A Typology to Understand Some Dynamics of Supply Chain Innovation Location

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This paper presents a new typology to understand some aspects of supply chains innovation. The typology proposed specifically attempts to capture and compare the dynamics of innovation location in supply chains. The typology classifies different innovation location configurations based on the underpinning values driving the innovation activities as well as the level of innovation interdependencies between supply chains' echelons. A detailed explanation of each configuration dynamics is presented as well as an environed evolution pattern for innovation location dynamics. The new typology should aid practitioners and researchers to understand and capture the potential synergies stemming from the driving values, as well as interdependencies across supply chains' innovation echelons leading to better innovation and integration related decisions.

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I. BACKGROUND

Innovation in supply chain can be defined as the generation and implementation/commercialization (which can be radical or incremental) of novel ideas and/or technologies along the supply chain. This can be at the product level, the process level, configuration/organization level or the market level. Innovation location is the echelon along the supply chain where innovation is happening through the innovation internal or external capacity of that echelon.

Innovation is becoming the core strategy by which many supply chains hedge against today's uncertainty. Continuous technology development on the technical side and the rising/changing customers' value expectation on the market side are the main drivers for this uncertainty. Within these two dimensions, the dynamic evolution of innovation along the supply chain can be better understood and managed.

The importance of innovation for the competitiveness of supply chain has been studied for decades (see for e.g. Arlbjorn and Paulraj, 2013 for good review). However, the changes experienced by these chains in terms of interdependency level and innovation location dynamics makes the understanding of such dynamics an important need for their business sustainability. Echelons located downstream in the supply chain provide up-to-date information about the preferences of consumers and on new trends as well as complement the innovation generated by focal firms at the midstream. Echelons located upstream, in turn, tend to provide knowledge about new technologies

through innovative components supplied to focal firms. The level of participation of the upstream and downstream echelons in the innovation process also depends on their position in the chain. The farther upstream or downstream an actor is on the supply chain, the lower its participation in the innovation process of a focal firm (Wynstra et al. 2010).

The purpose of this paper is to propose a typology, which can be used to further our understanding of the evolution dynamics of innovation location along supply chain. The typology thus focus on the "where" rather than the "what" and the "how" of previous supply chain innovation literature. This typology identifies and defines two main innovation dimensions that helps governing the evolution of innovation location along the supply chain. These dimensions are the driving values and the innovation interdependency levels between focal firms and upstream/downstream echelons.

II. LITERATURE REVIEW

Defining supply chain innovation is quite diverse within this literature (see for example Graw 2009 and Krabbe 2007) and characterized mainly by being relatively depending on who along the supply chain is developing or implementing the innovation. A good definition and review on supply chains' innovation classification can be found in Arlbjorn et al. (2011)

The literature for understanding the innovation process within the supply chain is not as rich as the vast knowledge body that captures the design, operation and management of supply chain. Some of that literature proposed that understanding innovation generation in supply chain stems from the relationship between buyers and suppliers. The classical direction within this group assumed that innovation would be generated by the buyers (e.g. von Hippel 1988). However, later work acknowledged that innovation generation is a multidisciplinary activity among both buyers and suppliers. For example, Roy et al. (2004) propose a conceptual framework that describes how innovation is generated upstream as function in the degree of relationship between buyers and suppliers. Soosay et al. (2008) investigated how collaborative relationship enhance continuous innovation in supply chain using various case studies. Similar work can be found in Robertson and Gatignon, (1998) and Sivadas and Dwyer (2000).

Some work related to innovation in supply chain addressed the adoption potential and challenges of new technologies. For example, Thong et al. (1999) developed an integrated model for IT adoption for SMEs in supply chains, while Liu et al (2010) focused on internet enabled technology adoption for supply chain management.

Another direction for research on innovation in supply chain explored the new technology implementation and impact. New technology examples included information technology IT (Holstrom, 1998), RFID (Santosh and Smith 2008) and blockchain (Kshetri, 2018). The impact included different industries beyond manufacturing like healthcare (Lee et al. 2011) and Cement industry (Dubbey et al. 2012). This direction showed how these innovations positively affected the performance of echelons of the supply chains in terms of time, cost and quality.

