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Technology uncertainty in supply chains and supplier involvement: the role of resource dependence

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Abstract

Purpose – Technology uncertainty poses significant challenges to manufacturers, as rapid changes in product and/or process standards and specifications can disrupt the smooth flow of materials in extended supply chains. Practitioners and researchers alike who take a relational perspective widely regard supplier involvement as a potentially effective strategy to cope with technology uncertainty, as focal manufacturers can tap into their upstream supply networks for complementary resources and capabilities. However, the literature lacks a nuanced understanding of the supplier involvement processes. Specifically, the role of resource dependence for supplier involvement has yet to be systematically understood. To fill this gap, this study aims to combine the relational perspective with the resource-dependence perspective to explore how buyer dependence, supplier dependence and buyer–supplier interdependence influence buyers' decision-making on tapping into upstream supply networks for coping with technology uncertainty.

Design/methodology/approach – To test the hypotheses, a survey is conducted among Dutch firms with more than 50 employees in the discrete manufacturing industries (ISIC 28-35), resulting in a sample of 125 manufacturers.

Findings – First, there is a significantly positive relationship between technology uncertainty and supplier involvement, giving support to the expectation that buyers are indeed involving their key suppliers in the product/process design and improvement, as a response to technology uncertainty. Second, buyer dependence and interdependence are found to be positively moderating the relationship between technology uncertainty and supplier involvement. In contrast, supplier dependence has a negative moderating effect on the baseline relationship.

Research limitations/implications – The authors contribute to a relational view on buyer–supplier relationships by showing that the validity of this view, in the context of technology uncertainty, is contingent on the resource dependence between buyers and suppliers, and the authors contribute to the supply chain management literature more generally by combining a relational perspective with a resource-dependence perspective.

Practical implications – The findings provide several nuanced insights into the effect of resource dependence (buyer dependence, supplier dependence and interdependence) on supplier involvement for coping with technology uncertainty.

Originality/value – This study contributes to the supply chain management research by going beyond the benefits of supplier involvement and highlights the circumstances under which supplier involvement is likely to occur.

Keywords Uncertainty, Supplier involvement, Interdependence, Buyer dependence, Relational view, Resource dependence theory

Paper type Research paper

Introduction

It is a cliché to say that the business environment is becoming more and more uncertain: consumer preferences are becoming more diverse and transient, and new products need to be introduced regularly to cater for the changing tastes and preferences (Wong *et al.*, 2011; Zhou *et al.*, 2014). Changing demands and fierce competition are driving rapid adaptations and innovations in manufacturing technologies (Chung and Swink, 2009). As such, it is not surprising that manufacturers around the world generally feel challenged by technology uncertainty: on the one hand, they have to exploit their manufacturing technologies to seek stability and efficiency; on the other, they have to explore new technologies so as to avoid market obsolescence (Andriopoulos and Lewis, 2009; Lüscher and Lewis, 2008).

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An aspect of this is that the rapid changes in product specifications and process technologies pose significant challenges to supply chain management, where one is seeking a dynamic balance between demand and supply (Ellram *et al.*, 2013). How can manufacturers cope with technology uncertainty? From a relational perspective, supplier involvement, which entails close collaboration between buyers and key suppliers in product design/modification and in process design/modification (Takeishi, 2001; Menguc *et al.*, 2014; Yan and Nair, 2016; Cheng and Krumwiede, 2018), is regarded as a potentially effective strategy for coping with this issue.

Technology uncertainty concerns changes in the standards and/or specifications of products and processes that are inherent to a firm's industry (Oh and Rhee, 2008; Stock and Tatikonda, 2008; Huo *et al.*, 2018). Technology uncertainty reduces the ability of manufacturers in a chain to control the flow of materials, imposes adaptation problems, and thus increases the need for additional support from suppliers in the design of, and adaptations to, products and processes (Song and Di Benedetto, 2008; Huo *et al.*, 2018). Growing evidence indicates that involving suppliers in the product and process design and improvement can help manufacturers cope with technology uncertainty (Johnsen, 2009). For example, systematic comparisons between Japanese and American automotive manufacturers found that "the problems associated with technology uncertainty can be mitigated by greater use of technology sharing and direct supplier participation on new product development teams" (Petersen *et al.*, 2003, p. 284). This perspective is referred to as a relational view on buyer–supplier relationships.

This study aims to extend this relational view of supplier involvement by exploring the role of resource dependence in shaping buyers' decision-making regarding tapping into upstream supply networks to cope with technology uncertainty. The relational view (Dyer and Singh, 1998; Dyer *et al.*, 2018) proposes four primary determinants of inter-organizational value creation: complementary resources and capabilities, relationship-specific investments, knowledge-sharing routines and effective governance. Adopting the relational view, we propose a positive relationship between technology uncertainty and supplier involvement because having access to complementary resources in supply networks is pivotal to firm survival in the face of technology uncertainty. This hypothesis underpins this study. Further, using the resource dependence theory, we develop two moderating hypotheses to gain more nuanced insights into the effects of resource dependence (reflecting situations in which the buyer is dependent and in which the supplier is dependent) on the baseline relationship between technology uncertainty and supplier involvement. The resource dependence theory (Pfeffer and Salancik, 2003; Hillman *et al.*, 2009) contends that organizational actions are primarily driven by resource considerations, and that resource complementarity among firms can, to a large extent, explain the relationships and interactions among them. Finally, we argue that the baseline relationship can be further strengthened in situations where the buyer and the supplier are interdependent (or mutually dependent).

To test these hypotheses, we conducted a survey among Dutch manufacturers with more than 50 employees who were active in discrete manufacturing industries. Approximately 700 firms formed the target population of this study, and 125 completed responses were collected, a response rate of 17.86 per cent. Hierarchical regression analyses were conducted, and all three moderating hypotheses received adequate support from the empirical data.

