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Adaptive supply chains in industrial districts: A complexity science approach focused on learning

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ABSTRACT

This paper investigates the relationship between learning and adaptation in supply chains located within industrial districts, with the aim of identifying the best adaptive supply chain. It is motivated by the increasing attention that the design of adaptive supply chains has been receiving in recent years, as it is considered one of the most important critical factors in gaining sustainable competitive advantage in the current hypercompetitive environment. Focusing on two learning processes (i.e., by imitation and by interacting), diverse types of adaptive supply chains recognizable within industrial districts are compared by means of an agent-based simulation on the basis of their adaptive performance in environments characterized by different level of complexity and turbulence. The results confirm that the supply chain type influences the relationship between learning and adaptation and that both the product complexity and the turbulence of the environment moderate this effect. Finally, the best adaptive supply chain in each type of context is identified.

1. Introduction

Globalization, innovation, and increased customer sophistication have profoundly modified the scenario, nowadays characterized by hypercompetition and fast change, in which firms compete (Wiggins and Ruefli, 2002). Firms have been forced to look for new sources of competitive advantage, other than cost, quality, and time. In particular, the new scenario has required firms to become adaptive, i.e. to change quickly and to adapt to the environment so as to meet the new environmental needs constantly. Adaptation is in fact recognized as one of the most crucial factors for gaining and retaining competitive advantage (Reeves and Deimler, 2011).

Since firms do not compete in isolation against one another, but jointly with their suppliers, suppliers of suppliers, customers, and customers of the customers (i.e., the supply chain), the need for rapid change and adaptation must exceed firm boundaries to include the whole supply chain (Malhotra et al., 2007; Reeves and Deimler, 2011; Seifert and Langenberg, 2011). Thus, firms should design adaptive supply chains to be successful.

Adaptive supply chains are able to plan, execute, sense, and respond to changes and uncertainty (Lee, 2004). They must possess dynamic capabilities such as adjustability to shock, resilience, and flexibility (Kogut and Kulatilaka, 1994; Lee, 2004; Teece, 2007). Adjustability means that the supply chains is able to adjust to external shocks by modifying organizational goals, procedures, processes, structures, and products, to meet the changing needs (Teece, 2007). Resilience regards the ability to cope with unexpected disruptive events and to return to the original state or to reach a new, more desirable one (Christopher, 2004; Cabral et al., 2012). Flexibility concerns the reconfiguration capacity of the supply chain (Vickery et al., 1999). For example, flexible supply chains are able to quickly select new suppliers and logistics providers, to increase production capacity when needed, to introduce different transportation modes, and to design different alternative supply chains for the products (Pathak et al., 2007).

This paper investigates the adaptive supply chain issue using a complexity science approach. Following a recent trend in the literature, we frame the supply chains as complex adaptive systems (CASs) (Bozarth et al., 2009; Choi et al., 2001; Pathak et al., 2007; Surana et al., 2005), i.e., a set of interconnected buyers and suppliers, and their relational patterns, which emerge over time into coherent forms through localized interactions, without any singular entity or mechanism deliberately orchestrating the activities of the overall system (Dooley, 1997; Goldstein, 1994; Kauffman, 1993, 1995; Holland, 1995, 1998). Adaptation is one of the key properties of a CAS, meaning that the system is able to spontaneously self-organization with no central control, assuming over time new structures (configurations) characterized by enhanced fitness in the environment (Kauffman, 1993; Gell-Mann, 1994). According to CAS theory, learning plays a fundamental role in the adaptation process because it is one of the most important drivers of change (Allen, 2001; Dooley, 1997). In particular, learning processes accomplished

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by interacting agents drive the system's evolution and allows the system to operate effectively in that environment. The new knowledge developed by learning is in fact used by firms to change structures, and procedures so as to fit the environmental needs better (Levinthal, 1997; Allen, 2001; Allen and Strathern, 2003). Along with adjustability to shock, resilience, and flexibility, learning is thus a further critical capability for building adaptive supply chains.

Even though the study of the link between adaptation and learning is not new (Levitt and March, 1988; March, 1991), few studies have explored this relationship in supply chain settings, mainly identifying the learning processes that lead to adaptive outcomes (Knoppen et al., 2010). Moreover, very few studies have adopted the complexity science to study the relationship between learning and adaptation and fully exploit the potentials coming from it (Rose-Anderssen et al., 2009; Mitleton-Kelly and Ramalingam, 2011).

According to the complexity science approach, adaptation is seen as the self-organized process undertaken by firms arranged in supply chain relationships and accomplishing inter-organizational learning processes. Considering the self-organization property of a supply chain conceptualized as a CAS, and recognizing that the network of interactions among agents influences the adaptive outcome of the system (Holland, 1995; Allen, 2001; Rivkin and Siggelkow, 2007), we argue that the features characterizing the supply chain influence the relationship between learning and adaptation, since they affect the network of interactions occurring among firms.

