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Radical innovations as supply chain disruptions? A paradox between change and stability

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Abstract

Supply chains withstand multiple tensions, and some of which are paradoxical. Radical product and process innovations bring such tensions to the forefront by disrupting supply chains. Using two illustrations, this article considers the paradoxical tension between change and stability in upstream supply chains, which becomes particularly salient after radical innovation. Furthermore, the article discusses why and how paradox theory can help firms understand and manage this pressing tension between stability and change. This article then presents future research opportunities for using paradox theory to investigate other persistent post-innovation tensions in upstream supply chains. The aim of this article is to encourage new studies that develop responses to such paradoxical tensions, an area ripe for research.

KEYWORDS

paradox theory, radical process innovation, radical product innovation, supply chain disruption, theory development

INTRODUCTION AND MOTIVATION

Schumpeterian theory of innovation states that innovation is the engine of economic growth (Schumpeter, 1934). Radical innovations can improve firms' performance, fulfill unmet market needs, improve quality of life, and raise societal standards. Within the context of supply chains, radical innovations can improve efficiency of supply chain processes, reduce resource consumption, and facilitate improved supply chain relationships. Such innovations, however, can also have severe negative impacts on supply chains: upending existing relationships, making current technologies obsolete, and requiring significant process re-design and/or re-assessment of capabilities. Thus, radical product and process innovations can have a dark side

(Coad et al., 2021) that severely disrupts supply chains. Indeed, such innovations can themselves be seen as a type of supply chain disruption or as a discontinuous change process, as Schumpeter's (1934) theory of economic development suggests.

Managing supply chains involves balancing several different paradoxical tensions, such as those in performance goals, and organization of the supply chain structure and relationships. Paradoxical tensions comprise a specific type of tension that involves "persistent contradictions between interdependent elements" (Schad et al., 2016, p. 5). These opposing contradictions create an ongoing tug-of-war. Responding well to such tensions would result in enhanced competitiveness (Smith & Lewis, 2011); however, failure to do so can be destructive to firms

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(Lewis, 2000). Examples of such paradoxical tensions have been identified in past supply chain research on the tensions between environmental, social, and economic goals (e.g., Brix-Asala et al., 2018; Matthews et al., 2016; Xiao et al., 2019; Zehendner et al., 2021), on social-welfare commercial logics in social enterprises (e.g., Longoni et al., 2019), and on cooperation and competition in supplier management (e.g., Wilhelm & Sydow, 2018).

This article focuses on one particular tension: that between stability and change in a supply chain, where its members seek to maintain structural stability (Son et al., 2021), whereas the buying firms' ever-evolving resources and knowledge needs continuously introduce changes (Vanpoucke et al., 2014; Wagner, 2012; Yan et al., 2020). When radical product and process innovation disrupts processes, systems, and relationships in a firm's supply chain, the tension between stability and change begins to surface, which can cause challenges for buying firms. For example, the introduction of music download services disrupted physical supply chains in the music industry and disturbed existing supply chain relationships. Although the disruptive nature of radical innovations has received a good deal of attention across disciplines, no prior work has specifically considered which paradoxical tensions organizations face in their supply chains post-innovation and how organizations could effectively manage them.

In this article, we argue that radical innovation itself can be considered a supply chain disruption and discuss how companies can respond. We reflect on how radical innovations disrupt upstream supply chain structures and reshape relationships using two illustrations: one for a radical product innovation and one for a radical process innovation. Next, we introduce paradox theory and discuss the paradox of stability versus change to conceptualize one of the major paradoxical tensions organizations face in upstream supply chains after innovation. We explain how and why paradox theory can help us understand, accept, and respond to this tension using our examples. We then extend our discussion to other paradoxical tensions and propose further research opportunities at the intersection of radical innovation and supply chain disruption.

RADICAL INNOVATIONS AS SUPPLY CHAIN DISRUPTIONS

Innovation is a complex and multi-dimensional concept. This article focuses on radical technological innovation, as opposed to administrative innovation; radical technological innovation is defined as "an invention which has reached market introduction in the case of a new product, or first use in a production process, in the case of a process

innovation" (Utterback, 1971, p. 77). Thus, innovation is not a single activity but rather a process that encompasses the stages of idea generation, invention, development, and market reach (Marquis, 1969). A product innovation is "a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market" (OECD/Eurostat, 2018, p. 21). Meanwhile, a process innovation is "a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use by the firm" (OECD/Eurostat, 2018, p. 21). A radical product innovation is one that is new not only to a firm but also to the market. Similarly, a radical process innovation is new to the sector rather than to a single firm (UK Innovation Survey Report, 2021, p. 30). These definitions of radical product and process innovation have regularly been used in empirical innovation research (e.g., Ganter & Hecker, 2013; Kesidou et al., 2022).

Firms invest in radical product innovations to achieve market growth and superior performance through sustained profitability (Geroski et al., 1993; Roberts, 1999) and invest in radical process innovations to improve quality and reduce costs (Damanpour, 1991; Hatch & Mowery, 1998; Utterback, 1994). Although ample literature examines how radical innovations affect economic growth and profitability, limited research emphasizes their disruptive nature for the supply chain.

This article focuses on supply chain disruptions, described as "events that disrupt the flow of goods or services in a supply chain system" (Parast & Subramanian, 2021, p. 548). We contend that radical product and process innovations are disruptive events (Schumpeter, 1934) that can have far-reaching consequences on supply chain structures, processes, and relationships.

Consequences of radical innovations on upstream supply chain relationships: A product and process illustration

This article focuses specifically on radical product and process innovation. In the following examples of these types of innovation, we discuss how radical innovations can disrupt an upstream supply chain by bringing the latent stability-change tension to the surface.