This study makes two main contributions to the literature on supplier involvement. First, this study goes beyond exploring the direct relationship between technology uncertainty and supplier involvement, which has been the dominant research paradigm in the relational view of buyer–supplier relationships (Petersen *et al.*, 2003; Petersen *et al.*, 2005; Yan and Nair, 2016). Specifically, we differentiate between buyer dependence, supplier dependence and interdependence in exploring the effect of inter-organizational resource dependence in shaping buyers' responses to technology uncertainty. That is, we discuss three dependence situations:

1 a situation in which the buyer is dependent;
2 a situation in which the supplier is dependent; and
3 a situation in which the buyer and supplier are mutually dependent.

We contribute to the relational view of buyer–supplier relationships by showing that the validity of this view is contingent on the dependences of buyers and suppliers, and we contribute to the more general supply chain management literature by combining a relational perspective with a resource-dependence perspective. In doing so, this study takes an incremental step in delving into the process of involving suppliers to cope with technology uncertainty. Second, the empirical setting of this study, 125 Dutch small- and medium-sized enterprises in discrete manufacturing industries, enables a contribution to the literature on supplier involvement, given that earlier studies have mostly drawn on American and Japanese electronics and automotive industries (Johnsen, 2009; Yan and Nair, 2016). Testing the hypotheses in more diverse social, economic, cultural and institutional environments can increase the robustness of operations and supply chain management theories.

Theoretical foundation and hypotheses development

This section consists of two subsections. First, we provide an overview of the challenges posed by technology uncertainty for supply chain management and discuss the role of supplier involvement in coping with these challenges. Taking the relational view as our theoretical lens, we develop the baseline hypothesis between technology uncertainty and supplier involvement in this subsection. Second, taking the resource dependence theory as our second theoretical lens, we introduce three forms of buyer–supplier resource dependence (buyer dependence, supplier dependence and interdependence) and elaborate on their effects in shaping buyers' decision-making on tapping into upstream supply networks to cope with technology uncertainty. We formulate three moderating hypotheses, which are the focus of this study.

Technology uncertainty and supplier involvement

Technology uncertainty is present when the standards and specifications of products and processes are subject to rapid changes (Oh and Rhee, 2008). Technology uncertainty can disrupt the flow of materials throughout the supply chain by posing adaptation problems for supply chain partners. Such adaptation problems may lead to products that do not meet the requirements of customers. Revenue losses may result, which can spread along the supply chain and impact the buyer's suppliers, and even the suppliers' suppliers (Fynes and Voss, 2002). As a consequence, it is in the interest of focal firms in the supply chain to involve their suppliers in their decision-making processes to counteract technology uncertainty and assure the smooth flow of materials throughout the supply chain (Steele and Court, 1996; Lapré, and Scudder, 2004; Cousins, 1999; Handfield and Nichols, 2004; Ketokivi and Schroeder, 2004; Stock *et al.*, 2000; Schmenner and Vastag, 2006; Simpson *et al.*, 2007). It is not only in the interest of the focal firm to resolve technology uncertainty but also in the interest of the buyer's suppliers (Petersen *et al.*, 2003; Yan and Nair, 2016).

Researchers with various backgrounds (e.g. new product development, manufacturing technologies and supply chain management) have highlighted supplier involvement (Takeishi, 2001) as an effective strategy for coping with technology uncertainty. In this literature, the authors emphasize that supplier involvement can occur in various areas such as the design and adaptation of products and processes, cost control and quality improvement (Vickery *et al.*, 1997; Dyer and Singh, 1998). From this relational perspective, the value of involving key suppliers in the product/process design resides in having access to the resources and capabilities in upstream supply networks (Johnsen, 2009). In other words, supplier involvement does not simply mean getting one or two key suppliers on board. Rather, it provides the focal manufacturer with the opportunity to understand the core resources and capabilities of tier-one suppliers and also the configurations of upstream supply networks (tier-two and even tier-three suppliers) (Hartley *et al.*, 1997; Petersen *et al.*, 2005; Song, and Di Benedetto, 2008). This broader overview of upstream supply networks can facilitate knowledge sharing and creation, new product development and resource/capability pooling (Reinholt *et al.*, 2011).

Adopting the theoretical lens of the relational view, we argue that supplier involvement can help the focal manufacturer tap into a larger network of suppliers and access complementary resources and capabilities. As an example, during a field study in the consumer electronics industry, we observed the following example. To comply with newly enforced laws on environmental protection in China, an original equipment manufacturer had to change its product design as well as its production technologies. By involving a key supplier of printed circuit boards, the manufacturer could access its tier-two and tier-three suppliers. The manufacturer could then start a project on product redesign with the project team consisting of product engineers and quality managers from three tiers of supply chain partners. The collaboration project was very successful, and the redesigned product met the environmental standards. Moreover, the production process also became less polluting and manufacturing costs fell by more than 40 per cent.

Several supply chain studies have shown that 30 per cent of quality problems and 80 per cent of product lead-time problems originate at suppliers (Petersen *et al.*, 2005; Takeishi, 2001). Supplier involvement can counteract such disturbances, for example, by providing the supplier with detailed insights into the buyer's needs and processes. Consequently, within supply chains, buyers and suppliers can derive benefits such as reduced transaction costs, increased revenue through reduced uncertainty, increased innovativeness, improved quality of purchased components, reduced lead-times and enhanced supply chain responsiveness. Based on these arguments, the baseline hypothesis is as follows:

H1. There is a positive relationship between technology uncertainty and supplier involvement because manufacturers experiencing technology uncertainty will benefit from tapping into upstream supply networks to access complementary resources and capabilities.