Thus, we are interested in identifying which values of supply chain features foster adaptation thanks to learning. In other words, our research question is to define which supply chain type (defined by a specific combination of values of the supply chain features) best promotes adaptive outcomes as a result of learning.

Two contextual factors are also included in this analysis, i.e., the level of product complexity and environmental turbulence. In particular, we investigate how these factors affect the design of the adaptive supply chain and identify the supply chain type that guarantees the highest adaptation in diverse types of context. In this way we fill a gap in the literature, which so far has provided scarce investigation on the contingent factors affecting the design of the adaptive supply chain.

This study is contextualized by choosing a setting where alternative types of adaptive supply chains are recognizable and where learning processes play a critical role. Industrial districts are chosen because they offer the possibility to analyze alternative types of supply chains (Albino et al., 2006, 2007; Carbonara et al., 2002), which show adaptive behavior (Carbonara et al., 2010; Press, 2008). Moreover, there is a rich body of literature investigating the learning processes activated by firms in industrial districts and underlining that they are one of the most important sources of competitive advantage (Aydalot and Keeble, 1988; Baptista, 2000; Enright, 1998; Krugman, 1991; Maskell and Malmberg, 1999; Porter, 1998).

This study first classifies the diverse types of supply chains existing in industrial districts and the main learning processes activated within them. Then, an investigation is provided on which types of supply chain offer the best adaptive performance in the different contexts considered.

Simulation is used as research methodology and NK framework by Kauffman (1993) as simulation technique. Specifically, a NK model of each type of supply chains in industrial districts is developed, reproducing the way in which adaptation is driven by the learning processes and then the supply chain adaptive performance is simulated, so as to identify which supply chain type is the most adaptive. To develop the NK model, we refer to previous studies that have simulated firm organizational behaviors (Rivkin and Siggelkow, 2003; Siggelkow and Rivkin, 2005) and more recent NK applications to inter-organizational systems such as alliances (Aggarwal et al., 2011), supply chains (Giannoccaro, 2011), and industrial districts (Press, 2008).

Simulation is chosen because it is a powerful methodology for shedding light into complex relationships among constructs and revealing the outcomes of the complex interactions among multiple organizational variables (Davis et al., 2007). Compared to empirical research, it allows the behavior of "real world" systems to be examined by developing simplified analogous models of reality and permits the researcher to study processes in ways nature prohibits, given that it can be run many times with the values of the model parameters modified in each run and changes observed in outputs (Carley and Gasser, 2000; Berends and Romme, 1999). Furthermore, in such a case conducting an empirical analysis to test the proposed theory would have been a challenging task, because it would have required the collection of longitudinal data on a number of supply chains in several industrial district configurations and sectors, characterized by varying levels of product complexity and environmental turbulence.

The main contribution of the paper to the literature is twofold. It contributes to supply chain management literature on the design of adaptive supply chains, by recognizing the importance of learning as a critical capability for adaptation and by identifying which specific combinations of supply chain features (i.e., supply chain type) strengthens the relationship between learning and adaptation in specific contexts characterized by a level of product complexity and environmental turbulence. At the same time, it contributes to the literature on industrial districts, because considering industrial districts as collections of supply chains, an insight is given as to which types of industrial districts offer higher adaptation.

The paper is organized as follows. First, the theoretical background of the study is presented, focusing on the conceptualization of the supply chains as CASs, the relationship between learning and adaptation, and the role played by the supply chain features, the level of product complexity, and the level of environmental turbulence. Successively, the conceptual model is contextualized to the case of industrial districts and the main supply chain types and learning processes activated by firms identified. A discussion of the methodology follows, describing the simulation models and showing how each variable is coded. The simulation results are then described and the main outcomes and contributions of the paper are discussed and conclusions are drawn.

2. Theory

In this section first the supply chain is framed as a CAS and the relationship between learning and adaptation is discussed in the light of the CAS theory. Then, the conceptual model is presented, including the moderating effect of the supply chain type on the learning–adaptation relationship and the role played by two contextual factors, i.e. the product complexity and the environmental turbulence.

2.1. Adaptive supply chains as complex adaptive systems

The notion of CAS has its roots in the biological sciences (Gell-Mann, 1994) and refers to a system that emerges over time into a coherent form, and adapts itself without any singular entity deliberately managing or controlling it (Holland, 1995). Examples of CASs include social systems, ecologies, economies, cultures, politics, technologies, traffic, weather, etc. A number of researchers have developed concepts and notions to explain CASs: Gell-Mann (1994), Holland (1995), Axelrod and Cohen (1999), Choi et al. (2001), Lane (2002).

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