One example of a radical process innovation is a digital transformation offered via end-to-end platforms (MacCarthy & Ivanov, 2022). Catalent, a development company in the pharmaceutical industry, is offering a new platform for product development, launch, and introduction to market, which also conducts the testing

required to get a drug to market. This cloud-based platform enables the streamlining of the entire drug trial supply chain and then connects a network of scientists and suppliers within the pharmaceutical industry. The structure of this digital supply chain makes the product development process easier to manage and less wasteful and shortens lead times (Arora et al., 2022). Scaling up the use of one common partner's facilities in this way makes it possible for multiple supply chains to reduce both their inventories and the risk of obsolescence. In terms of changes to the supply base, this innovation creates opportunities for organizations around access to new suppliers—both their knowledge and intellectual capital, and their technologies. This further presents learning opportunities across the multiple, connected supply chains and the potential for new relationships to be forged.

However, such process innovation also disrupts incumbent processes and relationships, while increasing transaction costs among supply chain actors that might not share relational capital. Organizations are faced with the challenge of developing new supply channels and relationships, while maintaining stability in existing supply arrangements. The change in how information is managed, stored, and transferred in this digital supply chain can also increase the risk of knowledge leaks. Moreover, outsourcing the drug development and trial process can result in these capabilities becoming outdated or obsolete at pharmaceutical companies themselves. In terms of the external environment, there are also regulatory challenges around that must be confronted given the change in supply arrangements.

We observe similar contrasting tensions in examining a radical product innovation example, such as the electric vehicle (EV). Introduced in 2010, the Nissan Leaf was the first 100% electric car for the mass market. In introducing this vehicle, Nissan has needed to rethink both inbound and outbound supply chain structures: their sourcing process, priorities, and upstream relationships. Latent tensions in sourcing, which already existed within this competitive industry, have been exacerbated by political and ethical pressures, meaning raw materials for the key central power trains and batteries have grown scarce; this necessitates the development of new supply channels and protection of existing relationships. To stabilize supply, Nissan and other such organizations are seeking joint venture or equity sharing arrangements with a broader portfolio of suppliers, from digital and technology companies to battery manufacturers (e.g., Energy Japan Inc. and Envision) and to competitors (Groupe Renault, co-developed with Nissan, the CMF-EV [Common Module Family] platform). The battery technology itself requires entire supply chains to change and reskill to ensure safe

battery handling, movement, storage, and recycling (World Economic Forum, 2019).

Stakeholders also need to collaborate in novel ways to support the product—such as Nissan partnering with utility providers to establish charging infrastructures—and deal with the challenges associated with establishing the circular supply chain—such as Nissan repurposing EV batteries through a partnership with 4R Energy Corporation, installing them at train crossings in east Japan (Nissan Stories, 2021). The structures of Nissan's supply chain and supplier profile have changed fundamentally after the development of the EV; therefore, it has become necessary for Nissan to ensure the security of supply. This need has shifted the power balance against original equipment manufacturers in the vehicle manufacturing sector. Restricted supply, coupled with political and regulatory constraints, has resulted in heightened competition among rival manufacturers, price surges, and a greater risk of opportunistic behavior in upstream supply chain relationships.

In both examples, we observe a latent supply chain tension coalescing around maintaining stability, while seeking change and adaptation. This tension, which organizations deal with daily, is manifested through efforts to manage a varied and diverse supplier portfolio; balance competing goals and priorities with suppliers and competitors; and monitor power dynamics and dependencies. We contend that such tension can be exacerbated following radical innovation. Focusing on upstream supply chain relationships, we observe changes in the functioning of supplier relationships and adjustments to the supply chain structures, all of which are driven by the innovation, as well as other factors that might render the tension more salient.

To analyze one specific tension in the upstream supply structures and relationships after a radical innovation—that of stability and change—we refer to paradox theory. Paradox theory is a particular approach that sets forth a dynamic equilibrium model of organizing and responding to these tensions and enables a sustainable functioning of the supply chain (Smith & Lewis, 2011).

USING PARADOX THEORY TO UNDERSTAND THE UPSTREAM SUPPLY CHAIN IMPLICATIONS OF RADICAL PRODUCT AND PROCESS INNOVATIONS

Paradox theory focuses on a specific type of tension. Although they might appear distinct, the opposing poles of such paradoxical tensions are interdependent,

informing and defining each other, and preventing them from being separately managed (Schad et al., 2016). Their contradictory nature creates a constant tug-of-war between their polarizing elements (Quinn & Cameron, 1988). Paradox theory highlights these oppositions, but it also considers them as parts of a whole.

Paradox theory recognizes that these tensions are persistent, in that we can seemingly resolve paradoxes in the short term, but they prevail in the long term, regularly coming back into focus. This is because most decisions lean toward one particular element of the paradox, eventually creating a counter-pressure from its opposing element. In acknowledging this persistence, paradox theory suggests moving away from an emphasis on control and resolution and toward coping and dynamic balance (Schad et al., 2016). Paradox theory sees these interdependent elements as double-edged swords, with the potential to be either positive or destructive to organizations, depending on how firms frame and respond to the tensions (Lewis, 2000).

In management literature, examples of paradoxes include tensions between inter-organizational cooperation versus competition (Wilhelm & Sydow, 2018); exploration versus exploitation (Andriopoulos & Lewis, 2009); stability versus change (Farjoun, 2010); and individual versus shared performance (Smith & Berg, 1987). Paradoxes surface across levels—inter-organizational, organizational, group, and individual. The paradoxes at different levels can also be nested and therefore interdependent across levels (Smith & Lewis, 2011).