Resource dependence: contingent on supplier involvement

While supplier involvement can enable the focal manufacturer (i.e. the buyer) to access complementary resources and capabilities in its supply networks, the downsides of this practice should not be overlooked (Menguc *et al.*, 2014). First, involving suppliers can reveal the buyer's core product and process technologies, increasing the risk of knowledge leakage to the suppliers and even to other buyers sourcing from these suppliers (Dyer and Nobeoka, 2002). Second, inter-organizational collaboration on new product development and process improvement can trigger substantial transaction costs, including investments in streamlining communication channels between managers and engineers, and coordination costs in conflict avoidance and resolution (Wynstra and Pierick, 2000; Yan and Nair, 2016). Third, supplier involvement adds to the embeddedness of the buyer–supplier relationship, making it more difficult for the buyer to switch to alternative suppliers, should the supplier fail to perform adequately or behave opportunistically (Zhou *et al.*, 2014). Therefore, when faced with technology uncertainty, a buyer has to balance the bright and the dark sides of supplier involvement. Resource dependence (Pfeffer and Salancik, 2003; Gulati and Sytch, 2007; Hillman *et al.*, 2009) between the buyer and supplier can be an important factor in shaping a buyer's decision-making on supplier involvement. Here, prior studies (Petersen *et al.*, 2005; Song and Di Benedetto, 2008; Wasti and Liker, 1997; Schoenherr and Wagner, 2016) have suggested that resource complementarity should be a prime criterion when considering supplier involvement or integration.

In a nutshell, resource dependence is an indication of the extent to which a firm in a supply chain needs to maintain information and material resources exchange with individual supply chain partners (Gulati and Sytch, 2007; Marshall *et al.*, 2015). In general, it reflects the number of alternative partners a firm has, the switching costs to an alternative partner and the disruption costs when a relationship is terminated. In the specific context of supply chain management, resource dependence has the following three facets: buyer dependence, supplier dependence and interdependence (also referred to as mutual dependence or joint dependence) (Gulati and Sytch, 2007). Below, we elaborate on the specific sources of each aspect of resource dependence and discuss its effect on the buyer's decision-making on involving suppliers in coping with technology uncertainty.

Buyer dependence

Manufacturers rely on their upstream supply networks for materials, components and services (Pathak *et al.*, 2007). While the literature on supply chain management has provided strong evidence of the value of single sourcing, manufacturers are widely adopting dual or even multiple sourcing to create competition among suppliers, to facilitate knowledge sharing and creation and to mitigate supply risks associated with supplier breakdown, quality issues and natural disasters (Zorzini *et al.*, 2015; Ellram *et al.*, 2013). From a resource-dependence perspective, manufacturers would, whenever possible, prefer having multiple suppliers available to avoid becoming dependent on any single supplier. However, buyer dependence on suppliers cannot always be avoided. For example, a buyer as powerful as Apple can still be dependent on Foxconn, the world's largest manufacturer of electronic products. There are many sources of buyer dependence, and a common source widely reported in the literature is the unbalanced distribution of complementary resources and capabilities between the manufacturer and supplier. Here, a manufacturer can be dependent on a supplier that has non-substitutable strategic resources, superb technological expertise and/or competitive supply networks (Bensaou, 1999). Taking the Apple–Foxconn relationship as an example, Apple's dependence on Foxconn is mainly due to the latter's new product development capabilities, manufacturing capacity and extensive and competitive supply network. In short, buyer dependence means that the manufacturer cannot easily switch to another supplier and/or retain access to the strategic inputs provided by the current supplier. From a resource-dependence perspective, a buyer will, when faced with technology uncertainty, very likely be willing and even eager to involve such a supplier in the product design/modification and process improvement. This is because such a supplier can provide the buyer with access to complementary resources and capabilities that are embedded in the supplier and its upstream networks (Song and Di Benedetto, 2008). This leads to our second hypothesis:

H2. Buyer dependence positively moderates the relationship between technology uncertainty and supplier involvement because it makes manufacturers more willing to involve those suppliers on which the manufacturers are dependent for strategic resources, technological expertise and/or upstream supply networks for coping with technology uncertainty.

Supplier dependence

Suppliers rely on downstream manufacturers to have access to downstream markets. A golden principle of customer management is to avoid being heavily dependent on a small number of buyers (Olsen and Ellram, 1997). If a supplier is trapped in a relationship with a specific buyer, the supplier may well have limited bargaining power and be vulnerable to exploitation (Cox *et al.*, 2003). From another perspective, supplier dependence can be beneficial for the buyer, as the latter can take advantage of its greater power to seek performance improvements. The resource-dependence perspective suggests several strategies that suppliers can apply to maintain balanced relationships with their customers. For example, a supplier can supply a large pool of customers so that none of them can easily dominate the supplier. Second, the supplier can develop advanced technologies and capabilities that have wide applications in different industrial sectors. Third, the supplier can form strong alliances with its upstream suppliers, ones that cannot be easily replicated. However, due to the asymmetrical nature of buyer–supplier relationships, supplier dependence remains the norm rather than the exception (Moeller *et al.*, 2006; Klassen and Vachon, 2003).

In a buyer–supplier relationship that is characterized by supplier dependence, it is very likely that the buyer is already providing more than it is receiving in terms of complementary resources and capabilities from this dyad (Huo *et al.*, 2017). As such, from a resource-dependence perspective, involving such a supplier cannot substantively help the buyer cope with environmental uncertainty. On the contrary, in terms of technology acquisition and/or development, such a supplier can be a burden rather than a valuable asset for the buyer (Stock and Tatikonda, 2000; Ragatz *et al.*, 2002). Involving the supplier in new product development and process improvement will further embed this relationship, which will make it more difficult for the buyer to cope with environmental uncertainty (Primo and Amundson, 2002; Johnsen, 2009; Uzzi, 1997; Choi and Kim, 2008). As an example, Primo and Amundson (2002) found that involving dependent suppliers would not help new ventures succeed with radical innovations. The potential risk of becoming trapped will discourage a buyer from involving the dependent supplier in new product development and process improvement. In such scenarios, the dark side of supplier involvement will very likely outweigh the bright side of supplier involvement in coping with technology uncertainty. This leads to our third hypothesis:

H3. Supplier dependence negatively moderates the relationship between technology uncertainty and supplier involvement. Faced with technology uncertainty, the buyers are less willing to involve dependent suppliers in product and process improvement because such suppliers cannot provide them with complementary resources and capabilities.

