboration, which "involves modifying the logic of the general theory in order to reconcile it with contextual idiosyncrasies" (Ketokivi & Choi, 2014, p. 236). Theory elaboration approaches are most appropriate where a potent general theory

exists, such as IPT in our case, but where the research context also portrays important features that must be considered in the theorizing process, such as the supply chain level of analysis and the sustainability topic in this research. More specifically, it is the preferred case research design when a-priori hypotheses cannot be deduced, as in our case in which neither the forms of sustainability-related uncertainty nor the available adaptation measures were known beforehand, while the theoretical perspective augments the understanding of the contextually derived data ex post, as we hope is the case with our findings (Ketokivi & Choi, 2014).

We have selected a multiple case study approach for four reasons. First, our literature review revealed a limited understanding of sustainability-related uncertainty and IPT applications at the level of the supply chain. Thus, case studies provide a solid means for exploration and theory elaboration because, to date, knowledge on managing sustainability-related uncertainty is lacking (Barratt, Choi & Li, 2011). Second, case studies allow for the collection of multiple data sources and allow asking clarification questions, which enables triangulation. Triangulation contributes to enhancing the validity of a study (Meredith, 1998) and facilitates a strong substantiation of constructs and propositions (Eisenhardt, 1989). Third, cases enable us to generate managerially relevant knowledge due to the involvement of managers operating in real SSCM situations (Gibbert, Ruigrok & Wicki, 2008). Lastly, case studies have been encouraged as the method of choice when developing or extending theory in SSCM (Carter & Easton, 2011; Tate, Ellram & Dooley, 2012).

We followed a purposeful four-step sampling process. First, we concentrated on large, internationally operating firms. Second, to ensure the generalizability of our results, we opted for firms across four industries, which are exposed to typical sustainability challenges. Firms within (1) the chemical and (2) the pharmaceutical industries (Christmann, 2000; Foerstl, Reuter, Hartmann & Blome, 2010) buy raw materials that are potentially harmful to the natural environment and humans. Firms within (3) the furniture (Handfield, Walton, Seegers & Melnyk, 1997) and (4) the apparel industries (Yu, 2008) have been frequently criticized for uncontrolled environmental degradation and unethical labor practices among their suppliers. By concentrating on large firms in these industries, we ensured that each case is affected by stakeholder pressure to actively manage sustainability in its supply chain.

Third, to arrive at a deeper understanding of each industry and ensure a theoretical representation of the whole population in our sample, we chose diverse case firms within each industry (Seawright & Gerring, 2008) by selecting one sustainability leader and one sustainability follower. Sustainability leaders who were assumed to apply more sophisticated SSCM measures were identified based on the firms' listings in the Dow Jones Sustainability Indexes (DJSI) as well as the public mention of the firms' sustainability by nongovernmental organizations (NGOs) or in newspaper articles (Pagell & Wu, 2009; Reuter, Foerstl, Hartmann & Blome, 2010). After we talked to these firms and found support for their leadership positions, we selected follower firms, which were characterized by devoting fewer resources to handle the same industry-specific challenges. This approach was expected to yield a more differentiated picture on the emergence and management of sustainability-related uncertainty. We talked to more than one leader and one follower in each industry. As none of these additional cases revealed previously unobserved practices, we are confident that we reached theoretical saturation in our eight-case sample (McCutcheon & Meredith, 1993). Fourth, we sought to select firms that have maintained high levels of information processing fit in recent years. To this aim, we scanned Web and print sources for the absence of public scandals or negative press. Last, it should be noted that the sustainability-related uncertainty dimensions could not be used within the sampling process because they are not transparent to firm outsiders.

To understand how firms choose between different alternatives for managing uncertainty, we also analyzed multiple decision situations as embedded cases at each case firm (Ellram, 1996; Yin, 2009). To this aim, we asked our participants within each case for such relevant situations in a retrospective manner (Leonard-Barton, 1990). This procedure most likely did not trigger any confirmation or hindsight bias, because the practitioners did not view the interviews from the perspective of the ongoing theory elaboration effort. Moreover, as one of the authors is familiar with four of the eight firms from a prior SSCM-related research project between 2008 and 2009, he could validate many of the answers produced. We applied the data collection and analysis procedures recommended by Yin (2009) to enhance case study rigor, such as using data triangulation, maintaining a case study database, and pattern matching.

Data Collection

The most important type of data stems from interviews with knowledgeable managers in each case. We conducted initial interviews with executive managers such as the chief executive officer, chief procurement officer, or sustainability director. These interviews provided us a general understanding of each case firm and enabled us to identify

appropriate additional interview partners. Because our research focused on information processing for SSCM, we sought out the most knowledgeable informants for SSCM. Because SSCM is cross-functional and comprises input from numerous corporate functions, we involved representatives from the purchasing, production, quality, and sustainability departments in the semistructured interviews. Altogether, we conducted 32 interviews with 36 informants (see Table 2 for details). The interviews lasted between 45 and 150 minutes and were conducted by two researchers whenever possible. The interviews were recorded and transcribed, and each interviewer individually took minutes of the meetings. Internal documents such as procurement guidelines and supplier evaluation sheets, as well as publicly available data such as annual reports, sustainability reports, or newspaper articles, were analyzed to triangulate and probe the obtained information during the interviews (Eisenhardt, 1989; Voss, Tsikriktsis & Frohlich, 2002). This process ensured the internal validity by controlling for social desirability bias inherent in the sustainability topic (Carter & Easton, 2011).

We modified the interview guideline (see the Appendix) whenever additional interesting facets of general interest were identified, and we ensured that they were included in the subsequent interviews. Once no more new themes and patterns emerged in additional interviews, saturation was assumed to have been reached (Yin, 2009). To ensure reliability, we kept notes of our analysis and shared the interview transcripts with the informants for final release to verify that all facts had been accurately captured. To store these large amounts of data in a structured way, we created a case database, which incorporates individual notes, interview transcripts, content from firms' websites, observation sheets, and internal and publicly available data (Gibbert et al., 2008; Yin, 2009). Table 2 provides an overview of our database.

Coding

As soon as all primary and secondary data had been collected, we began the coding to structure the information obtained at each firm for a within-case analysis (Strauss & Corbin, 1990). By analyzing transcripts and internal and publicly available data, we acquired a thorough understanding of each case firm's unique pattern (Eisenhardt, 1989). Any emerging findings were discussed among all authors and critically challenged until consensus was reached (Gioia, Corley & Hamilton, 2013). Having established a consistent coding and classification of each case, we relied on tabular displays (Ellram, 1996) to detect the commonalities and differences across firms in our cross-case analysis (Pratt, 2008). Specifically, reoccurring critical themes (Wilhelm, 2011) across the cases inspired our codes on the different types of sustainability-related uncertainty that each case firm faced. We elaborated the identified concepts and relationships, based on IPT and relevant SSCM literature, to enfold prior theory (Pratt, 2009). Doing so allowed us to begin the operationalization of the different types of sustainability-related uncertainty, which in turn facilitated a cross-case coding of sustainability-related uncertainty, and of the information processing needs arising thereof. Pattern matching (Yin, 2009) pointed us to the detection of a hitherto undiscovered boundary condition of IPT, which becomes visible as a moderator termed "uncertainty intolerance." Again, unfolding prior theory helped us to substantiate our empirical findings at a more general level and to elaborate the existing theory in the field of SSCM. We present our most important findings in the form of propositions, thereby pointing to the essence of our results and facilitating the subsequent validation efforts. We also incorporated the feedback from independent researchers when presenting the study at various conferences and research colloquia.