Frequently, the question of how to manage the polarizing tensions is answered through “either/or” thinking where the poles of the paradox are considered as alternative choices and eventually prefer one. For example, by applying contingency theory, scholars have sought to specify the contexts in which one solution outperforms the other (Lawrence & Lorsch, 1967). As an alternative, paradox theory encourages a “both/and” approach (Smith & Lewis, 2011, 2022). It encourages exploring paradoxes and tapping into their energy, insight, and power, rather than aiming to resolve them (Lewis, 2000). This different way of thinking about tensions broadens both the types of questions scholars ask in management research and the answers they derive. Recent examples illustrate the value of a paradox lens in supply chain research (see Gölgeci et al., 2019; Zhang et al., 2021).

Paradox mindset

Central to the “both/and” approach of conceptualizing paradoxical tensions is a shift in assumptions (Smith & Lewis, 2022). This entails consciously re-examining

assumptions about competing forces. For example, if an organization wants to pursue both radical and incremental innovation, what are the characteristics of both? Whereas conventional thought might suggest these characteristics would be contradictory, a paradox mindset sees their potential to co-exist. Rather than electing to move toward one end, a paradox mindset considers both polar ends, in a positive or creative way.

A paradox mindset serves to embrace tensions and develop a paradoxical frame to understand conflicting and interconnected demands (Miron-Spektor & Paletz, 2020; Smith & Tushman, 2005). As “mental templates individuals use to embrace seemingly contradictory statements or dimensions of a task or situation” (Miron-Spektor et al., 2011, p. 116), paradoxical frames, or cognitive filters, enable managers to first identify and then accept tensions (Smith & Tushman, 2005). Establishing a paradoxical frame not only necessitates re-examination of taken-for-granted frames but also requires individuals or teams to be motivated to engage in inconsistencies and tensions (Miron-Spektor et al., 2022).

The stability versus change paradox in upstream supply chains

One type of paradox that management literature identifies is that of stability and change (Farjoun, 2010; Leana & Barry, 2000). Stability and change are interdependent: On the one hand, stability enables change, as habitual behavior during stability frees up resources with which to manage non-routine tasks carried out for change (Farjoun, 2010; Feldman, 2000). On the other hand, changes allow experimentation and risk-taking, which enhance learning and provide organizations with more response options to achieve stability (Farjoun, 2010).

Stability and change have received significant attention in supply chain management research, either independently or as opposites (Aoki & Wilhelm, 2017; Kristal et al. 2010). One aspect of stability in upstream supply chains is structural stability, such as a buying firm’s choice to work with the same set of suppliers for a period of time (Son et al., 2021). Buying firms are inclined to seek structurally stable supply chains for various reasons. First, working with existing suppliers helps a firm reduce costs and time required to search for new suppliers (Barden & Mitchell, 2007; Goo et al., 2007; Gulati & Gargiulo, 1999; Hagedoorn, 2006; Li & Rowley, 2002). In addition, in a structurally stable supply chain, repeated positive interaction with the same set of suppliers results in accumulation of trust (Gulati, 1995; Carey et al., 2011; Sako et al., 2016; Son et al., 2016). This, in turn, improves relational stability (Dyer & Singh, 1998; Lumineau &

Henderson, 2012; Poppo & Zenger, 2002), yielding various performance benefits for buying firms. Furthermore, stability in a supply chain often results in the formation of routines (Barden & Mitchell, 2007; Hagedoorn, 2006) and network norms (Coleman, 1988; DiMaggio & Powell, 1983; Gao et al., 2015), both of which make collaboration within the network easier for buying firms (Kim & Jin, 2017; Lin et al., 2016). From an inertia perspective, firms tend to rely on historical experience and return to known solutions to avoid uncertainty (Li & Rowley, 2002), not only at the dyadic level but also at the supply network level (de Toni & Nassimbeni, 1995).

In contrast, buying firms continuously pursue changes in upstream supply chains to meet new resource and knowledge needs (Wagner, 2012; Yan et al., 2020), as well as to respond to changes in their external environments (Vanpoucke et al., 2014; Walker et al., 1997; Zaheer & Soda, 2009). For example, buying firms constantly search for new suppliers that can provide improved services, components, and products, as well as the latest knowledge (Wagner, 2012; Yan et al., 2020). Moreover, they are often forced to make changes in their supply chains to counter major external shocks such as natural disasters or mergers and acquisitions (Chae et al., 2022; Li et al., 2010; Madhavan et al., 1998; Son et al., 2021).

Although stability in upstream supply chains provides tangible benefits to buying firms, remaining competitive simultaneously requires changes (Das & Teng, 2000). These realities co-exist, rather than supply chains oscillating between periods of stability and change. This stability and change tension in upstream supply chains is indeed paradoxical, as the opposing poles are highly interdependent and the tension between them creates a persistent tug-of-war (Quinn & Cameron, 1988). Prior supply chain research has predominantly regarded stability of the supply chain as the desired state, broken by periods of episodic change. In other words, the underlying goal of supply chain management research has tended to be achieving stability between periods of change. More recent research has challenged this notion (Wieland, 2021). However, the prior body of research has previously not considered the question of how tending stability and change simultaneously would change supply chain management.

The current literature on the duality of stability and change is predominantly at the organizational level (e.g., Reinecke & Lawrence, 2022; Sonenshein, 2016; Wareham et al., 2014). The reality that buying firms do not have as much control over their suppliers as they do over their internal processes requires reflection on whether and how response strategies developed to manage the stability–change paradox can be extended to the inter-organizational context (Aoki & Wilhelm, 2017).

The impact of radical innovations on the stability versus change paradox

Paradox research conceptualizes tensions as both ingrained in organizational systems and socially constructed. Similarly, paradoxes in the upstream can be seen as a result of both the supply chain structure and the inter-organizational relationships. A supply chain is a complex system (Choi et al., 2001), in which relationships are guided by varying expectations and involve different goals (Mahapatra et al., 2010; Bai et al., 2016). Consequently, activities of organizing upstream supply chains may result in several structural and relational tensions. As Clegg et al. (2002, p. 491) state, “most management practices create their own nemesis.”