Interdependence

The resource dependence theory posits that buyers and suppliers in supply chains will generally avoid becoming dependent on each other (Bensaou, 1999; Chae *et al.*, 2017). Buyers can implement multi-sourcing and then play suppliers against each other. Conversely, suppliers can develop multiple customers to avoid becoming overly dependent on a single buyer, which could place them in a disadvantaged position. Nevertheless, the regular interactions between buyers and suppliers will inevitably create a sense of interdependence between them, that "we are in the same boat," even if managers on both sides take measures to avoid it becoming an asymmetrical relationship in which they are the more dependent party. Interdependence breeds a sense of embeddedness such that supply chain partners will increasingly identify with each other and, in the long term, their values, attitudes and goals will converge (Gulati and Sytch, 2007; Lins *et al.*, 2017).

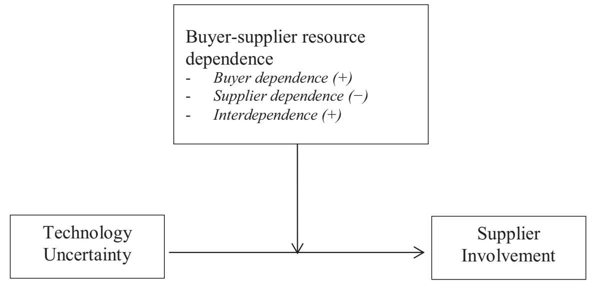
While the resource dependence theory does not provide a clear prediction of the effect of this interdependence, the relational view (Dyer and Singh, 1998; Dyer *et al.*, 2018) suggests that interdependence may drive the buyer to involve the supplier in coping with technology uncertainty. First, interdependence can motivate the buyer and supplier to develop knowledge-sharing routines. As managers in mutually dependent relationships increasingly develop convergent values, attitudes and goals, they will find it easier to exchange information and knowledge with each other. In time, explorative practices in knowledge sharing and creation will gradually solidify into more systematic routines between the buyer and supplier. Second, interdependence can facilitate the development of goodwill and trust between partners (Caniëls and Gelderman, 2007; Marshall *et al.*, 2015), which will act as a safeguard for relationship-specific investments. Knowledge-sharing routines and relationship-specific investments will dynamically co-evolve in the relationship, providing a fertile ground for the generation, activation and adaptation of complementary resources and capabilities in the buyer–supplier relationship, and even in a broader network. That is to say, when faced with technology uncertainty, the buyer may well be willing to involve suppliers that are interdependent with the buyer (Petersen *et al.*, 2005). Even if the supplier does not readily have the resources and capabilities to help the buyer cope effectively with technology uncertainty, the knowledge-sharing routines and relationship-specific investments in the interdependent buyer–supplier relationship can motivate and facilitate them to develop these resources and capabilities from their upstream supply networks. Further, the additional costs and risks of involving such suppliers will be minor as communication channels are already at place, and the increased transaction costs will not be substantial.

When interdependence is high, the risk that one of the parties will terminate this relationship is low, and it is unlikely that either party will demonstrate opportunistic behaviors. Rather, it is more likely that both parties will trust and share knowledge with each other. Buyers and suppliers in interdependent relationships may achieve a symbiosis through their better understanding of each other's interests, greater cooperation and more mutually beneficial behaviors. This leads to our fourth hypothesis:

H4. Interdependence positively moderates the relationship between technology uncertainty and supplier involvement because the manufacturer can leverage the interdependent buyer–supplier relationship to identify and develop complementary resources and capabilities for coping with technology uncertainty.

The hypothesized relationships between the main concepts are shown in Figure 1.

Figure 1 Research framework



Methods

Sample

To test the hypotheses, we conducted a survey among Dutch firms with more than 50 employees operating in discrete manufacturing industries (Dutch Chamber of Commerce BIK codes 28-35; 28 metal parts and products; 29 machines and equipment; 30 office equipment and computers; 31 other electronic machines, devices and appliances; 32 audio-, video- and telecommunication devices and appliances; 33 medical devices and instruments; 34 cars and trailers; 35 transportation means other than cars). Approximately 700 firms formed the target population. Potential respondents were approached by telephone. If the manager in charge of supply chain relationships agreed to participate, a link to a website was sent to them where they could complete the questionnaire online. If the questionnaire was not completed within two weeks, we phoned the respondent as a reminder. To ensure that the supply chain relationships were comparable, we asked the respondents at the buying firms to complete the survey for their *fourth* largest supply relationship in terms of revenue. Our reasoning was that the fourth largest supplier would be a relevant supplier, and that buyer responses were less likely to be biased than for the largest suppliers where, for example, socially desirable responses might be provided (Anderson and Narus, 1990). This selection criterion also ensured sufficient variation in the relationships studied. We collected 125 completed questionnaires (a response rate of 18 percent).

Measurements

Content validity was achieved through a comprehensive review of the literature to distill initial items and the involvement of practitioners and researchers to refine them further. First, five academics from different business and economics disciplines reviewed the items. These experts were active international researchers on supply chain management and/or global value chains. Following this, 12 supply chain practitioners, from the UK, USA, Germany and The Netherlands, with extensive experience in the discrete manufacturing industries (having worked on average in this field for more than 20 years) commented on the appropriateness of the research constructs and items. No item was found to be ambiguous or inappropriate. Furthermore, the academics and practitioners deemed the constructs to be adequately covered by the items. The questions, items and answer categories of all scales are provided in Appendix.