RESULTS

Our concluding framework is depicted in Figure 1 and will be explained in depth throughout this section. We first explore the information processing—firm performance chain. We argue that fitting information processing represents a crucial prerequisite to SSCM and ultimately translates into economic performance for the buying firm. Subsequently, we turn to the emergence of information processing needs. Specifically, we present three types of sustainability-related uncertainty that we identified in our cases, and consider how these uncertainties create information processing needs. Finally, we illustrate how some firms occasionally employ sustainability-driven supply chain modification measures that reduce their sustainability-related uncertainty directly, and analyze how buying firms deploy these measures.

Information Processing—Firm Performance Chain

Based on our empirical results, we derived a three-step model (depicted at the bottom of Figure 1) that helps explain the link between a buying firm's sustainability-related information processing and its economic performance. The model is explained below, and illustrative quotes are presented in Table 3.

Economic performance is the overarching goal behind SSCM from the buying firm's perspective, as emphasized by Carter and Rogers (2008). We

TABLE 2

Case Firm and Interviewee Demographics

	Chem1	Chem2	Pharma1	Pharma2	Furniture1	Furniture2	Apparel1	Apparel2
Employees	>100.000	>20.000	>100.000	>30.000	>1.000	>1500	>10.000	>1500
Revenue	>€ 70 Bio.	>€ 6 Bio.	>€ 40 Bio.	>€ 10 Bio.	>€ 150 Mio.	>€ 400 Mio.	>€ 3 Bio.	>€ 400 Mio.
Listing	DJSI	DJSI	DJSI	FTSE4Good	None	None	DJSI	None
Strategy	Leader	Follower	Leader	Follower	Leader	Follower	Leader	Follower
Uncertainty intolerance[a]	Very high	Medium	Very high	Medium	Low	Very low	High	Very low
Main products	Chemicals, fine chemicals	Chemicals, fine chemicals	Medicaments	Medicaments	Office furniture	Kitchen furniture	Sports and fashion wear	Lifestyle and fashion wear
Informant job title	A_{C1}. Head of Sustainable Procurement B_{C1}. Manager of Sustainable Procurement C_{C1}. Specialist of Sustainable Procurement D_{C1}. Specialist of REACH Procurement E_{C1}. Head of Product Safety F_{C1}. Manager of Purchasing Raw Material G_{C1}. Head of Business Development	A_{C2}. Head of Procurement Strategy B_{C2}. Head of Global Compliance C_{C2}. Head of REACH Procurement D_{C2}. Global Procurement Manager of Indirect Spent E_{C2}. Head of Performance and Process Management	A_{P1}. Head of Responsible Procurement B_{P1}. Manager of Responsible Procurement C_{P1}. Head of Third Party Operations	A_{P2}. Associate Director of Group Procurement B_{P2}. Director of Corporate Social Responsibility C_{P2}. Director of Environmental/ Occupational Safety	A_{F1}. Chief Executive Officer B_{F1}. Head of Strategic Sourcing C_{F1}. Head of Environmental Management[b,c] D_{F1}. Project Manager Ergonomics[b]	A_{F2}. Regional Senior Buyer B_{F2}. Corporate Senior Buyer Plastics C_{F2}. Corporate Senior Buyer Timber D_{F2}. Head of Quality and Environmental management E_{F2}. Head of Occupational Health and Safety	A_{A1}. Chief Sourcing Officer[b] B_{A1}. Head of Project Management Sourcing[b] C_{A1}. Global Director of Social Accountability & Environmental Standards D_{A1}. Strategic Compliance Officer E_{A1}. Specialist of Project Management Sourcing	A_{A2}. Strategic Controlling/ Sustainability Coordinator[b] B_{A2}. Head of Strategic Controlling/ Sustainability[b] C_{A2}. Specialist of Corporate Sustainability Strategy[b] D_{A2}. Specialist of Corporate Sustainability[b]

(continued)

TABLE 2 (continued)

	Chem1	Chem2	Pharma1	Pharma2	Furniture1	Furniture2	Apparel1	Apparel2
Publicly available information	Sustainability report, supplier code of conduct	Sustainability report, supplier code of conduct	Sustainability report, supplier code of conduct	Sustainability report, supplier code of conduct	Sustainability brochure	Corporate site	Sustainability report, supplier code of conduct	Sustainability report, corporate site
Internal documents	Supplier self-assessment, audit guideline	Supplier self-assessment	Supplier self-assessment, audit guideline	Supplier self-assessment	Supplier self-assessment, audit guideline	Supplier audit guideline	Supplier self-assessment, audit guideline	None

[a]Uncertainty intolerance denotes the amount of information processing needs per sustainability-related uncertainty and is specific to the firm context. It is measured with a 5-point scale (very high, high, medium, low, or very low). [b]Respondents from the same company interviewed jointly. [c]Respondent interviewed twice.