Measurement of innovation performance in supply chain was the focus of some related work like Algre et al. (2006), Chan and Qi (2003) and Cordero (1990) while the innovation process within the supply chain was explored in other work like Flint et al. (2008), Flint (2005) and Tang et al. (2003). A good example for a review that captures both of these directions (innovation measurement and performance in supply chain) can be found in Zimmermann et al. (2016) who also propose a framework for improving innovation process along the chain.

The previous quick review shows that most of the work focused mainly on

investigating the innovation process within the supply chain, its elements/strategies and how to optimize this process under different conditions. The "where" question is rarely asked or explored in the context of supply chain innovation. This paper adds to the few existing literature on supply chain innovation through capturing for the first time (to the authors' knowledge) some dynamics of the innovation location along the supply chain and more specifically how this dynamics relates to the changing customers' values and level of interdependencies among the echelons.

III. SUPPLY CHIAN INNOVATION LOCATION TYPOLOGY

In this section, we attempt to capture some of the dynamics of innovation location in supply chain through proposing a typology that can help in the characterization and understanding of this dynamics.

The typology concept is usually used to represent complicated and interrelated relationships among many variables while avoiding oversimplification (Dess et al., 1993). This rich descriptive tool will be used to differentiate among different innovation location dynamics in supply chains and to provide a classification scheme. However, it is important to note that the categories in most typologies (including the one presented here) are those that are most commonly presented in an environment but they are not meant to be exclusive or all encompassing.

The proposed typology is a configurational one. The supply chain location identified in the outlined configurational typologies are regarded as ideal types. In this specific context, an ideal type is seen as a theoretical construct used for representing a comprehensive configuration of supply chains (Doty et al., 1993). It also serves as an abstract model so that deviation of the type can be noted and explained.

The configuration approach in the suggested typology is based on the relationship between innovation location of the supply chain echelons, the interdependency level of innovation among these echelons and the driving value(s) of the supply chain innovation.

The innovation location refers to the relative position of innovation activities to the focal firm at the heart of the supply chain. The locations in this typology can be upstream of the focal firm (in most cases the components' suppliers at different tiers) or downstream of the focal point (like distributors, retailers, or service complimentary bodies).

The innovation interdependency refers to the way each of the supply chain's echelon in their relationships influence one another and the nature of their relationships for obtaining the desired innovation. This interdependency level analysis follows the construct proposed by Sheppard and Sherman (1998). This construct distinguishes four forms of interdependence based on the form and the depth of the interaction and relationship among parties. The form (or nature) is defined as the type of interdependence in a given relationship and can be dependence or interdependence. The depth (or intensity) is defined as a structural feature of a relationship between parties and can be deep or shallow. A unidirectional nature of dependency and transfer of responsibility from one party to another characterize shallow dependence. Shallow interdependence entails a loose form of reciprocity in which both parties effectively coordinate their activities in order to achieve their goals. Deep dependence is a principal-agent type of relationship based upon asymmetric knowledge while deep interdependence suggests wider-ranging, unity-type relationships between the parties and greater reliance on one another. The innovation interdependence form can manifest itself in the level of trust and the decision-making mechanisms among supply chain echelons. The interdependency depth on the other hand can be demonstrated in degree of information sharing

as well as the alignment in innovation strategies among these echelons.

The innovation driving values in this typology points to the underpinning objectives that the innovation along the supply chain is catering for. In this analysis, values are categorized into two categories. The first category is operation-oriented values, which drive the focal firm to innovate and collaborate with other supply chain echelons in innovation to improve operation performance objectives. This include values such as cost reduction, higher flexibility, improved lead times and quality levels. The other category is customer-oriented values that are mainly the rising expectation dictated by customers. This include values such as convenience, safety and sustainability.

Table 1 summarizes the proposed four configurations in the typology of innovation location dynamics in supply chains and their relationship to interdependency level as well as their driving values. Each configuration will be explained in details with examples in the next section.