Supplier involvement

To measure this construct, we reviewed and slightly adapted the "joint action" construct of Gulati and Sytch (2007). This scale was designed to reflect the involvement of a supplier in a buyer's decision-making. To align the operational definition with the conceptual definition provided in the introduction, we modified the scale to specify the extent to which the supplier is involved in various aspects of the design/modification of the product and the production process (whereas the original scale only captured involvement in "design"). The respondents were asked "Please indicate this supplier's involvement in your plant's decision-making about the products of your plant which contain components that this supplier supplies to you." This was coupled to several items. An example item being "Product modification," and the answer categories were: 1 = not involved at all, 2 = slightly involved, 3 = moderately involved, 4 = involved and 5 = involved to a great extent.

Technology uncertainty

This measure was developed to reflect unpredictable changes in products and processes. We combined the "technology uncertainty" scale of Chen and Paulraj (2004), which emphasizes process innovation, with the "supply chain dynamism" scale of Zhou and Benton (2007), which more explicitly includes items on product uncertainty. The items were introduced by "Please indicate if the following statements apply to the relationship between your plant and this supplier." Here, an example item is "Products and services are innovated frequently." The response categories were: 1 = completely disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree 5 = completely agree.

Resource dependence

The measures for resource dependence were adapted from Gulati and Sytch (2007) to reflect the number of alternative trading partners (Kumar *et al.*, 1995), the costs of switching (Heide and John, 1990) and the extent of potential disruptions in production or sales if a switch would occur (Pfeffer and Salancik, 2003). The items for buyer and supplier dependence were similar, but reworded as appropriate (see the examples below). The items were introduced with: "Please indicate if the following statements apply to the relationship between your plant and this supplier." An example item for buyer dependence was "We would face serious production problems if this supplier stopped supplying these components to us," and an example for supplier dependence was "If we withdrew our business from this supplier, it would require much trouble and expense for them to find other buyers." The response options were: 1 = completely disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree 5 = completely agree. Interdependence was operationalized as the intersection between buyer and supplier dependence (Casciaro and Piskorski, 2005; Gulati and Sytch, 2007). More specifically, the scores for buyer and supplier dependence were multiplied. In previous research, these scores were sometimes added to calculate interdependence (Caniëls and Gelderman, 2007; Gulati and Sytch, 2007) and sometimes multiplied. We accepted Casciaro and Piskorski's (2005) arguments that multiplication is a superior method.

Measurement model

Validation of constructs

Exploratory factor analysis (EFA) was performed using SPSS. To extract the factors, we used the principal component method with varimax rotation (see Table I). The items loaded onto the four expected factors: technology uncertainty (TU), buyer dependence (BD), supplier dependence (SD) and supplier involvement (SI) with no significant cross-loadings. The variance explained was 61.1 per cent. Cronbach's α was 0.79 for BD and 0.77 for SD, values that compare favorably to earlier studies (Gulati and Sytch, 2007). Further, Cronbach's α for TU and SI were 0.84 and 0.87, respectively.

Table II provides the descriptive statistics and correlations between the main variables. All the independent variables (BD, SD and TU) are significantly and positively correlated with SI. This is in line with previous studies in supply chain management (Chen and Paulraj, 2004; Gulati and Sytch, 2007; Zhou and Benton, 2007). Furthermore, the dependencies of buyers and suppliers in the supply chain are also significantly positively correlated.

Common method variance

There are ex ante and ex post ways to address concerns over common method variance (Guide and Ketokivi, 2015). Ex ante, we ensured that the respondents used were knowledgeable, guaranteed their complete anonymity and asked them to answer questions as best they could or alternatively to leave the question blank if they were unsure. In practice, no items were left blank by the respondents. Ex post, we statistically tested for common method bias (CMB) using Harmon's single-factor test (Podsakoff *et al.*, 2003). The single un-rotated factor explained less than 50 per cent of the variation, and this indicates that CMB is not a major concern.

Control variables

We followed the recommendations of Becker (2005) and only included control variables that have conceptually and empirically been shown to affect the dependent variable. Such variables should be included because they may suppress the effects of the independent variables and may affect the generalizability of a study's results. However, variables that do not meet these criteria should be excluded to avoid Type II errors and a loss of statistical power (Becker, 2005).

Control variables that could play a role are relationship length and the type of industry because these demographics could influence the level of supplier involvement. It is plausible that buying firms may more readily involve suppliers with whom they have had lengthy relationships than suppliers with whom they have a relatively short relationship. Similarly, it is possible that supplier involvement is more common in some industries than in others.

Using our data set, we found that relationship length was not significantly correlated to supplier involvement ($r = -0.11$, n.s.) and we, therefore, did not include it as a control variable. We then performed an ANOVA test using the BIK codes to assess if industry was significantly associated with SI. This indicated that the level of SI does not differ across industries (F [8,116] = 0.97, n.s.) and, therefore, industry was also excluded from the regression analyses.