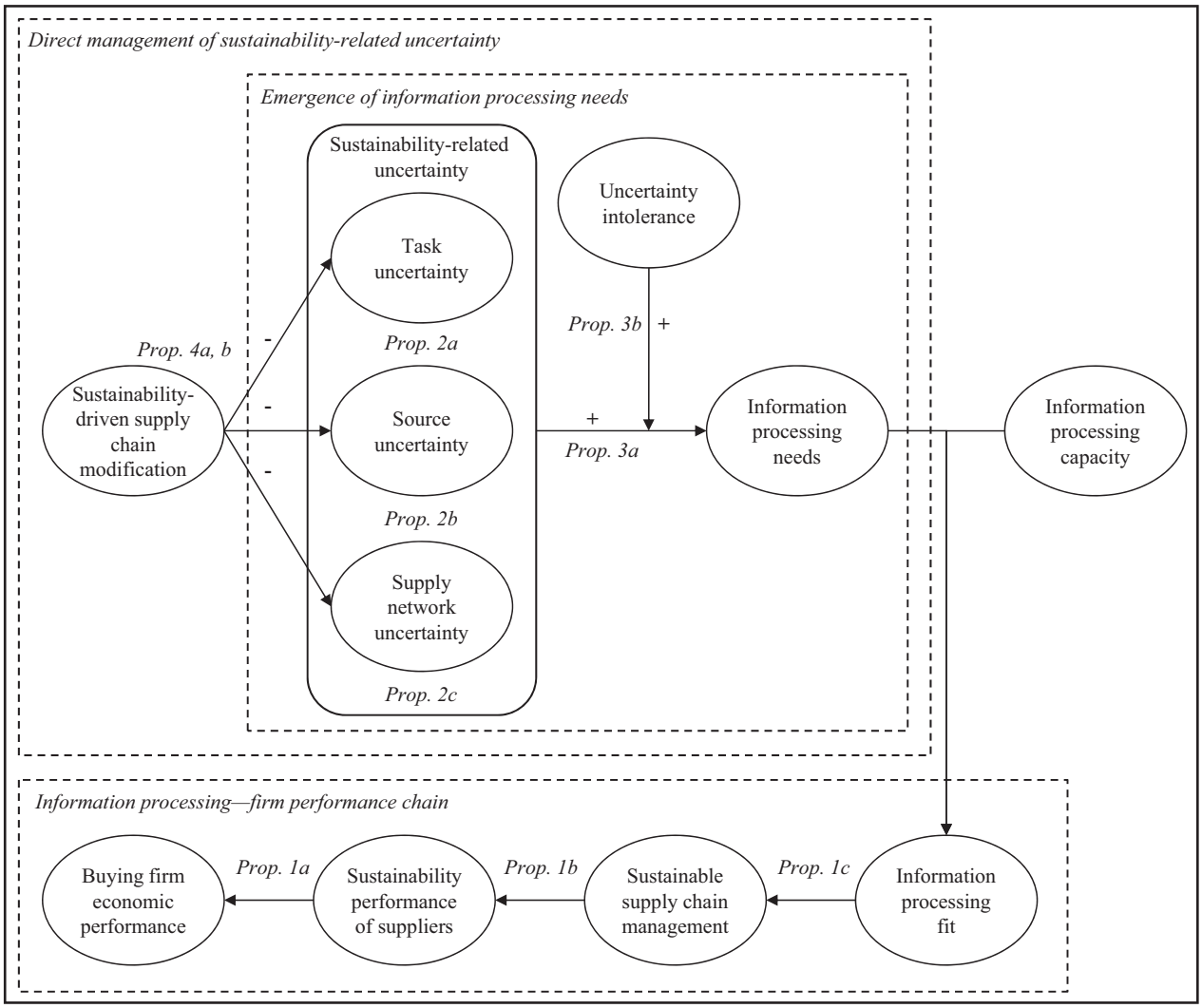
understand this performance as a measure of success, considering the benefits and costs associated with SSCM practices jointly (Busse, Mahlendorf & Bode, 2016). The superordinate-target role of economic performance assigns SSCM the role of an *instrument* for achieving higher economic performance (Donaldson & Preston, 1995). Indeed, our data show that SSCM practices influence buying firm economic performance, mediated through the sustainability performance of the suppliers in its supply chain. Firms are well aware of this influence, as highlighted by the following statement by Chem1's Manager for Sustainable Procurement: *"Managing our suppliers towards a higher sustainability performance is from a risk-mitigation approach very important for us. We don't want to quit profitable business relations, but neither do we want to suffer reputational damage."* Suitable sustainability performance of suppliers not only prevents the manifestation of supply chain sustainability risks (Hofmann et al., 2014), but also helps buying firms to develop and market sustainable products (Kirchoff, Koch & Nichols, 2011; Seuring, 2011). It can also lead to improved collaboration between buyer and supplier (Busse, 2016; Carter & Jennings, 2002), and self-promotion of the supplier may even spill over to the buyer when the respective component is visible to the buyer's stakeholders (Busse, 2016; Foerstl, Azadegan, Leppelt & Hartmann, 2015). Therefore, we posit the following:

> **Proposition 1a:** The sustainability performance of the suppliers in the buying firm's supply chain influences the buying firm's economic performance.

Buying firms observe their suppliers' green and social performance through sustainable supplier evaluation and selection and seek to improve it via collaborative development or target setting (Busse, Schleper, Niu & Wagner, 2016; Meinlschmidt, Foerstl & Kirchoff, 2016). The firms employ these SSCM processes and practices with the aim of influencing the sustainability performance of their supply chain partners to the levels required according to their internal sustainability strategy or to meet external stakeholder demands. For example, Apparel1's Chief Sourcing Officer noted that *"if you want to reduce the water usage of a product by 25% you need to know how. We seek collaborative approaches and offer assistance to our suppliers that are mainly based in developing countries. As they don't know how to make required changes we provide active support."* Thus, we posit the following:

> **Proposition 1b:** The buying firm's sustainable supply chain management practices influence the sustainability performance of its suppliers.

FIGURE 1
Theoretical Framework



Sustainability-related uncertainty can prevent buying firms from utilizing their SSCM practices effectively. For example, if a buying firm expected a supplier to produce the component of a sustainable product, but the supplier lacked the competencies to do so, then a supplier development activity for sustainability would only be possible if the buying firm was aware of the supplier's need to be developed. Conversely, suitable information processing activities enable SSCM. For example, one of the case firms underscored the importance of sustainability-related information gathering by stating that "*Identifying relevant sustainability issues helps us to develop tailored solutions to manage our suppliers*" (Chem1, Sustainability Report 2011). In the same vein, sustainability-related information must also be interpreted correctly, as Apparel1's Global Director of Social Accountability & Environmental Standards pointed out: "*As I work at our office in Vietnam and frequently visit our headquarters in Germany, I understand both worlds. Therefore, it is much easier to support the development and implementation of environmental and labor standards at suppliers.*"

The aforementioned examples highlight the importance of suitable information processing at a microlevel. At the macro level at which IPT operates, firms must strive for fit between their information processing needs and their internal information processing capacity, which they can improve through adequate needs-reducing or capacity-increasing mechanisms. The previously established link to the buying firm's economic performance helps us to specify further exactly *when* fit between information processing needs and capacity exists. Apparently, fit exists when no incremental changes to information processing needs and capacity configurations are imaginable that would improve the buying firm's economic performance

TABLE 3

The Information Processing—Firm Performance Chain

Information Processing → Buying Firm Sustainable Supply Chain Management Practices

"As I work at our office in Vietnam and frequently visit our headquarters in Germany, I understand both worlds. Therefore, it is much easier to support the development and implementation of environmental and labor standards at suppliers." C_{A1}

"We are collecting and storing ISO and other standardized certifications of our suppliers as they proof that the respective suppliers follow certain standards. This will dramatically reduce the evaluation effort because about 10% of the suppliers represent 80% of the spent." A_{C2}

"Our employees conduct health, safety and environmental audits. For social audits, we use external experts because we do not have the capacity." A_{P1}

"It is important that every employee within the sourcing department is trained and concerned about environmental protection and social responsibility because they actually conduct the supplier audits." B_{F1}

"Identifying relevant sustainability issues helps us to develop tailored solutions to manage our suppliers. The continuous information exchange with stakeholders helps us to focus on the particular challenges that we face." (Chem1, Sustainability Report 2011)