In the day-to-day management of supply chain operations, these tensions remain latent, therefore inconspicuous and unnoticed (Smith & Lewis, 2011). These tensions become salient when a major shock occurs (Schad et al., 2016). Radical product and process innovations are examples of such shocks (Schumpeter, 1934), embodying traits of plurality, change, and scarcity, disrupting supply chain structures and relationships (Smith & Lewis, 2011). “Plurality” in this context refers to a multiplicity of views on the consequences of innovations, as they might create uncertainties and inconsistent perspectives among supply chain partners. Radical innovations also exemplify change and spur new opportunities for sense-making, as actors need to adapt to the new reality innovations create, often with competing yet co-existing roles and emotions (Huy, 2002). Lastly, radical innovation intensifies scarcity, whether temporal, financial, or human resources. For example, in the supply of batteries for EVs, paradoxical tensions intensify as a direct result of companies needing to make choices about how to allocate resources to support the innovation (Smith & Tushman, 2005).

The tensions that radical product and process innovations thrust from being latent into salient ones are varied. Given our particular focus on the upstream relationships and considering our illustrations in Section 2.1, we see that several issues they face are manifestations of the paradoxical pull of stability and change. In other words, firms attempt to respond to changes in both their relationships with suppliers and the upstream structure, while simultaneously endeavoring to maintain a coherent overall procurement strategy, structure, and processes.

Reflecting on our radical product innovation example, the development of the EV has brought about a complete shift in the complexity of the vehicular product, requiring substantive changes to the supply chain. The complexity has shifted from the chassis (as in internal combustion engine vehicles) to the power train and electronics—entirely different modules where most of the value add is

now found. This will pose a significant disruption to “traditional” notions of automotive design, engineering, prototyping, and procurement, which requires companies like Nissan to change organizational routines around knowledge sharing, supplier involvement, and collaboration strategies. Nissan has focused on developing collaborative relationships with a few suppliers with the technical capabilities to support innovations around battery development and power train mechanics. This allows Nissan to access those suppliers’ unique knowledge and resources. Following the changes to its supply base, Nissan is experiencing a tension between developing these relationships to support innovation and attempting to ensure the stability and reliability of its existing supply arrangements. Resource requirements and conflicting objectives among buyers and suppliers, often from different sectors (e.g., digital or electronics), can further exacerbate this tension (Bode & Wagner, 2015; Mikkelsen & Johnsen, 2019). Additional concerns come into play when a firm is developing such relationships with suppliers with whom the firm has no prior experience. Although these suppliers may bring new opportunities for collaboration, the selection process is prone to various risks and uncertainties (Li & Rowley, 2002) because the precedence of an existing relationship is absent.

As for existing suppliers, a new product is likely to require them to change technical and product designs (Mikkelsen & Johnsen, 2019). Although this can motivate suppliers to become innovative and creative, it also makes their operations more complex (Bode & Wagner, 2015) and increases uncertainties (Frizelle & Woodcock, 1995); this in turn gives rise to supply chain disruptions such as production delays (Ambulkar et al., 2022). Moreover, if such changes are imposed coercively upon suppliers, trust may erode (Ambulkar et al., 2022; Benton & Maloni, 2005; Chae et al., 2017). This could negatively influence alignment of future goals (Krause et al., 2007; Johnson et al., 2013) and resource mobilization (Ambulkar et al., 2015; Olcott & Oliver, 2011) for collective supply chain response strategies, threatening stability upstream.

In addition, the potential supplier pool tends to be relatively limited for key suppliers that support radical product innovations, as has been the case for Nissan. In addition to the relational concerns, this also has effects on supply network considerations. Under such circumstances, the buying firm’s options for alternatives greatly diminish during any kind of disruption (Ambulkar et al., 2022; Chopra & Sodhi, 2014; Dolgui et al., 2018). The larger the supplier base, the greater a firm’s chances of finding replacement capacities and capabilities within that supply base (Chowdhury et al., 2019; Johnson et al., 2013; Hearnshaw & Wilson, 2013). Moreover, a

buying firm’s increased dependence on its suppliers can tilt the balance of power toward those suppliers (Emerson, 1962). An unintended consequence could be opportunistic behavior among suppliers, for example, prioritizing other buyers’ orders during a material shortage.

Considering the process innovation illustration, outsourcing the entire development supply chain creates dependence on the digital platform provider. Although too much dependence creates possible future disruptions, it also aligns the supply chain partners, thereby creating possibilities to gain scaling advantages as this partner offers its service to multiple pharmaceutical industry players. Similarly, the contraction of available suppliers to EV original equipment manufacturers has caused automakers like Nissan to become reliant on a limited pool of battery manufacturers, pursuing either vertical integration strategies or joint ventures with the goal of securing supply in a fiercely competitive market. Simultaneously, with increased dependency on a smaller number of suppliers come opportunities to improve coordination.

Radical innovation might also require the redesign of supply chains where activities that were previously in-house become transferred to suppliers. This switch can reduce operational costs (Lacity & Hirschheim, 1993); transform fixed costs into variable costs (Alexander & Young, 1996); and increase focus on core competencies (Quinn & Hilmer, 1994), while establishing access to industry-leading external competencies and expertise (Kakabadse & Kakabadse, 2002). At the same time, particularly for strategic activities or in case of co-developing innovations, there are risks of becoming dependent on a supplier (Alexander & Young, 1996); dealing with hidden costs (Barthelemy, 2001); and losing important knowledge, particularly in cases of outsourcing or strong collaborations on core competences (Doig et al., 2001). In the long run, these negative effects can even include loss of revenue, damage to reputations, and loss of productivity. This might result in decreased bargaining power and could even create new competitors. Certainly, in the case of rare, inimitable, and non-substitutable knowledge, the recovery process can be highly challenging (Barney, 1996).