Table I EFA result for SI, technology TU, BD and SD. Only factor loadings above 0.40 are shown

Items	Factor loadings			
	F1-SI	*F2-TU*	*F3-BD*	*F4-SD*
Initial product design	0.70			
Product modification	0.80			
Initial production process design	0.78			
Production process modification	0.81			
Production process planning	0.72			
Quality improvement	0.73			
Cost control	0.66			
Products and services are innovated frequently		0.80		
The innovation rate of operating processes is high		0.79		
These products are characterized by rapidly changing technology		0.81		
If we do not keep up with changes in technology, it will be difficult for us to remain competitive		0.65		
Production processes quickly become outdated for these products		0.66		
The production technology changes frequently and significantly		0.77		
Switching to another supplier would involve us in considerable trouble and expense			−0.70	
For the components which we procure from this supplier, there are enough other potential suppliers to ensure adequate competition among the current suppliers			0.82	
Satisfactory alternative sources of short-term supply are available for these components			0.83	
We would face serious production problems if this supplier stopped supplying us with these components			−0.67	
If we withdrew our business from this supplier, it would be a lot of trouble and expense for them to find other buyers				0.77
For the components which we procure from this supplier, the supplier could find enough other potential buyers to ensure an adequate price				−0.82
In the short term, there are satisfactory alternative buyers available for this supplier's components				−0.62
This supplier would face a serious financial crisis if we withdrew our business				0.73
Initial eigenvalue	*5.38*	*3.27*	*2.50*	*1.69*
% of variance	*25.6*	*15.6*	*11.9*	*8.0*
Cumulative % of variance	*25.6*	*41.2*	*53.1*	*61.1*

Table II Descriptions and correlations of SI, TU, BD and SD

Variables	Mean	SD	Min	Max	1	2	3	4
1. BD	3.02	0.92	1.00	4.75	–			
2. SD	3.03	0.80	1.00	5.00	0.34**	–		
3. TU	2.70	0.69	1.00	4.33	0.12	0.00	–	
4. SI	1.89	0.84	1.00	4.14	0.25**	0.21*	0.28**	–

Notes: **Significant at $p < 0.01$; *significant at $p < 0.05$

Analyses

We tested the hypotheses through hierarchical multiple OLS regressions using SPSS. We first included the three independent variables: TU (*testing H1*), BD and SD. In the second model, we added the interaction effects between TU and BD (*testing H2*), TU and SD (*testing H3*), BD and SD (the measure for interdependence) and the interaction between the three variables (TU, BD and SD) (i.e. the interaction between TU and interdependence (BD by SD), *testing H4*). In all the regressions, we used standardized predictors to enhance the interpretation and to reduce multicollinearity problems. Hypothesized weights were subjected to a one-sided test.

Results

The results of the regression analysis are presented in Table III. It is clear that TU is positively related to supplier involvement

Table III Results of OLS regression (standardized variables) for SI with technology uncertainty = TU, buyer dependence = BD, supplier dependence = SD. Interdependence = BD × SD

Variables	Model 1 Estimate	Model 1 SE	Model 2 Estimate	Model 2 SE
Constant	1.89**	0.07	1.82**	0.07
TU	0.21**	0.07	0.15*	0.08
BD	0.15*	0.08	0.19**	0.08
SD	0.13*	0.08	0.05	0.08
TU × BD			0.22**	0.07
TU × SD			− 0.15*	0.07
BD × SD			0.10	0.07
TU × BD × SD			0.11*	0.06
R^2	*0.15***		*0.23***	
R^2 *change*	*0.15***		*0.08***	

Notes: **Significant at $p < 0.01$; *significant at $p < 0.05$

($b = 0.21$, $p < 0.01$, Model 1), giving support to *H1*: that technology uncertainty drives manufacturers to tap into their upstream supply networks for complementary resources and capabilities.

H2 posited that BD would positively moderate the relationship between TU and SI, as buyers would be more willing to involve suppliers on whom they were dependent for strategic resources, technological expertise and upstream supply networks to cope with technology uncertainty. Table III (Model 2) shows that the interaction is significant and positive ($b = 0.22$, $p < 0.01$). The moderation effect is depicted in Figure 2. Simple slope tests show that, with low BD, there is no significant relationship between TU and SI ($b = -0.07$, n.s.) and that, with high BD, the relationship is significant and positive ($b = 0.37$, $p < 0.01$). These results are in line with *H2*.

In *H3*, we claimed that SD would negatively moderate the relationship between TU and SI. Table III (Model 2) shows that the interaction term is significant and negative ($b = -0.15$, $p < 0.05$). The moderation effect is shown in Figure 3. Simple slope tests indicate that there is a positive relationship between TU and SI if SD is low ($b = 0.30$, $p < 0.01$), but not if SD is high ($b = 0.01$, n.s.). These findings support *H3*.

H4 stated that interdependence would positively moderate the relationship between TU and SI because the buyer could leverage the interdependent buyer–supplier relationship to identify and/or develop complementary resources and capabilities to cope with TU. Table III (Model 2) demonstrates that the interaction (TU × BD × SD) between TU and independence (BD × SD) is indeed significant and positive ($b = 0.11$, $p < 0.05$). Simple slope tests (see Figure 4) show that the relationship between technology and SI is not significant for low interdependence ($b = 0.04$, n.s.) but significant for high interdependence ($b = 0.26$, $p < 0.05$). These results support *H4*.