"To identify which supplier will have to pass an audit, we structure them into risk-groups based on country, product and sales volume." (Pharma2, Corporate Responsibility Report 2012)

Buying Firm Sustainable Supply Chain Management Practices → Sustainability Performance of Suppliers

"If you want to reduce the water usage of a product by 25% you need to know how. We seek for collaborative approaches and offer assistance to our suppliers that are mainly based in developing countries. As they don't know how to make these changes we provide information to help them." A_{A1}

"We conducted a water management program at a South American supplier that was endangered of running out of fresh water (to improve their sustainability performance)." A_{C1}

"We exploit the cost advantage of sourcing from suppliers in emerging economies. But at the same time we collaborate with these suppliers to achieve working conditions according to high, western standards." A_{P1}

Sustainability Performance of Suppliers → Buying Firm Economic Performance

"Managing our suppliers towards a higher sustainability performance is from a risk-mitigation approach very important for us. We don't want to quit profitable business relations, but neither, we want to suffer reputational damages." A_{C1}

"We have achieved very important results already. We are evaluating and developing our suppliers towards six key performance indicators including the usage of water or energy. That was an important step for us in becoming a DJSI member" A_{C2}

"Until 2015, 2016 we want to launch new products that contain 50% more sustainable material. We want to source them only from suppliers that are evaluated as A+ or A." C_{A1}

(i.e., be associated with incrementally higher benefits than costs) in a given situation. Correspondingly, misfit exists when such changes would be possible. This clarification is important because it highlights why firms do not simply avoid the sustainability-related uncertainty "at all costs," but need to optimize the relation between information processing needs and capacity. We consider a firm's assessment of its information processing as well informed if it assesses fit to the best of its ability and does not fail to notice any apparent misfit.[1] To conclude, we posit:

Proposition 1c: The degree of sustainability-related information processing fit influences the buying firm's sustainable supply chain management practices.

Emergence of Information Processing Needs

Given that neither the intraorganizational IPT framework of Galbraith (1973) nor the interorganizational (i.e., dyadic) framework of Bensaou and Venkatraman (1995) is directly applicable at the supply chain level, we explored the types of sustainability-related uncertainty which buying firms are exposed to. We identified three such types of uncertainty that reflect "characteristics that contribute to high levels of

[1]For the sake of thoroughness, it should be noted that any buying firm's organizational capability for assessing fit will necessarily feature bounded rationality.

information load" (Handley & Benton, 2013; p. 110). We refer to them as task, source, and supply chain uncertainty. Table 4 highlights these critical themes.

We define task uncertainty as uncertainty that stems from the aggregate of the products that are bought with regard to their amount, variety, novelty (Campbell, 1988), and environmental (green) product characteristics. Prior research has shown that the higher the task's scale (Espinosa, Slaughter, Kraut & Herbsleb, 2007), variety (Novak & Eppinger, 2001), and novelty (McQuiston, 1989) are, the greater the resulting task uncertainty will be (Handley & Benton, 2013). We further took notice that firms are also exposed to task uncertainty due to product-related characteristics. In each industry, there exists an environmental issue salience that depends on the specific materials (e.g., hazardous versus noncritical) that are usually bought (Desai, 2014). For example, products bought in the chemical industry such as acids are often hazardous for humans and the natural environment, whereas wood and plastics that are predominantly bought in the furniture industry are less critical in that respect. The four measures of task uncertainty are summarized in Table 5.

We define source uncertainty as uncertainty stemming from the aggregate of suppliers (i.e., from the nodes and links to them, see Carter et al., 2015) in the supply chain, given a certain network structure. Source uncertainty originates from distinct locations, length of business relations, and production process-related characteristics. Our case firms revealed that *"A major challenge is that the understanding and importance*

TABLE 4

Critical Themes Identified across Cases with Respect to the Sustainability-Related Uncertainties

Uncertainty	Representative Statement
Task	"We are currently buying more than 20.000 different products, so you can imagine the task is very high." D_{C2}
	"As the materials that we are purchasing are changing twice a year due to new products the task is very complex." A_{A1}
	"Environmental protection plays a major role in the chemical industry. Chemical firms face higher needs than pharmaceutical firms to evaluate their suppliers with regard to ecological criteria." A_{P2}
Source	"A major challenge is that the understanding and importance of sustainability is not the same in each region of the world. In Germany and in many parts of Europe we have high standards. But in emerging markets such as China environmental protection has a much lower importance as cultural differences are very high." A_{A2}
	"Suppliers from countries such as Vietnam, Cambodia and Bangladesh are underdeveloped regarding sustainable development. A few years ago we needed to explain why we do not want child labor." A_{A1}
	"I have never seen children working at a chemical plant. I am sure to 99.99% that there is no child labor in the chemical sector." E_{C2}
	"Chemical plants are not that affected by social criteria, ecologic criteria play a prior role." A_{C1}
Supply chain	"We have a verification problem in our supply network if we want to evaluate beyond tier-1 supplier. The big challenge that we face is that we cannot control the data, there are just too many information that we would need to process." A_{C1}
	"In supply chains information gets lost due to the chain's complexity and the suppliers' secrecy very easily. Sustainability-related information are very difficult to obtain starting from tier-2, tier-3. If you want to have a compliant supply chain you need to install mechanisms to control the entire chain up to its origin. To do so, you would need a whole department." C_{C2}
	"If you want to obtain more sustainability-related information from your suppliers it is unavoidable to evaluate the upstream tiers as well. I am not sure if this is possible in the same way as you reach a capacity limit due to the high number of suppliers." A_{A1}
	"To audit up to tier-4 is almost impossible. That would be the cattle farms and the cotton plantation. We do not even know how the supply chain continues." C_{A1}