ACCEPTING AND MANAGING PARADOXES

Once a latent paradoxical tension becomes salient, it prompts a response. One response is to display inertia (Smith & Lewis, 2011). By holding on to the past, a reinforcing vicious cycle is created that focuses on a single choice. This leads to ignoring both the paradox and the opportunities that facing it head on would bring (Smith & Lewis, 2011). In our context, such response

would involve either downplaying the stability–change tension post-innovation or cut down on innovation creation due to fear of the resulting disruptions.

The alternative reactions are either to accept the tension and manage it, through separation or synthesis strategies. Acceptance of the paradoxical tensions is a critical first step in responding to them (Smith & Lewis, 2011, Schad et al., 2016; Poole & Van de Ven, 1989). In our context, acceptance of this stability–change paradox invites managers and organizations to think creatively and see these tensions as opportunities (Beech et al., 2004).

Empirically, Lüscher and Lewis (2008) find that once managers accept that they are unable to choose between the poles of a paradox, they can become more open to considering “both/and” options. Paradox can then be managed via either separation or synthesis strategies (Poole & Van de Ven, 1989). Separation strategies use strategy and structure to insulate tensions, either spatially or temporally (Hahn et al., 2015; Puranam et al., 2006; Smith & Lewis, 2011).

Spatial separation involves using differing structures and processes to manage the polar ends—for example, a firm using efficient supply chains for functional products and responsive supply chains for innovative products (Poole & Van de Ven, 1989). In our product innovation example, this separation might take place by splitting production to different plant locations and by separating the supply chains for internal combustion engines and EVs. Although this might create an overall more complex supply chain network, it would also simplify decision-making for each product independently. Alternatively, spatial separation might be achieved by separating the management processes of existing and new supplier groups post-innovation. Although these groups are intrinsically interdependent, especially from the supplier–supplier triads and supply network perspectives, handling their management separately creates different structures and processes for each group.

Temporal separation involves prioritizing the opposing poles at different points in time (Poole & Van de Ven, 1989). In our process innovation example, pharmaceutical companies might decide to collaborate via the innovative development platform during only the very early stage of R&D projects, before handing the projects over to their supply chain partners. This layered approach would help build relational capital before fully committing to the innovative platform. Developing experience first contributes insights that can inform future contract management with a partner, while laying groundwork for a phased exposure to knowledge risks.

Spatial and temporal responses build on separating the contrasting poles while acknowledging their interdependencies (Poole & van de Ven, 1989). However, rather than separating the poles, companies can work toward

reconciling them (Stadtler & Van Wassenhove, 2016). This results in fostering synergies between the paradoxical elements (Andriopoulos & Lewis, 2009). Although the responses to the poles share timing and location, firms manage them as conflicting ends. In the literature, this strategy is often described as ambidexterity or as combining two opposing ends of the strategy spectrum (Tushman & O’Reilly, 1996).

Synergistic approaches build on fundamental changes in leadership; structure and processes; and routines (Harreld et al., 2007; Smith & Tushman, 2005). Adler et al. (1999) use their study of the US NUMMI plant, a Toyota subsidiary in California, to explain how, in the context of innovation, a synergistic approach to managing the paradoxical tensions of flexibility and efficiency manifests in operations and supply chains. One of the approaches was to use meta-routines—for example, routines designed to change other routines—to enhance the efficiency of non-routine tasks. Another involves engaging both workers and suppliers who had previously worked in routine production in non-routine tasks.

Regarding the stability–change paradox, literature on organizational ambidexterity provides a useful starting point. Gibson and Birkinshaw (2004, p. 209) define contextual ambidexterity as “the behavioral capacity to simultaneously demonstrate alignment and adaptability.” This requires building systems and processes that support a synergistic approach. This synergistic approach might even create something larger than its individual parts, adding new features. An example related to our production innovation illustration would be the development of the hybrid car, which combines features of an internal combustion engine vehicle with an electric power train. Thus, although this situation might be perceived as tension between the old, stable supply chain versus changing to a new, risky supply chain, combining the technologies of both contributes to creating a new product with new features. This often involves identifying a higher purpose, which can also translate into metrics that capture the entire organization’s performance (Hahn et al., 2015). This type of plan can create a unified sense of belonging among all members of the organization and make the paradox consistent with the firm’s vision and values. In this example, a synergistic approach might also translate into the development of an industry network consortium with a range of stakeholders—suppliers, competitors, dealerships, and so on—focused on reframing challenges in the sector and co-designing strategies to resolve them.

This resolution strategy also may involve behavioral and social levers, such as social processes, culture, and interpersonal relationships (Andriopoulos & Lewis, 2009), as observed in Table 1. Parallels are observable with supply chain research that leverages social

TABLE 1 Manifestations of the post-innovation stability–change paradox and potential response strategies.

Radical innovation	The stability–change tension	Manifestations	Potential supply chain response strategies
Process innovation illustration	<p>(Change): The new platform provides buying firms with faster access to, swifter adoption of, and more effective management of new suppliers</p> <p>(Stability): Maintaining the existing relationships with suppliers, who perceive the new direction as a threat to their business</p>	<p>Creating opportunities to innovate with these new links while maintaining the appropriate level of innovation capability that has been developed with existing suppliers</p> <p>Tapping into the competencies of the new suppliers without derailing the innovation process built on existing suppliers</p> <p>Tapping into the knowledge from the new suppliers while protecting technologies/processes built with existing suppliers from appropriation</p>	<p>Outsourcing elements of the drug development process, but retaining other, often more strategic parts of the development process, for established relationships</p> <p>Modularizing the process and using new suppliers for some selected stages of the process</p> <p>Revising partnership agreements to offer increased security regarding IP rights (e.g., using JV, equity sharing arrangements)</p>
Product innovation illustration	<p>(Change): Seeking out new supply chain partners with competence in new technologies</p> <p>(Stability): Transition to EV impacts the IC (and vice versa) supply chain as two product lines share common elements.</p>	<p>New supply chain needs for the EV (components/knowledge/talent), being managed alongside original IC supply chain needs. Managing common platforms/modules across both.</p> <p>Coordination with new, scarce battery suppliers and digital firms with a view to collaboratively engage on innovation projects for medium-longer term</p> <p>Supporting IC and EV supply chains with resources while also preparing for possible dynamic changes in resource needs, product scarcity or regulatory shifts as the EV market grows</p>	<p>Separating (e.g., locations, plants, or production lines) for the supply chains for engine and electric cars. Movement away from global sourcing to local sourcing of suppliers with domestic production serving domestic market.</p> <p>First, establishing the relationship and developing norms of working and securing supply, and only later working on developing new components/solutions with these suppliers</p> <p>Develop industry-network consortium with a range of stakeholders (suppliers, competitors, etc.) focused on reframing challenges in sector and co-designing strategies to resolve them.</p>