Figure 2 The two-way interaction between TU and BD for SI

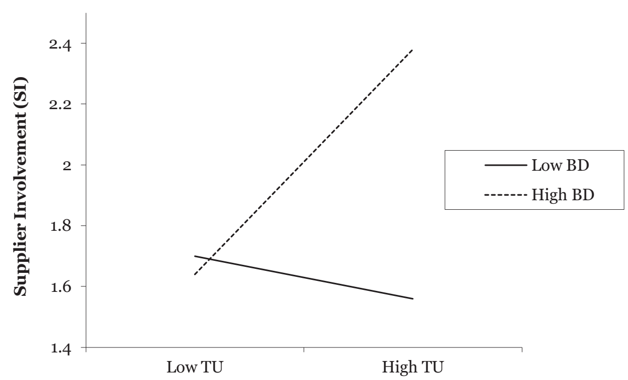


Figure 3 The two-way interaction between TU and SD for SI

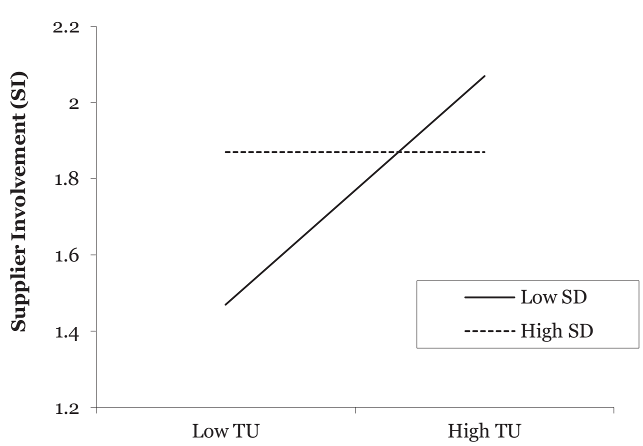
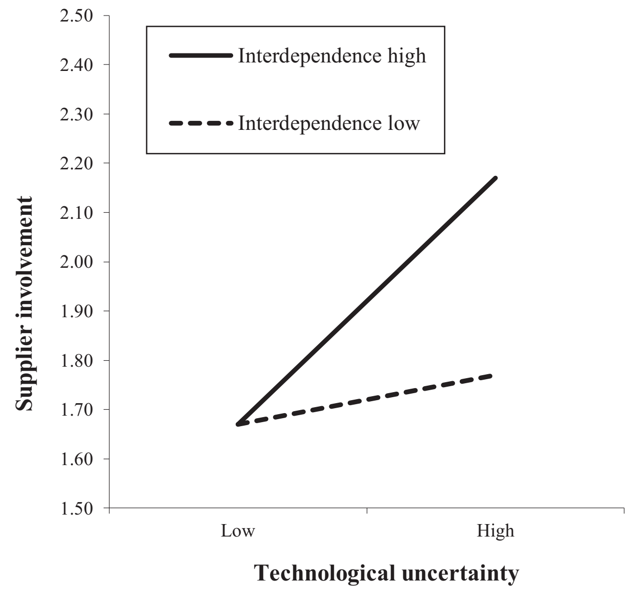


Figure 4 The two-way interaction between TU and interdependence (SD × BD) for SI



Discussion and conclusions

Theoretical implications

Previous studies (Stock and Tatikonda, 2008; Johnsen, 2009; Yan and Nair, 2016) indicate that higher levels of TU induce higher levels of SI, a finding in line with the relational view. In this study, we argued that the resource dependence theory could inform a more nuanced understanding of the relationship between TU and SI. More specifically, resource dependence between supply chain members could impact on buyers' decision-making, when faced with technology uncertainty, over tapping into upstream supply networks for complementary resources and capabilities. Incorporating the resource dependence theory, we formulated three moderating hypotheses to address the effects of BD, SD and interdependence on the relationship between TU and SI. First, we hypothesized that BD positively moderates the relationship between TU and SI because buyers would be more willing to involve suppliers on which they are dependent for strategic resources, technological expertise and upstream supply networks to cope with TU. Second, we hypothesized that SD would negatively moderate the relationship between TU and SI because dependent suppliers generally have little to offer when the buyer is struggling to cope with TU. Third, we hypothesized that buyer–supplier interdependence positively moderates the relationship between TU and SI because the buyer can leverage interdependent buyer–supplier relationships to identify and/or develop complementary resources and capabilities to cope with TU. Statistical analyses of data from 125 Dutch firms in discrete manufacturing industries provide substantive support for all our hypotheses. As such, the results provide nuanced insights into the role of resource dependence in SI.

First, this study has distinguished between the effects of BD and of SD. Faced with rapid changes in product specifications and/or production technologies, buyers may face the following dilemma. On the one hand, involving suppliers that have strong technological and manufacturing technologies may not be easy and, moreover, involving such suppliers in the buyers' product and process design can further add to the buyers' dependence on the suppliers. On the other hand, involving suppliers that are dependent on the buyer may have only limited added value, although such suppliers can be eager to participate in the buyers' product and process modification and improvement. Involving the right suppliers is of strategic importance because focal manufacturers can then have a better overview of their upstream supply networks through these suppliers, and then tap into the supply networks for developing complementary resources and capabilities. Our results suggest that buyers are generally opting for the former (involving suppliers that have strong technological and manufacturing technologies) because BD positively moderates the TU–SI relationship, whereas SD negatively moderates this relationship.

Second, considering both *H2* (on the moderating effect of BD) and *H4* (on the moderating effect of interdependence) shows that SD can reinforce the positive effect of BD on SI. Faced with TU, buyers generally tend to involve those suppliers on whom they depend for key resources, components, technologies, etc. in the processes of product design/modification and process design/modification (Gulati and Sytch, 2007). The presence of SD, alongside BD, can breed a sense of interdependence: that *we are in the same boat* (Caniëls and Gelderman, 2007), which can further increase the focal manufacturer's tendency to involve the supplier as a way to tap into upstream supply networks to identify and/or develop complementary resources and capabilities for coping with TU.

Third, considering *H3* (on the moderating effect of SD) and *H4* (on the moderating effect of interdependence) together shows that the effect of SD is further contingent on the level of BD in the buyer–supplier relationship. In the absence of BD, focal manufacturers have a clear tendency to keep dependent suppliers away from participating in product and process modification in their response to TU. The confirmation of *H4* shows that BD can alleviate the negative effect of SD on SI. This is because interdependence can breed an additional relational mechanism linking BD/SD to SI that can be used in seeking more valuable resources and capabilities in the upstream supply networks.

Finally, our findings also lend substantial support to the validity of combining the relational perspective and the resource-dependence perspective in explaining and predicting organizational behaviors in the context of SI in addressing TU. In arguing our hypotheses, *H1* and *H4* were derived from the relational view, whereas *H2* and *H3* were more informed by a resource-dependence perspective. As such, we have been able to show that these two theories can complement each other in guiding nuanced explorations into the role of resource dependence in the processes of involving suppliers to cope with TU.