TABLE 5

Current Firm Uncertainty and Information Processing Needs Profiles

	Chem1	Chem2	Pharma1	Pharma2	Furniture1	Furniture2	Apparel1	Apparel2
Uncertainty intolerance	Very high	Medium	Very high	Medium	Low	Very low	High	Very low
Task uncertainty								
Information processing needs resulting from task uncertainty	Very high	Medium	Very high	Medium	Low	Low	High	Low
Overall task uncertainty	High	Medium	High	Medium	Low	Medium	Medium	Medium
Task scale (Direct spend volume)	High (>€ 10 Bio.)	Medium (>€ 1 Bio.)	High (>€ 10 Bio.)	High (>€ 10 Bio.)	Low (< € 1 Bio.)	Low (< € 1 Bio.)	Medium (>€ 1 Bio.)	Low (< € 1 Bio.)
Task variety (Number of different purchased products)	High (>20.000)	High (>20.000)	High (>20.000)	Medium (>10.000)	Low (<10.000)	High (>20.000)	Medium (>10.000)	NA
Task novelty (Change rate p.a.)	Low (<10%)	Low (<10%)	NA	Low (<10%)	Medium (>10%)	Medium (>10%)	High (>20%)	High (>20%)
Product-related ecologic issue salience	High	High	Medium	Medium	Low	Low	Medium	Medium
Source uncertainty								
Information processing needs resulting from source uncertainty	Very high	Medium	Very high	Medium	Low	Very low	Very high	Low
Overall source uncertainty	High	Medium	Medium	Medium	Medium	Low	High	High
Cultural distance (Hofstede: Headquarters to most important supplier region)	High (Germany to China)	Medium (Switzerland to EU)	High (Switzerland to China)	Medium (Germany to EU)	Low (Germany to Germany)	Low (Germany to Germany)	High (Germany to China)	High (Germany to China)
Socioeconomic distance (HDI: Headquarters to most important supplier region)	High (1,3)	Medium (1,1)	High (1,3)	Medium (1,1)	Low (1)	Low (1)	High (1,3)	High (1,3)
Dynamic within business relations (%<2 years)	Medium (20%)	Low (10%)	Medium (20%)	Medium (20%)	Low (5%)	Low (5%)	High (65%<5)	Low (5%)
Production process-related ecologic issue salience	High	High	Medium	Medium	Medium	Medium	Medium	Medium
Production process-related social issue salience	Medium	Medium	Medium	Medium	Medium	Medium	High	High

(continued)

TABLE 5 (continued)

	Chem1	Chem2	Pharma1	Pharma2	Furniture1	Furniture2	Apparel1	Apparel2
Supply chain uncertainty								
Information processing needs resulting from supply chain uncertainty	Very high	High	Very high	Medium	Low	Low	High	Low
Overall supply chain uncertainty	High	High	High	Medium	Low	Medium	High	Medium
Horizontal complexity (Suppliers per product)	High (1–5)	High (1–6)	Medium (1–3)	Medium (1–3)	Medium (1–3)	Medium (1–3)	Medium (1–3)	Low (1–2)
Vertical complexity (Number of tier levels)	High (2–4)	High (2–4)	High (2–4)	Medium (1–3)	Low (1–2)	Medium (1–3)	High (4)	High (4)
Spatial complexity (Headquarters to most important supplier region)	High (Germany to China: 8700 Km)	High (Switzerland to China: 8800 Km)	High (Switzerland to China: 8800 Km)	Medium (Germany to EU: 1000 Km)	Low (Germany to Germany: 300 Km)	Low (Germany to Germany: 300 Km)	High (Germany to China: 8700 Km)	High (Germany to China: 9000 Km)

Sustainability-related uncertainties were measured with a 3-point scale (high, medium, or low). Uncertainty intolerance and information processing needs were measured with a 5-point scale (very high, high, medium, low, or very low).

of sustainability is not the same across the world due to cultural and regulation differences between western European countries and emerging markets such as China." (Coordinator Sustainability, Apparel2). Resonating with this observation, prior research has found that the institutional distance between the buyer country and the supplier country augments the supply chain sustainability risks (Busse, Kach & Bode, 2016).

Similarly, short, adversarial relationships with suppliers cause uncertainty regarding the supplier's behavior (Flynn & Flynn, 1999; Mudambi & Helper, 1998). Moreover, we identified an industry-specific issue salience that is connected to the production process (e.g., its labor intensity vs. capital intensity) contributing to source uncertainty. These sustainability-related conditions under which suppliers produce the products encompass both environmental and social aspects (Busse, 2016). For example, *"environmental protection plays a major role in the chemical industry. Chemical firms face higher needs than pharmaceutical firms to evaluate their suppliers with regard to ecological criteria"* (Pharma2's Associate Director Group Procurement), thereby indicating high production process-related ecologic issue salience. Hence, we measure source uncertainty based on cultural (Hofstede, 1985) and socioeconomic differences between the buying firm's location and its primary sourcing region (HDI[2]), the dynamic of the business relations between the buying firm and its major suppliers (Awaysheh & Klassen, 2010), and the environmental and social issue salience associated with the suppliers' production processes reported by our informants or revealed by the documents that we analyzed.

Supply chain uncertainty is the third identified type of sustainability-related uncertainty. We define it as uncertainty that arises from the supply chain's *structural* characteristics referring to horizontal, vertical, and spatial complexity (Choi, Dooley & Rungtusanatham, 2001; Choi & Hong, 2002; Choi & Krause, 2006). Managers across all industries agreed that *"We have a verification problem in our supply network if we want to evaluate beyond tier-1 suppliers. The big challenge that we face is that we cannot control all practices and provided data, there is just too much information that we would need to process"* (Head Sustainable Procurement, Chem1). Previous literature has identified supply chain uncertainty to be driven by the number of suppliers per sourced product (horizontal complexity), the number of tiers (vertical complexity), and the physical distance between buying and supplying firms (spatial complexity) (Choi & Hong, 2002). As these dimensions apply to our research context, we assess supply chain uncertainty according to this tripartite measure.[3] To summarize, we posit:

Proposition 2: Buying firms are exposed to sustainability-related (a) task, (b) source, and (c) supply chain uncertainty from their supply chains.

We now turn to the influence of sustainability-related uncertainty on information processing needs. The seminal IPT studies posited that uncertainty results in information processing needs (Bensaou & Venkatraman, 1995; Galbraith, 1973; Tushman & Nadler, 1978), but did not dedicate any attention to the boundary conditions surrounding this effect (Busse, Kach & Wagner, 2016). Our findings indicate, however, that the resulting amount of information processing needs compared with the sustainability-related uncertainty varies across firms (Table 5).

Because information processing needs are not directly measurable, we assessed them indirectly via the application of information processing mechanisms. Information processing mechanisms are the instruments that buying firms employ to create information processing capacity or reduce information processing needs. Therefore, the higher the information processing needs arising from a certain type of uncertainty, the more the information processing mechanisms should be employed that match this type of uncertainty. Therefore, we noticed extreme situations in which some firms, even though facing the same amount of a certain type of uncertainty, apply the fitting information processing mechanisms with different intensity. For example, *Furniture2* and *Apparel1* both face medium levels of sustainability-related task uncertainty, but *Furniture2* does not apply any of the fitting information processing mechanisms, whereas *Apparel1* applies all three intensively. This led us to suspect that some firms face relatively more information processing needs compared with the sustainability-related uncertainty than others. We identified several factors that appear to be effective here. Firms that are listed in financial indexes such as the DJSI are subject to stronger stakeholder scrutiny for sustainable supply chain conduct. Also, firms that proclaim sustainability to be a key cornerstone of their strategy must attain higher performance levels than firms that do not send such symbolic signals. Relatively larger firms also tend to be more visible to stakeholders. Hence, we introduce a moderator for the influence of sustainability-related uncertainty on information processing needs, labeled as *uncertainty intolerance*. We measure the uncertainty intolerance concept with three

[2]The Human Development Index ranks countries regarding their human development, considering life expectancy, education, and income.