capital and relationship embeddedness but lacks acknowledgment of paradoxes. These parallels suggest opportunities to study the roles of partnerships and synergistic learning with partners, in managing supply chain paradoxes.

During post-innovation periods, paradoxical tensions, specifically between stability and change, could be managed by building strong social capital, in combination with a strong supply chain structure. Social capital as an informal control mechanism to manage a partnership could increase relational gains while protecting against the opportunity costs of dependence. Social capital can thus function as governance that curbs suppliers' behavior-related uncertainties (Kale et al., 2000; Son et al., 2021; Tsai & Ghoshal, 1998; Zaheer et al., 1998) and facilitates coordination (Villena et al., 2011). Social capital takes time to accumulate; it emerges because of positive past interactions (Carey et al., 2011; Hagedoorn, 2006; Son et al., 2016). The absence of existing social capital with new suppliers means buying firms lack an important mechanism for mitigating suppliers' opportunism and coordinating with them. In addition, unfamiliarity with each other's operating routines and managerial practices would significantly increase coordination loads between a buying firm and its newly selected suppliers. However, given social capital's effectiveness in reducing opportunistic behavior, understanding how to develop it under time pressure could help managers more swiftly navigate post-innovation supply chain changes. Figure 1 provides a framework for post-innovation paradoxical tensions in the upstream supply chain, specifically that of stability versus change.

FURTHER RESEARCH OPPORTUNITIES AT THE INTERSECTION OF RADICAL INNOVATION AND SUPPLY CHAIN DISRUPTION: APPLYING PARADOX THEORY AS A LENS

In the prior sections, this article has examined one particular paradox in the upstream supply chain—change versus stability—in the context of radical innovation. The aim of this article is to illustrate the ways in which radical product and process innovations create paradoxical tensions in the upstream supply chain, and the ways in which companies can respond to these tensions. Although the prior sections have focused on the tension between stability versus change, this section highlights research opportunities for examining other important issues related to paradoxes that arise when radical innovations disrupt upstream supply chains.

In the supply chain field, authors often launch research with questions of “which” and “when.” Framed by such research questions, possible answers fall on a continuum. “Which” questions tend to either pose a dilemma to be solved or beg for a trade-off (Taylor, 1919). Alternatively, “when” questions set up research to identify an ideal solution based on “if/then” logic (Lawrence & Lorsch, 1967). Where tensions are persistent and interdependent, paradox theory helps supply chain management researchers shift these “if/then” questions toward “both/and” questions. Importantly, paradox theory also enables researchers to explore the dynamics of this interdependence and means to manage the tensions. Hence, scholars can advance the supply chain management discipline by expanding the portfolio of possible questions alongside the response strategies that might be appropriate.

In this section, the authors present three themes for further research opportunities, with associated research questions, as outlined in Table 2. These are (1) response strategies; (2) types of paradoxes; and (3) outcomes and dynamics of paradoxes (Schad et al., 2016).

Response strategies

The core message of paradox theory is that firms' competitiveness is related to their capabilities of resolving paradoxical tensions (Smith & Lewis, 2011). As Section 4 discusses, the organizational responses to paradoxes include acceptance, spatial separation, temporal separation, and synergy (Poole & Van de Ven, 1989). Although this article has specifically investigated these responses to stability–change tension within the upstream supply chain, other paradoxes also become salient and create issues for buying firms after radical product and process innovations. Future research might, for example, focus on post-innovation paradoxical tensions such as collaboration versus competition or exploration versus exploitation.

Types of paradoxes

Paradox theory suggests that understanding the nature of a paradox and its complex relationships with other paradoxes is an important prerequisite for resolving it in order to support a firm's competitiveness (Taylor & Rosca, 2022). Four different paradox types have been identified (Lewis, 2000; Smith & Lewis, 2011). *Learning paradoxes* stem from using, critiquing, and often destroying past understandings and practices, to construct new and more complex frames of reference. *Organizing*