TABLE 1. TYPOLOGY FOR SYPPLY CHAIN INNOVATIO LOCATION DYNMAICS

Supply Chain Innovation Location Dynamics	Interdependency Level		Driving Values
	Form	***Depth***	
Focal Point Innovation (FPI)	Dependent	Shallow	Operation values (e.g. cost, time, flexibility and quality)
Focal/Upstream Innovation (FUI)	Interdependent	Shallow/ Deep	Operation values (e.g. cost, time, flexibility and quality)
Focal/Downstream Innovation (FDI)	Interdependent	Shallow	Customer oriented values (e.g. convenience, safety, customization)
Full Stream Innovation (FSI)	Interdependent	Deep	Customer oriented values (e.g. convenience, safety, sustainability)

IV. DISCUSSION OF SUGGESTED SUPPLY CHAIN INNOVATION LOCATION TYPOLOGY

The first configuration of the proposed typology (focal point innovation – FPI) represents the classical innovation dynamics where the innovation took place within the focal firm through intensive R&D activities. This form of innovation is typically driven by operation-oriented values like cost and time reduction or responsiveness to market. FPI will have innovation at both the process level as well as the product level. Robotics industry is a good example of FPI supply chains as most of the innovations are carried out by the focal firm to improve the cost of robots (operation value). Specifically, the innovation associated with collaborative robots managed to reduce the cost of the industrial robot by around 50-75% (from $100K average price of a factory floor robot down to $25K-$40K) (IDC FutureScape report 2018). The development of technology in this industry is pushing for having robots more intelligent and can work side by side with humans leading to making robots a more mainstream industrial technology (the market is anticipated to triple in the next 10 years). The focal firm (the robots OEM) mainly carries out the incorporation of the new innovative technologies into the traditional robots like artificial intelligence (AI), internet of things (IoT), open control architecture (OAC) and modular designs. This form of internal dependence in terms of innovation results in a shallow relationships with supplier upstream as well as downstream that is unidirectional towards the focal firm's R&D innovation. This

type of dynamics is also common in chemical industries (e.g. plastics and paints).

The second configuration is focal/upstream innovation (FUI) type of location dynamics. This type of innovation location dynamics is widely spread among many supply chains with the increasing trend of horizontal integration in today's global competition. Operation-oriented values are again more common than customer-oriented values in driving this type of location innovation decisions (higher quality and first to the market are good examples of such values). FUI experiences an innovation interdependency relationship between the focal firm and upstream suppliers. This relationship varies between being shallow or deep depending on the level of collaboration and integration the focal firm is willing to have with upstream innovation recourses. Innovation in this dynamics is usually driven by technology advancement in the components comprising the finished product or service and these components are usually produced upstream at different tiers increasing the level of interdependency (from shallow to deep). A good example of this type is in the electronic industries, where a product like the new hard disks generation would require internal design innovation by the focal firm as well as significant innovation on the part of upstream suppliers of components such as read-write heads, motors, and disk substrate materials (Adner and Kapoor 2009).

The third configuration extend the innovation dynamics downstream and is referred to as focal/downstream innovation (FDI) type. Unlike the previous two types, FDI is characterized by being driven more by customer-oriented values like convenience, safety and sustainability. This innovation location dynamics is gaining more popularity with the increasing contribution of downstream supply chain echelons innovations in complementing innovative products and services generated by the focal firm. This complementation generates a level of innovation interdependency between the focal firm and the downstream echelons. However, this interdependency is usually shallow unless the customer value generation or realization is highly dependent on downstream innovation. An example for such location innovation dynamics is the hardware platforms for electronic book readers that required downstream electronic book content innovation in order for these focal firms to create value with their innovation. Many examples of market-driven FDI can be also found in the Ag-business supply chains. For instance (with shallow interdependence) in the tea industry downstream innovative serving setups like new tea bars and high-end tea houses had driven focal firms to innovate their tea production and packaging processes to realize the convenience customer value expected at these downstream setups. Similarly (with deeper interdependence) in cold and dry chains, many downstream innovations (in terms of distribution and retailing) were required to help focal firms realize organic and sustainable customer values.