One can reasonably expect these results to hold beyond the relationships studied, i.e. between focal manufacturers and their tier-one suppliers and to have implications for more extended supply chains. Although only a limited number of supply chain management studies have focused on multi-tier supply chain management, several recent studies do illustrate the potential of extending current supply chain management theories further upstream. For example, in the context of managing sustainability in multi-tier supply chains, Wilhelm *et al.* (2016) found that the resource availability at tier-one suppliers plays an important role in shaping these suppliers' strategies for developing the sustainability of their tier-two suppliers. More specifically, they found that resource constraints prevent tier-one suppliers engaging in collaborative practices to boost the sustainability performance of tier-two suppliers. This is consistent with the literature on sustainability management in the relationship between focal western buying firms and tier-one suppliers (Gimenez and Tachizawa, 2012; Awaysheh and Klassen, 2010). Comparable to the context of supplier sustainability management, we can expect that resource dependencies can have similar effects in shaping decision-making over involving tier-two and even tier-three suppliers in product/process improvement for coping with TU.

Managerial implications

To cope with TU, focal manufacturers need to tap into their upstream supply networks to develop complementary resources and capabilities. Already, focal manufacturers in industries such as electronics, apparel and car manufacturing are increasingly reaching out to their upstream supply chain partners to seek opportunities for further improving supply chain performance, including cost competitiveness, quality assurance, resilience and sustainability, as well as developing the capabilities of supply chains to cope with both demand and technology uncertainties. Having developed some nuanced insights into the role of resource dependence on supplier involvement, this study can highlight certain implications for supply chain managers. Our results indicate that focal manufacturers, usually the ones orchestrating global supply chains, tend to access complementary resources and capabilities that are readily available at key tier-one suppliers (i.e. those on whom buyers are dependent for key inputs). In contrast, they make little use of interdependent relationships to explore potential sources of complementary resources and capabilities embedded further up their supply chains, such as the capabilities of tier-two and even tier-three suppliers. Nearly 20 years ago, Primo and Amundson (2002) highlighted that existing suppliers may be less important than new suppliers in conditions of TU. Our findings show that this message has yet to reach practitioners and, given our findings, we would urge focal manufacturers to make more use of interdependent relationships to explore complementary resources and capabilities in a broader supply network. Moreover, supply chain managers may benefit from taking a broader perspective to assess resource dependencies within supply chain relationships: a seemingly dependent supplier might have a competitive upstream network that can enable the buyer to cope with TU.

Limitations and directions for future research

The study has several limitations and offers several directions for future research. First, the cross-sectional nature of the data inevitably raises questions regarding causality. Specifically, the relationship between resource dependence and SI could be dynamic. It could be that SI may influence the resource dependence setting by binding buyers and suppliers. Future studies could conduct longitudinal research to gain further insights.

Second, the study may be prone to bias as we only collected data from buyers in the supply chain. It would be useful to capture dyadic data or data pertaining to the complete supply chain and so measure the extent to which suppliers have different perceptions of the concepts measured in this study.

Third, it would be beneficial to investigate how resource dependence and SI in a supply chain affect buyer performance. Do power-advantaged buyers, who integrate more than their peers as TU increases, underperform compared to their peers? Our finding that integration under these conditions may be ineffective would indicate this is the case. Is it that they are less able to promote higher performance in their suppliers? Are there negative effects where SI does not need to be promoted by buyers?

Fourth, in this study, we focused on one aspect of integration between buyers and suppliers within a supply chain, namely, SI. It would be beneficial to investigate how resource dependence affects other aspects of buyer–supplier integration and how different aspects of integration jointly affect performance. As suggested by Van der Vaart and Van Donk (2008), attention could be paid to integration attitudes (e.g. trust, common goals and conflict) and to integration practices (e.g. transaction-specific investments).

Finally, our empirical setting focused on direct relationships between focal manufacturers and their tier-one suppliers. We would encourage future researchers to broaden the scope of analysis to include tier-two and even tier-three suppliers because SI, by definition, entails gaining access to complementary resources and capabilities in upstream supply networks. Taking a broader perspective on supply chains could well lead to developing novel insights into the effects of resource dependence and resource complementarity in the context of TU. We see this as a very promising avenue for research.

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Further reading

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Appendix. Questionnaire

Resource dependence

1 Resource dependence of the buyer on the supplier
- BD1: It would require much trouble and expense for us to switch to another supplier.
- BD2: For the components which we procure from this supplier, there are enough other potential suppliers to ensure adequate competition among the current suppliers.
- BD3: There are satisfactory alternative sources of short-term supply available for these components.
- BD4: We would face serious production problems if this supplier stopped supplying these components to us.

2 *Resource dependence of the supplier on the buyer*
- SD1: If we withdrew our business from this supplier, it would require much trouble and expense for them to find other buyers.
- SD2: For the components which we procure from this supplier, this supplier can find enough other potential buyers to get an adequate price.
- SD3: On the short term, there are satisfactory alternative buyers available for this supplier's components.

- SD4: This supplier would face a serious financial crisis if we withdrew our business from them.

Technology uncertainty

- TU1: New products account for a high fraction of total revenue. **
- TU2: Products and services are innovated frequently.
- TU3: The innovation rate of operating processes is high.
- TU4: These products are characterized by rapidly changing technology.
- TU5: If we do not keep up with changes in technology, it will be difficult for us to remain competitive.
- TU6: Production processes quickly become outdated for these products.
- TU7: The production technology changes frequently and sufficiently.
- ** = item was removed due to insufficient factor loading.

Supplier involvement

- DI1: Initial product design;
- DI2: Product modification;
- DI3: Initial production process design;
- DI4: Production process modification;
- DI5: Production process planning;
- DI6: Quality improvement; and
- DI7: Cost control.

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