[3]Because uncertainty is traditionally viewed as comprising complexity plus dynamism (Duncan, 1972), a measurement of the dynamic component associated with supply chain uncertainty appears desirable. However, due to difficulties in measuring this component reliably, this study focused on the complexity dimension only.

items, considering a firm's sustainability listing, its sustainability strategy according to our leader–follower sampling approach, and its relative size in our sample in terms of revenues (Table 2). The influences of uncertainty intolerance on the effect of sustainability-related uncertainty on information processing needs are depicted in Table 5. We thus posit the following:

Proposition 3a: The higher the (i) task uncertainty, (ii) source uncertainty, and (iii) supply chain uncertainty, the higher the firm's information processing needs.

Proposition 3b: Uncertainty intolerance positively moderates the influences of (i) task uncertainty, (ii) source uncertainty, and (iii) supply chain uncertainty on the firm's information processing needs.

Direct Management of Sustainability-Related Uncertainty

We now turn to our second research question related to direct influences on a firm's sustainability-related uncertainty. The previously posited moderating influence of uncertainty intolerance on the effect of sustainability-related uncertainty on information processing needs helps us to clarify the notion of a direct influence and why it is distinctive. Needs-reducing information processing mechanisms identified by prior IPT studies such as slack resources or self-contained tasks (Galbraith, 1977) also exert moderator effects because they help firms to mitigate the detrimental effects of uncertainty. In contrast, we direct our attention to managerial efforts aimed at directly reducing a form of sustainability-related uncertainty. Given that numerous examples demonstrate on a reoccurring basis that firms often cannot control sustainability-related information processing needs even when they might think they can—as per the introductory examples—direct reduction of sustainability-related uncertainty may be required more often, if we are to progress toward higher sustainability standards in our global supply chains.

We identified measures that directly reduce a type of sustainability-related uncertainty in four of the eight case firms (see Table 6). Three of the four companies are sustainability leaders.

Chem1 pointed us to *insourcing* as a potential reaction to uncontrollable sustainability-related uncertainty. When Chem1 cannot find a supplier that provides accurate, trustworthy, and complete sustainability-related information, it may insource activities to its own production plants as explained by its Head of Sustainable Procurement: *"Lately we tend to make products than to buy them when we can't make sure that the supplier meets our requirements regarding safety standards, etc."* This insourcing decreases the task scale and task variety, thereby reducing a firm's task uncertainty. Depending on the specific supplier's origin, source uncertainty and supply chain uncertainty also decrease.

As another measure, *product redesign* can be employed to decrease the product-related ecologic issue salience, thereby reducing the task uncertainty. *Furniture1* referred to this measure on multiple occasions. For example, their Head of Strategic Sourcing described how the firm required its suppliers to confirm the absence of polycyclic aromatic hydrocarbons, which are potentially carcinogenic chemicals, in the plastic components they delivered. In the same vein, their Head of Environmental Management and the Project Manager Ergonomics portrayed the firm's successful long-term strategy to reduce solvent-containing varnish.

Pharma1's Head of Third Party Operations mentioned two measures, which we denominate as *prolongation of supplier collaboration* and *concentration of the supplier base*, simultaneously by saying *"We actively strive towards fewer suppliers and long-term relations as it is easier to manage sustainability information from 100 suppliers than from 1,000."* Prolongation of supplier collaboration reduces the dynamic within the business relationships with suppliers. When buying firms change their suppliers less frequently, they can rely on past experience and data more strongly, which fosters their rational decision making (Stanczyk, Foerstl, Busse & Blome, 2015). Therefore, this measure effectively reduces the sustainability-related source uncertainty. Concentration of the supplier base is effective as it reduces the supply chain uncertainty, specifically the horizontal dimension of complexity.

Another uncertainty-reducing measure that we labeled *vertical integration within the supply chain* refers to shortening the supply chain in terms of the number of tier levels upstream of the buying firm itself, thereby reducing the supply chain uncertainty, more precisely its vertical complexity component. As such, it is distinct from the aforementioned insourcing measure (i.e., vertical integration to the buying firm). For example, Chem1's Head of Sustainable Procurement explained that new suppliers are deliberately selected based on their value added and are subsequently requested to maintain their high levels of value added.

Our data indicate that *reshoring and nearshoring* represents another uncertainty-reducing measure. Furniture1's Head of Strategic Sourcing not only pointed to the firm's application of this measure, but also underscored that the reason for applying it referred to the sustainability-related uncertainty: *"We withdrew from two Chinese suppliers because we neither could make sure that the information we received was correct, nor could we control on-site. To play it safe, we shifted to collaborating*

TABLE 6

Utilization of Information Processing-Related and Sustainability-Driven Supply Chain Modification Measures

Measure	Reduces...	Chem1	Chem2	Pharma1	Pharma2	Furniture1	Furniture2	Apparel1	Apparel2
Insourcing	Task scale	Yes	No	No	No	Yes	No	No	No
Product standardization and modularization	Task variety	No	No	No	No	No	No	No	No
Product life cycle prolongation	Task novelty	No	No	No	No	No	No	No	No
Product redesign	Product-related ecologic issue salience	No	No	No	No	Yes	No	No	No
Reshoring and nearshoring	Cultural distance	No	No	No	No	Yes	No	No	No
Reshoring and nearshoring	Socioeconomic distance	No	No	No	No	Yes	No	No	No
Prolongation of supplier collaboration	Dynamic within business relations	Yes	No	Yes	No	Yes	No	No	No
Process redesign	Production process-related ecologic issue salience	No	No	No	No	No	No	No	No
Process redesign	Production process-related social issue salience	No	No	No	No	No	No	No	No
Concentration of the supplier base	Horizontal complexity	No	Yes	Yes	No	No	No	No	No
Vertical integration within the supply chain	Vertical complexity	Yes	No	No	No	No	No	No	No
Reshoring and nearshoring	Spatial complexity	No	No	No	No	Yes	No	No	No

with two German suppliers." Reshoring and nearshoring reduces spatial supply chain complexity. In the case of *Furniture1*, which is based in Germany, applying this measure also decreased two facets of source uncertainty simultaneously, namely cultural and socioeconomic distance. On the other hand, the firm incrementally increased the dynamic within its business relations, resulting in a rise of its source uncertainty (although it appears that *Furniture1* seriously doubted the sustainability-related information provided by its original supplier). Again, we see that a single measure taken to reduce sustainability-related uncertainty can have multiple effects which must be viewed in tandem to assess the overall uncertainty effect. If, for example, a New Mexico-based buying firm replaced its long-term Canadian supplier with a Mexican supplier so as to decrease the spatial complexity, the overall sustainability-related uncertainty might actually increase.

