

An agent-based model of competition and collaboration in supply chains

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Abstract

This paper proposes an agent-based simulation model to study how competition and collaboration affect supply chains by looking at the problem at a market level. A theory-driven approach is applied to the modelling. The model reflects customers, manufacturers, and suppliers competing and collaborating in a supply chain strategic space. Preliminary results show that the market structure is determined primarily by bounded-rational behaviours of the supply chains and not by demand. This study is expected to provide a new perspective for understanding the implications of firms' behaviour as supply chains to the market. It is also intended to act as a building block to study more complex and real supply chains, and encourage academics, business managers, and market regulators to invest time in studying the impact of competition and collaboration strategies in supply chains.

Keywords: *agent-based modelling, supply chains, competition, collaboration.*

Introduction

An agent-based simulation model of a simplified supply chain is developed in this study. It models competition and collaboration in supply chains to understand how firms' behaviours in supply chains affect the market. A simple representation of the supply chain strategic landscape and a theory-driven approach are applied to characterise the model.

This study aims to obtain knowledge of how competition and collaboration behaviours affect supply chains at system level. This aim is based on the supply chain practice that is hard to achieve ideal supply chain collaboration. This issue is difficult to observe in the real world, but it is a critical problem in supply chain practice, particularly in understanding collaboration failures in supply chains.

This research has three main objectives. The first one is to develop an agent-based model for modelling competition and collaboration in supply chains. Secondly, to understand the impact of collaboration and competition behaviours on supply chain performance. Lastly, to identify interventions and strategies that lead to a better supply chain performance and enhance individual firm and market competitiveness. This paper focuses on the model that has been developed to address these objectives (objective 1).

The intended contribution of this work is to provide a new perspective for understanding the implications of firms' behaviour in collaboration and competition at a market level. This has not been investigated by previous studies in supply chain management (SCM) literature which tend to focus on a single supply chain. Also, our simple model is expected to be able to act as a building block to study more complex and real supply chains. This work aims to encourage academics, business managers, and market regulators to invest

time in studying the impact of firms' behaviour, as supply chains, in competition and collaboration to the market.

Previous studies on competition and collaboration in supply chains

Supply chain collaboration is considered to be the main driving force of supply chain success. However, many firms have failed in establishing appropriate collaborations within their supply chain.

A factor presumed to deter supply chain collaboration is competition. Competition may enhance the uncertainty level both in upstream and downstream markets. Supplier competition, for example, has been empirically proven to produce higher transaction costs for the manufacturer (Walker & Weber, 1987). This drawback is also supported by numerical results from theoretical models that show a high potential for quality distortion from the supply side (Altug & van Ryzin, 2013). Moreover, researchers who work on Total Quality Management, such as Walley (1998), demonstrate that competition provides fewer opportunity to reduce variations in lead time and quality.

On the other hand, the strategy implemented in supply chain collaboration may also contribute to supply chain failure. The most debatable issue in supply chain collaboration is around the value of establishing long-term partnerships. This strategy is the basic approach in SCM to improve and optimize supply chain competitiveness over the long term. It can secure the supply flow and price (Kraljic, 1983), and reduce the lead time to market (Christopher, 2000). In other words, it can be an enabler to achieve better supply chain performance (Boddy, Cahill, Charles, Fraser-Kraus, & Macbeth, 1998; Lee, 2004). This notion is also supported by SCM best practices, such as Toyota and Benetton, which demonstrate that these strategies lead them to gain better profit.

However, long-term partnerships do not suit all supply chains. Several findings, such as Anderson and Jap (2005), Burke, Carrillo, and Vakharia (2007), Leeuw and Fransoo (2009), Squire et al. (2009), and Sun and Debo (2014), suggest that this approach does not always provide a better supply chain performance.

In SCM and social science, competition and collaboration have been viewed from different perspectives. Most SCM researchers, such as Christopher (2000) and Lee (2004), claim that supply chain performance will be much better if businesses are able to develop long term collaborations with the supplier. This approach reduces the opportunity for the emergence of competition. However, in social science, competition has been regarded as beneficial to improve business competitiveness. It supports corporate success (Porter 1985, cited in Richardson 1993) and provides better value to the customer (Stucke, 2013). Agent-based modeling (ABM) implemented in this study is a simulation approach that is inspired by the intelligence of organisms in making decisions in biological science. The agent in the approach represents entities, which are independent, but interact with others. This modeling approach has become popular since it can be applied in a wide variety of problem situations (North & Macal, 2007).

To date, the use of ABM in SCM research is limited. It is mostly conducted through computer science research, such as Barbuceanu, Teigen, and Fox (1997), Parunak, Savit, and Riolo (1998), Barbuceanu (1999), García-Flores, Wang, and Goltz (2000), Jiao, You, and Kumar (2006), Kwon, Im, and Lee (2007, 2011), and Siebers and Onggo (2014). These works tend to focus on the software architecture rather than supply chain analysis. Also, even though several ABM studies have addressed collaboration issues in SCM, such as Zhu (2008) and Chen et al. (2013), they only focus on a single supply chain and do not investigate supply chains from a system perspective.

Most SCM and ABM research separates collaboration and competition issues into different studies. Thus, this study tries to provide new insights on the effects of competition on collaboration and performance, both for the academic literature and for business practice.

The model

The model simulates two-stage supply chains that consist of suppliers, manufacturers and customers. Supply chain strategic fit of responsiveness and efficiency (Chopra & Meindl, 2007) are considered as the dimensions of the firms' strategic position. The level of competition and collaboration is represented based on the relative positioning of firm performance in terms of responsiveness and efficiency. Responsiveness is reflected as the level of innovation from a customer's perspective and lead time from the firm's standpoint. Meanwhile, efficiency is represented as price and product value from the customer's view and operational costs from the firms' perspective.

The key experimental factors in this study are the collaboration strategy and competition behaviour.

Collaboration strategy involves the “duration of collaboration” between a supplier and a manufacturer, and “manufacturers’ number of sourcing”. Meanwhile, competition behaviour represented in this study is acquisitiveness, which reflects the desire to earn more revenue on an on-going basis. For instance, manufacturers change their strategy by incrementally moving towards nearby customers that are currently not buying from them. The manufacturers have no way of assessing the effect of moving towards a new customer, but due to acquisitive, they will always attempt to gain new customers. In doing so, they may lose some of their current customers to another manufacturer. In a similar way, suppliers move to try and gain collaborative relationships with new manufacturers by moving towards the closest manufacturer with whom they do not collaborate.

The outputs of this model are supply chain fill rate and the number of supply chains exist at the end of simulation run. Supply chain fill rate is calculated as the number of customers served divided by the total number of customers in the system; while the number of supply chains exist at the end of simulation run represents supply chains robustness at market level.

A classical spatial competition model that is introduced by Hotelling (1929) was used for the face validation. The resulting behavioural pattern of this model shows a similar behaviour to that is predicted by Hotelling’s model. The firms move to occupy almost the same strategic position.

Discussions and conclusions

An agent-based model has been developed to observe how firms’ behaviour in competition and collaboration affect supply chains as a market system. The preliminary runs of the model show that it is the bounded-rationality of each agent that drives the emergent outcomes. Market structure and supply chains performance is determined primarily by firms’ behaviour and not by demand.

The model represents the strategic space and firm behaviour in a very simplified fashion. However, it can be extended to address more supply chain issues inform a system perspective. Moreover, incorporating a learning capability for each agent and providing alternative measures of performance could enrich the model.

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