The last configuration is the full supply innovation (FSI) location dynamics. In this type, focal firms are striving to cater for new and rising customer values in terms of quality, convenience, sustainability and customization. This will require deep interdependence of the innovation process with upstream and downstream echelons. The supply chains of this type are usually characterized by being knowledge-intensive and the value-creation activities are scattered amongst all the supply chain echelons that specialize themselves in a particular activity or technology (Narasimhan and Narayanan 2013). The focal firm in FSI dynamics face the challenges associated with their dual role of generating innovation and acting as a knowledge integrator (resulting in a deep interdependency relationship). A good example of such location dynamics is the electric vehicles that require significant

innovation from the focal firm as well as innovation from upstream suppliers (e.g. engine, body and control systems) and finally downstream innovative infrastructure that will enable ease of charging and mobility for the users. Another example is the aerospace industry. The innovation in developing new airplanes at the focal firms will be highly challenged by upstream innovation capabilities at the suppliers to deliver the required components for the new technology. At downstream, modifications at airports (to accommodate new controls and communication innovations) and pilot training institutions (to ensure they are ready to handle the new innovated version of these planes) will be required.

It is important to note that supply chains innovation location dynamic is quite fluid and thus some supply chains can evolve from one configuration to another. Multiple factors govern this fluidity including strategic integration level, innovation capacity building, and technology development together with evolving customers' values. With the advancement of technology and integration enablers, we envision more supply chains innovation location dynamics departing from classical FPI type towards more integration of the FSI type. This does not necessary means the elimination of other innovation location patterns.

In addition, with more and more control shifting towards customers, customer-oriented values rather than operation-oriented ones will mainly drive innovation along the supply chain different echelons. Figure 1 depicts the expected evolution of supply chains' innovation location dynamics over time and along the spectrum of the discussed values.

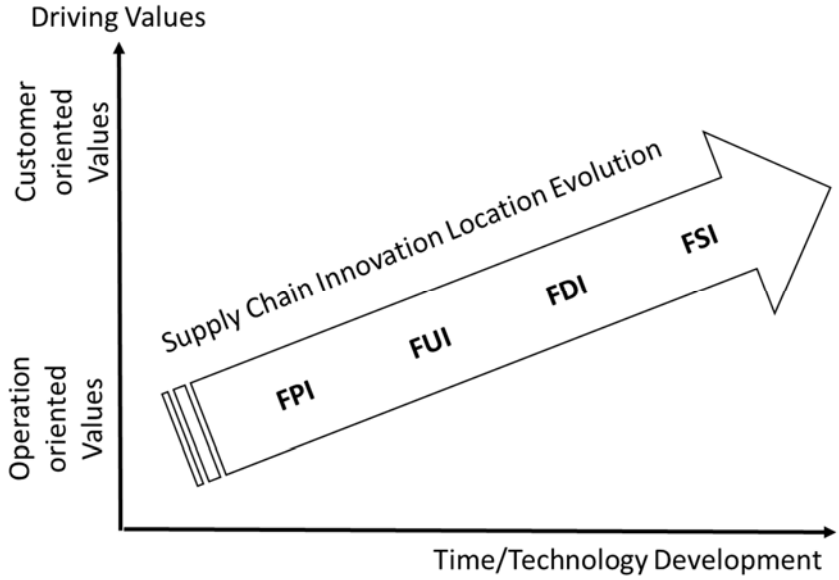

FIGURE 1. EVOLUTION OF SUPPLY CHAIN INNOVATION LOCATION DYNAMICS

V. SUMMARY

This paper contribute to the existing literature of supply chain innovation dynamics through addressing an underserved aspect within this literature. Specifically the paper addressed the location role in configuring the type of innovation dynamics among supply chain echelons using a new typology. The typology classifies these configurations based on the underpinning values driving the innovation activities as well as the level of innovation interdependencies between supply chains' echelons.

The typology proposed in this paper should aid practitioners and researchers to understand and capture the potential synergies stemming from the driving values, as well as interdependencies across supply chains' innovation echelons. More precisely, the proposed configurational typology could further assist:

- Researchers: in establishing for them a point of reference for their examination of different supply chains' innovation location dynamics and the applicability of the proposed forms/configurations of supply chain. Also it will help in giving more momentum to investigate more the location related innovation issues in supply chains.
- Practitioners: by facilitating their decision-making, by helping them understand the characteristics and challenges facing innovations within their supply chains. In addition, it will help them to identify the possible integration opportunities and/or future evolving direction**.**

Future work will focus on more empirical investigation to support the proposed typology. Case studies for each configuration will be used to demonstrate the suggested innovation location dynamics and perhaps add more elements to the proposed typology's configuration classification approach.

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