From our information processing perspective, the aforementioned measures are conceptually equivalent in that all of them decrease (at least one form of) the sustainability-related uncertainty directly. Therefore, it makes sense to assign a category label to them. We suggest the notion of *sustainability-driven supply chain modification* to refer to the mechanism behind these measures. Sustainability-driven supply chain modification refers to deliberate efforts of the buying firm to modify its upstream supply chain for sustainability-related reasons, in this study specifically also for information processing-related reasons. Sustainability-driven supply chain modification is a specification of environmental modification at the supply chain level of analysis and in the sustainability context. The notion of environmental modification captures the essence of Galbraith's (1977) aforementioned conjecture that firms could also seek to alter their business environment. In the following discussion section, we will consider additional measures that, while unobserved in this study, also employ the sustainability-driven supply chain modification mechanism (see Table 6). Thus, we posit:

> **Proposition 4a:** The sustainability-driven supply chain modification mechanism is capable of decreasing sustainability-related uncertainties directly. It comprises at least insourcing, product redesign, prolongation of supplier collaboration, concentration of the supplier base, and vertical integration within the supply chain, as well as reshoring and nearshoring measures.

Because sustainability-driven supply chain modification measures were observed at only some of the case firms, but not at the others, we further investigated when firms deploy such measures. Prior IPT studies had indicated that firms choose information processing mechanisms based on cost-benefit evaluations (Galbraith, 1970), suggesting that it may be a good idea to specify the respective benefits and costs in applying the sustainability-driven supply chain modification measures. We already elaborated on the benefits in the previous sections. To recap, lower sustainability-related uncertainty translates into lower information processing needs, which allows firms to achieve fit with their information processing capacity more easily. This better fit allows the buying firm to more effectively apply its SSCM practices so that the sustainability performance of the suppliers in its supply chain improves the buying firm's own economic performance (see Figure 1). We now direct our attention to understanding economic costs. Here, the firms that did not apply the sustainability-driven supply chain modification measures were particularly insightful. We focus on the reshoring and nearshoring example.

No respondent ever mentioned the actual costs of applying a sustainability-driven supply chain modification measure as decisive. Rather, highly idiosyncratic opportunity costs matter the most. For example, Pharma1's Head of Responsible Procurement explained the firm's abstinence from the sustainability-driven reshoring and nearshoring as follows: *"We are conscious about the sustainability issues associated with sourcing from China or India. Our credo is to use the price advantages from low labor cost, but at the same time collaborate with the suppliers to ensure high labor and safety standards."* The statement suggests that the opportunity costs associated with reshoring or nearshoring in terms of higher labor costs would overcompensate for the obtainable information processing-related benefits. Therefore, it is rational for the firm from the point of view of its own economic performance not to apply reshoring or nearshoring; rather, it invests in supplier evaluation, monitoring, and development capacity. In the same vein, *Apparel1* continues sourcing from Asian low-cost countries, such as Cambodia and Vietnam, where 90% of its suppliers are located. The costs of reshoring to Europe would be insufferable for the firm as expressed by Apparel1's Chief Sourcing Officer: *"Considering costs, it would be the wrong strategy to employ 200,000 workers to produce shoes in Germany. It is the right strategy to enable our existing supply base to produce sustainable products in a sustainable manner."* The statement also indicates that the firm trusts the manageability of high levels of sustainability-related uncertainty, despite the various recent scandals.

For *Chem1*, more than 50% of its suppliers are based in Asia. Their Manager for Raw Material pointed out that *"for many chemicals, auxiliaries, and pigments, there are simply no suppliers in Europe anymore. Suppliers are all located in Asia. That is why we have to source there."* From the respondent's perspective, the opportunity costs are hence practically infinite. Moreover, he elaborated that "*the big sales markets have changed*

and we serve many customers in Asia"; hence, *Chem1* does also not engage in nearshoring and reshoring.

Conversely, *Furniture1* decided to reshore the production of coated steel from China back to Germany, because its Chinese suppliers could not provide comprehensive and reliable sustainability-related information. In understanding the underlying drivers of this decision, it is worth noting that most of the steel production is now automated, indicating that the labor cost differential between the two locations did not result overall in large labor cost increases. Therefore, the firm assessed the information processing-related benefits of reshoring to be higher than the opportunity costs. Thus, we put forth our final proposition:

> **Proposition 4b:** The obtainable sustainability-related information processing benefits and the sustainability-unrelated opportunity costs are important criteria in explaining a firm's decision to engage in sustainability-driven supply chain modification.

DISCUSSION

We set out to find answers to two questions: (1) "How do sustainability-related uncertainty and information processing needs arise from buying firms' supply chains?" and (2) "Are there any measures for reducing the sustainability-related uncertainty directly?" If so, "How do buying firms deploy these measures?" Our answers to these questions offer both a theoretical and a practical contribution on which we elaborate in this section. Before doing so, we, however, seek to discuss the sustainability-driven supply chain modification mechanism that we identified more comprehensively.

A More Comprehensive View of Sustainability-Driven Supply Chain Modification

Across our case study firms, we identified six distinct measures of firms' attempts to reduce at least one type of sustainability-related uncertainty directly. We refer to the mechanism behind these measures as sustainability-driven supply chain modification. Our operationalization of the three types of sustainability-related uncertainty suggests additional variants of sustainability-driven supply chain modification, which, although we did not observe them in any of our case studies, are theoretically plausible. By going through the items with which we measured the sustainability-related uncertainty (see Table 5), we can thus identify another three theoretically feasible variants of information processing-related and sustainability-driven supply chain modification measures (see Table 6): *product standardization and modularization*, *product lifecycle prolongation*, and *process redesign*. We briefly sketch the basic idea behind each.

By standardizing products and product components (i.e., modularization), firms can decrease the task variety, thereby reducing the total amount of sustainability-related information that needs to be gathered, interpreted, and synthesized. Similarly, prolonging product lifecycles reduces the task novelty, thereby allowing the buying firm to rely on past experience and data more strongly. These measures are theoretically capable of decreasing the sustainability-related task uncertainty. Source uncertainty can also be decreased beyond the empirically identified measures. Specifically, the redesign of production processes can reduce the production process-related ecological and social issue salience. For example, avoiding sand blasting in the production of jeans may prevent buying firms from having to collect information on the protection of workers in these processes (Riddselius, 2010). With respect to supply chain uncertainty, we had already identified measures directed at each item in our case studies.

In line with Proposition 4b, the benefits associated with the aforementioned measures relate to better information processing. For determining the likelihood that the measures are adopted by performance-maximizing buying firms, the benefits must be contrasted with the buying firm's opportunity costs. For example, many consumers demand sand-blasted jeans (Riddselius, 2010), thereby preventing the firms from abolishing these hazards to workers' health.

In this study, we focused only on information processing-related and sustainability-driven supply chain modification measures. Of course, supply chains can (and should, from a normative perspective) also be modified when insufficient sustainability performance is clearly visible.

Theoretical Contribution

This study demonstrates the applicability of IPT to the specific context of sustainability-related uncertainty in the supply chain of the buying firm. It contributes threefold to SSCM and IPT research. First and most basically, it illuminates how information processing facilitates the buying firm's application of SSCM measures. Doing so allows them to steer the suppliers in their supply chain to the levels of sustainability performance that the buying firm requires for maximizing its own economic performance. As such, the sustainability-related information processing represents an instrument and crucial prerequisite for successful SSCM that should be studied in substantially more depth in future research (e.g., in order to develop integrated SSCM reporting measures).