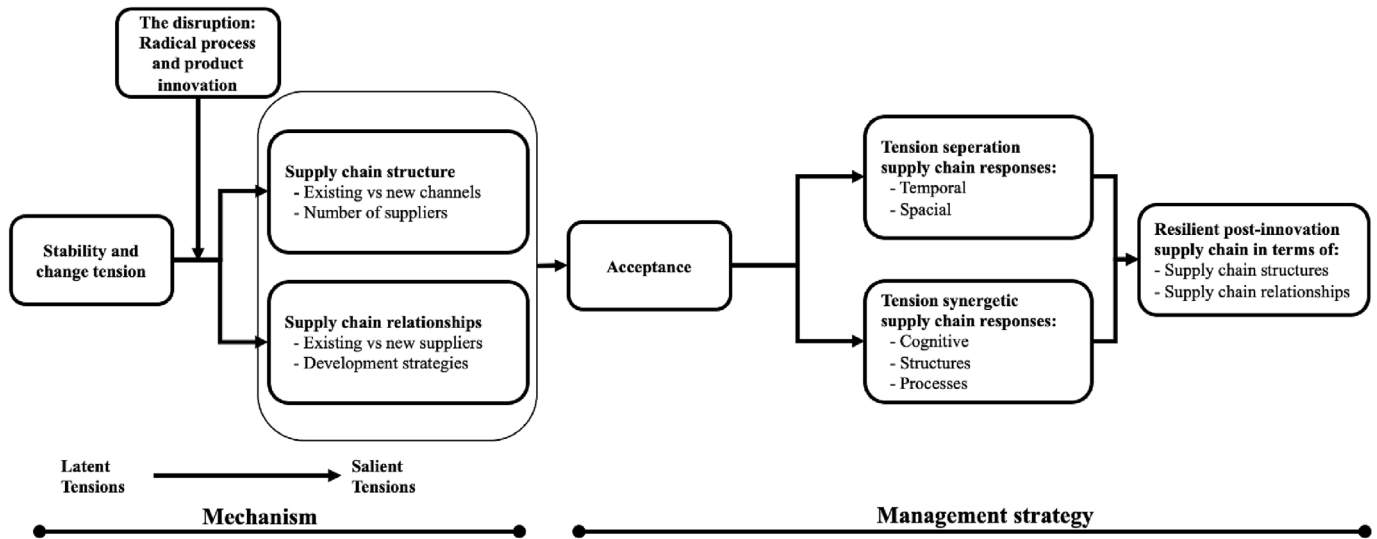


FIGURE 1 Understanding post-innovation paradoxical tensions in the upstream (adapted from Smith & Lewis, 2011).

TABLE 2 Further research questions using paradox theory.

Radical innovation as a supply chain disruption → supply chain tensions	
Firms' responses to paradoxes	
Acceptance	How can firms encourage supply chain managers to accept the paradoxical impacts of radical product and process innovations, rather than narrowly focus on the positives or negatives?
Spatial separation	How can firms align post-innovation flexibility versus efficiency challenges by spatially clustering their suppliers?
Temporal separation	How can firms manage and phase out soon-to-be obsolete elements of their supply chain while preparing the new supply chains radical innovation requires?
Synthesis	How do firms make simultaneous use of suppliers' cooperation and competition to support post-innovation supply chain needs?
Individual responses to paradoxes	
How does the paradoxical mindset of the supply chain manager affect their post-innovation approach to dealing with emerging paradoxical supply chain tensions?	
Types of paradoxes	
Performing paradox	How do supply chain managers simultaneously maintain focus on competitive, economic, social, and environmental goals following a radical innovation introduced by a competitor?
Organizing paradox	How can firms maintain commitment and trust with existing suppliers while actively integrating new suppliers into their supply chain without breaking the balance after a radical innovation?
Belonging paradox	How can managers balance the needs of their own organizations and the supply chain members post-innovation?
Learning paradox	How can managers simultaneously learn from positive and negative impacts on their supply chains after radical innovations?
Outcomes of paradoxes	
How does paradoxical thinking impact post-innovation supply chain trade-offs?	
Dynamics of paradoxes	
What are the drivers of virtuous and vicious disruptive cycles of post-innovation tensions?	

paradoxes denote ongoing processes of equilibrating opposing forces that encourage commitment and trust, while maintaining efficiency, discipline, and order.

Belonging paradoxes arise from seeking to become cohesive, influential, and distinctive while valuing both the diversity and interconnectedness of individuals and

groups. Lastly, *performing paradoxes* arise from the competing demands of diverse internal and external stakeholders.

Outcomes and dynamics of paradoxes

Ultimately, paradoxes have been categorized according to impact, which differentiates between the *outcomes* of different approaches and the *dynamics* of paradoxes. An opportunity is available to investigate the benefits of working through paradoxes and the potential costs of avoiding doing so (Schad et al., 2016). Such work includes insights into managerial outcomes that both separate and connect the poles (e.g., Andriopoulos & Lewis, 2009). Research is scant regarding how the management of paradoxes affects operational and supply chain performance, let alone quantifiable performance. In the studies at the intersection of paradox theory and supply chain research that Zhang et al. (2021) identify, performance returns are either implied or qualitative in nature. Studies on dynamics highlight the emergence of vicious and virtuous cycles that are fueled by ongoing responses to persistent tensions (e.g., Smith & Lewis, 2011).

A more long-term dynamic perspective on paradoxes can be enabled via a complexity lens. This lens could support exploration of nonlinear dynamics in systems, and could provide further opportunities to avoid predetermined trade-offs in research (Kauffman, 1995; Waldrop, 1993). In complex systems, small changes can create large fluctuations that have unexpected results. Furthermore, in response to such disturbances, systems oscillate between paradoxical states. Schad et al. (2016) stress the impact of paradox dynamics, noting that “cyclical processes to deal with the persistent tensions” are a scarcely studied theme in paradox literature that raises future research opportunities. This could help answer such questions as: How can organizations and their managers sustain dynamic equilibrium? What processes of system adaptation are observable via paradox management? Future inquiries could expand understanding, by exploring the timing, frequency, and nature of these dynamics (Klarner & Raisch, 2013).

Conceptually, the value of complex adaptive systems (CAS) has long been recognized in the study of supply networks (Choi et al., 2001; Hearnshaw & Wilson, 2013; Pathak et al., 2007; Pathak et al., 2009). Because the systems involve feedback in terms of competition or cooperation and in terms of utilization of the same limited resources (Zimmerman et al., 2008), environmental forces change the entities that reside within such systems, which in turn induce changes in their environments. Such bilateral dependencies ensure that

considerable dynamism persists in a given environment. Organizations can exploit many niches. For example, when a buying firm develops one parts supplier as its system supplier, this in turn spawns a whole new set of second-tier suppliers, who will now deliver parts to this new system supplier. This co-evolution does not portray a CAS as being in equilibrium within the environment but rather renders meaning to a CAS as being in disequilibrium.