Second, by elaborating on the original intraorganizational (Galbraith, 1973; Tushman & Nadler, 1978)

and interorganizational IPT (Bensaou & Venkatraman, 1995; Premkumar et al., 2005) with case research, the study generates a theoretical explanation for how information processing needs emerge in the context of sustainability at the interorganizational level of analysis. We identify three distinct types of sustainability-related uncertainty, namely task, source, and supply chain uncertainty. They resonate with the dyadic dimensions of task, partnership, and environmental uncertainty that Bensaou and Venkatraman (1995) had studied. The study offers a conceptualization and tentative operationalization for each form. In doing so, it makes a nascent step to elevate IPT to the supply chain level of analysis. From the SSCM perspective, attention to the sustainability-related uncertainty arising from a firm's supply chain facilitates the development of sustainable products, as well as the mitigation of supply chain sustainability risks.

The study also identifies the uncertainty intolerance of firms as an important boundary condition to the influence of uncertainty on information processing needs. While we can think of the three types of sustainability-related uncertainty as objective forms of environmental uncertainty, a firm's uncertainty intolerance captures the more subjective uncertainty amplification stemming from a firm's stakeholder environment. Publicly visible firms, for example, experience more scrutiny from their stakeholders than less visible firms (Chiu & Sharfman, 2011; Schmidt, Foerstl & Schaltenbrand, 2017) and therefore face more information processing needs in relation to their sustainability-related uncertainty.

Third, we identified a new information processing mechanism that decreases the sustainability-related uncertainty directly. We refer to this mechanism as sustainability-driven supply chain modification. It corresponds with the environmental management strategy conceived theoretically by Galbraith (1977). Based on our empirical data and conceptual considerations, we distinguished among nine measures pertaining to this mechanism. Moreover, we developed an explanation for how buying firms deploy this mechanism. We found their sustainability-related information processing benefits and the sustainability-unrelated opportunity costs decisive. The sustainability-driven supply chain modification mechanism is very important for SSCM as it represents an example of a very substantial change to supply chain management practice because of sustainability considerations. In contrast, many extant SSCM measures may best be described as additive, corrective, or even symbolic practices. Likewise, (sustainability-driven) supply chain modification is very important for IPT scholarship as it represents a new information processing mechanism.

Practical Contributions

This study makes a number of contributions to practice. First, it helps buying firms to understand the sustainability-related information processing needs that they face. Building on this study, a buying firm can assess its supply chain for the sustainability-related task, source, and supply chain uncertainty and determine its own uncertainty intolerance. Doing so also allows the firm to juxtapose its own uncertainty management with that of its peers while considering each firm's unique uncertainty context.

Second, the study offers advice to firms that seek to protect their reputation or ensure the sustainability of their products by conducting sustainability-driven supply chain modifications. The study offers a portfolio of nine measures which buying firms can potentially employ to tackle the root cause of the sustainability-related information processing challenge by means of directly decreasing their sustainability-related uncertainty. The study also provides firms with conceptual insights into the criteria with which these measures can be selected. Importantly, as these measures are currently applied only very selectively by other firms, they still offer a relatively high potential for competitive differentiation. In fact, they may even facilitate greenfield approaches and radical business model innovations. For example, some supermarket chains (e.g., Whole Foods Market in the United States or Alnatura in Germany) are positioned as sustainable businesses whose sustainability-related value proposition revolves to a large extent around full information transparency to its customers. These businesses tackle a segment of consumers for whom the information processing-related benefits (i.e., transparency on product components, production processes, origin) are so high that they are willing to pay premium prices for the sustainable products, thereby enabling the supermarkets in turn to purchase supply at premium prices. Accordingly, our sustainability-related information processing perspective may facilitate the identification of new product and customer segments or even help to identify entirely new sustainable business models.

Third, in reaction to supply-side sustainability scandals, focal firms often respond that they did not possess any information about the respective issues. By making the available sustainability-driven supply chain modification measures transparent, this study largely deprives firms of the basis for the usual excuse that the misconduct occurred outside of their organizational boundaries and that they had not known about it. Accordingly, we dare hope that transparency on the possible sustainability-driven supply chain modification measures will help to diffuse their more widespread application and contribute to the development of less unsustainable supply chains (Pagell &

Shevchenko, 2014). We believe this to be an important social contribution.

CONCLUSION

Arguing that insufficient supply chain sustainability is often caused by information deficits, this study explores the emergence of sustainability-related information processing needs in buying firms' complex supply chains. Using a case study research design and elaborating on information processing theory, the study describes three forms of sustainability-related uncertainty, namely task, source, and supply chain uncertainty. Their effect on a buying firm's information processing needs is moderated by a firm's uncertainty intolerance. We identify sustainability-driven supply chain modification as a new information processing mechanism that buying firms can apply to reduce their sustainability-related uncertainty directly and explore its utilization.

We took various means to ensure the validity of our case-based findings. Still, the study is subject to the usual limitations pertaining to this method. Therefore, several opportunities for validating, extending, and complementing this study exist. The measurements of the various types of uncertainty have not yet been formalized and fully operationalized. Future research should develop adequate measurement instruments at the supply chain level and seek to test and possibly refine our findings. The underlying analysis for this study is based on the case firms' uncertainty profiles and the measures they reported. However, the data we took into consideration are recent, and therefore, the profiles do not depict the evolution of uncertainty over time. Future research should amend a longitudinal analysis to verify our findings. Although these limitations need to be addressed in future research, they do not pose substantial limitations concerning our findings on how sustainability-related uncertainty emerges from supply chains and how it can be reduced.

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APPENDIX
Semistructured Interview Guideline

Authors' note: Our guideline depicts the typical questions that we always asked, only. In each interview, we amended specific prompts and questions that arose out of the situation.

- Please comment on the way your firm generally addresses the topic of sustainability.
- Since when and why do you pursue this sustainability strategy?
- What trigger or event motivated your firm to apply the sustainable supply chain management measures?
- What type of changes did this sustainability strategy have on your supply chain and on your purchasing organization?
- Why did you decide on this type of change?
- How is your sustainable supplier evaluation and selection process structured?
- Why do you evaluate and select your suppliers regarding sustainable criteria?
- How often do you evaluate existing and new suppliers?
- Up to which tier of your supply chain do you evaluate your suppliers?
- What challenges do you face in evaluating and selecting suppliers regarding sustainable criteria?
- What qualifies you to evaluate and select suppliers with regard to sustainable criteria?
- How is your sustainable supplier development process structured?
- Why do you develop your suppliers regarding sustainable criteria?
- How do you determine whether a supplier will be developed and with what type of support?
- What challenges do you face in developing suppliers regarding sustainable criteria?