However, most empirical supply chain literature that has taken a complex adaptive-systems perspective has ignored this disequilibrium and the paradoxical shifts in the supply chain structures; instead, the field has focused more on changes in the system that respond to a disturbance. For example, Nair (2016) shows the fluidity of the innovation process. Nevertheless, examinations of supply networks and their interactions from the complex adaptive-systems perspective do not necessarily consider the paradoxes inherent to these seamlessly adaptive interactions. Another example involves near-shoring production post-COVID, particularly across supply chains. Although supply chains might now be re-orienting to support one side of this seemingly dichotomous decision—“near” versus “off/out”—paradox theory suggests that the one-sided approach is likely to create a counter-reaction as it de-emphasizes opposing forces. As business environments become increasingly dynamic and prompt frequent changes in supply chains, the paradox perspective is an important addition to the research toolbox.

Supply chain researchers will be aware that the types of research questions highlighted here are best answered via qualitative methods. Case studies, already used regularly in supply chain research—specifically, longitudinal case studies—enable researchers to unpack interactions among nested paradoxes and examine tensions across different levels (e.g., Andriopoulos & Lewis, 2009; Touboulie et al., 2020). Action research, also gaining recognition in supply chain research, can help assess the impacts of different response strategies (e.g., Lüscher & Lewis, 2008). Additional questions would benefit from considering other, less-used techniques, such as ethnographic studies, specifically for emergent topics (e.g., Gylfe et al., 2019; Wenzel et al., 2019) or discourse analysis, to understand potentially differing responses on the part of diverse actors (Hardy et al., 2020). Conceptual research that makes use of metaphors and visual narratives helps scholars see problems “with fresh eyes” (Stephens et al., 2022). The methods outlined here are particularly relevant given the subjective nature of both innovation and disruption and given that both concepts are relative: One firm’s disruption can be another’s innovation opportunity, and one firm’s innovation is another’s disruption.

This leads to a final set of opportunities for future research, related to the focus in the supply chain. This article examines the paradoxical tension between change and stability that buying organizations face in their upstream supply chains following a radical innovation—be that a product or process innovation. Considerable scope, however, remains to examine the impact of disruption from a broader perspective, via focusing on different supply chain positions. For example, this might include researching downstream effects, either in isolation, or in comparison with upstream effects. Taking this broader perspective to investigate one of the examples in this article, that of Nissan's EV, would entail examining the effects of this product innovation on downstream relationships from dealerships through to end customer; the nature of the tensions that emerge around ownership, pricing, infrastructure, maintenance, and servicing; and how these might be managed. This approach could yield interesting research opportunities. Moreover, this would enable more comprehensive assessment of whether differences exist in the types of paradox faced and in the response strategies adopted in responding to upstream versus downstream effects following an innovation and associated disruptions.

Although this article has focused on radical disruptions, incremental changes might also create paradoxical tensions. These disruptions would not cause changes in the structures of organizations or supply chains through transforming their DNA, but rather by undertaking corrections within the guidelines of current processes and supply chain structures. Nevertheless, minor changes might also render paradoxical tensions salient and deserve further investigation to increase efficiency and flexibility beyond the traditional trade-offs. Regarding further areas of focus, there is merit to including the perspectives of both the buyer and supplier in one study. As previously discussed, the complexity of supply chains is tied up in relationships fundamentally being guided by different expectations and having different goals (Bai et al., 2016; Choi et al., 2001; Mahapatra et al., 2010). Investigating how buyers and suppliers might simultaneously manage related, but competing tensions would contribute to the literature base that seeks to disentangle these dynamic, complex social structures.

This article focuses on how a radical product or process innovation which a buyer creates requires that the firm to adapt, but that such an innovation impacts their suppliers also must be acknowledged; so, too, a radical product or process that an upstream supplier or downstream buyer creates will impact a supplier, requiring that supplier to adapt. The application of paradox theory in these contexts is not only equally valid but also likely to be highly useful as a theoretical frame. Moving beyond

the dyad or the supply chain/network, researchers could consider adopting a broader frame of reference to include societal tensions that might emerge after product or process innovations in the supply chain. This could be particularly pertinent when considering some of the innovations developed to tackle the “grand challenges” such as decarbonizing an industry, addressing ethical dilemmas, or adopting Industry 4.0 technologies, which might not necessarily have positive effects on all elements of society.

CONCLUSION

Paradox theory has its origin in the field of organizational studies; its use in the supply chain management field is sparse. Thus, this article has “borrowed” that theoretical lens to investigate the tension between change and stability in supply chains, and to present related research opportunities. Theory borrowing is prevalent in supply chain research (Flynn, Pagell, & Fugate, 2020; Halldórsson et al., 2015) and doing so has some advantages; for example, borrowed theories' constructs and the relationships among them are well established and empirically supported (Flynn, Pagell, & Fugate, 2020).

However, because paradox theory is predominantly a firm-level theory, vertically borrowing it and applying it to a different level of analysis—the level of the supply chain—requires careful thought on whether its predictive and explanatory power would remain constant (Bastl, Johnson, & Choi, 2013; Flynn et al., 2020). Morgeson & Hofmann (1999) suggest the appropriateness of theory borrowing depends upon whether a theory's functions are roughly equivalent in the new and the old setting. As illustrated above, the core functions of paradox theory—its ability to link resolution of “firm-level” paradoxical tensions with firms' sustainable competitiveness (Smith & Lewis, 2011)—remain largely potent to explain the role of resolution which “inter-firm level” paradoxical tensions play. This is relevant because in the current era, firms are held responsible not only for their own competitiveness, but also for the sustainable competitiveness of their respective extended supply chains.

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