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An iterative approach for a bi-level competitive supply chain network design problem under foresight competition and variable coverage

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ABSTRACT

This paper develops a bi-level program for a chain-to-chain competition under foresight competition and variable coverage. Customers patronize those retailers who are within their radius of influence. The demand of customers who are not in the catchment area of any retailer, are lost. An iterative global search method is proposed that incorporates the possible reaction of the follower in the leader's problem as new constraints (i.e. cuts) in each iteration. Several numerical experiments are conducted whose results demonstrate ignoring the foresight competition would lead to loss of market share and profitability of the new entrant's supply chain.

1. Introduction

In today's market, traditional competition among corporations has evolved to competition among supply chains (SCs). In the new type of competition, the firms compete against each other as dependent and integrated entities of SCs (Rezapour et al., 2011a). Ignoring competition in the supply chain network design (SCND) problem is indirectly equivalent to considering a monopoly in the market which is seldom the case in practice (Ashtiani et al., 2013).

To formulate a SCND problem under competition, following questions are naturally raised:

(1) Which entities of SCs do compete against each other?
(2) How the market shares of rival SCs are estimated?
(3) How do the existing competitors react to the entrance of a new competitor to the market?

Competition among entities of SCs can be categorized in three types (Amin-Naseri and Azari Khojasteh, 2015):

(1) Competition among several firms in a same echelon of a SC; such as the competition of rival retailers who buy products from a manufacturer and try to maximize their market shares independently (e.g. Bernstein and Federgruen, 2005; Jiang et al., 2012; Meng et al., 2009; Yamada and Febri, 2015).
(2) Competition among several firms of different tiers of a SC; such as the competition of retailers and manufacturers in a SC in determining the wholesale and retail prices (e.g. Kogan and Tapiero, 2008; Yu et al., 2009).
(3) Competition between rival SCs (e.g. Boyaci and Gallego, 2004; Rezapour et al., 2011b).

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The first and second types are in-chain competitions while the third type is a chain-to-chain competition. It is noteworthy that chain-to-chain competition deals with competition at the downstream end of rival SCs such that the retailers of rival SCs directly compete to maximize their market shares (Amin-Naseri and Azari Khojasteh, 2015). In other words, competition among rival SCs occurs in the retail outlets where each customer selects a specific retail outlet and ignores its rivals. Retail industry, pharmaceutical SCs and online bookstores are examples of chain-to-chain competition. Despite the vast applications of this type of competition, there are a few analytical models which consider interactions between different SCs in SCND problems. On the other hand, the current literature on chain-to-chain competition mostly focuses on tactical decisions like pricing (e.g. Amin-Naseri and Azari Khojasteh, 2015; Boyaci and Gallego, 2004; Xiao and Yang, 2008). Nevertheless, it is essential to take into account the effect of chain-to-chain competition in SCND problems.

Regarding the second question, there are some general rules for estimating the market shares of rivals. Some of them consider the effect of network's structure (e.g. location of retailers) and others consider tactical aspects (e.g. retail price). Nevertheless, they can be classified in the five categories as follows (Drezner et al., 2012; Farahani et al., 2014):

(1) **Proximity rule:** By this rule, customers simply select the nearest retailer.
(2) **Price dependent rule:** It assumes that demand allocated to a retailer is negatively related to its own price and positively related to the rivals' prices.
(3) **Utility model:** It assumes that customers select those retailers with the highest utility. Assume that u_{jk} is the utility of retailer j for the customer zone k. A typical utility function is defined as $u_{jk} = a_j \frac{1}{d_{jk}}$ where a_j is the service level of the facility j and d_{jk} is the distance among them. The service level depends on the existing side facilities (e.g. parking area) providing the convenience for customers (Küçükaydın et al., 2012). Generally, floor area serves as a surrogate for attractiveness (Drezner, 2014). It is more likely that they have enough parking area or shorter waiting time (Zanjirani Farahani et al., 2015).
(4) **Gravity rule:** In this rule, the probability of patronizing a customer to a retailer is proportional to its utility for the customer zones. Based on this rule, the market share of facility j from the customer zone k is as $MS_{jk} = \frac{u_{jk}}{\sum_j u_{jk}}$ (Aboolian et al., 2007). The important assumption behind this rule is that all the demands of customer zones are distributed among the competing facilities and there is no lost demand.
(5) **Covering approach:** The basic idea behind this rule is that customers may choose those retailers in the close vicinity and avoid patronizing too distant retailers (Drezner and Drezner, 2012). For example, if there is no book-retailer nearby the customer, she/he might use an online book store and the demand is lost. The term 'too distant' depends on the facilities' design. More convenient retailers can attract more distant customers. In this approach, it is assumed that each facility has a radius of influence (r_j). Customers may select a retailer, if they are within the retailer's radius of influence (i. e. $d_{jk} < r_j$). This approach actually translates the service level of retailers to the distance which can be covered by them. So, retailers with higher service level can attract more distant customers (Berman et al., 2010). In this way, the demands of those customers who are not in the catchment area of any retailer, are lost. Also, if there are more than one facility able to attract a customer zone, the total demand of that zone is equally divided among those facilities.

Although the gravity rule is popular in the context of competitive SCND problems, the cover-based approach is an emerging rule in the literature of competitive FL (Drezner et al., 2011, 2012, 2015), which has not been used in the literature of competitive SCND problems by now. However, by incorporating the concepts of "radius of influence" and "lost demand" and equal division of demand among the rival retailers, this approach provides simpler schema than gravity rule. It is also closer to reality as customers usually choose those retailers in the close vicinity and ignore distant retailers. Drezner et al. (2011) analysed the sensitivity of market share for different allocation rules. Based on their experiments, there is no evidence that more complicated rules mimic actual customers' behaviour more accurately. They also showed that the allocation rule has a secondary effect on the market share of attracting facilities while covering is the major criterion from the customers' view. Nevertheless, the covering approach provides a reasonable estimation of market shares by equal division. Even in the extreme case, equal division does not impose a significant deviation to the estimate (Drezner et al., 2012).

Noteworthy, the competitive characteristics can conceptually be divided into the two groups (Farahani et al., 2014): (1) those related to the strategic decisions of a SC like the distance of retailers and customer zones and (2) those related to the operational decisions of a SC like pricing. Strategic decisions like establishing new facilities are long-term decisions of SCND phase that are difficult and costly to be changed over the planning horizon. Other characteristics are more flexible operational decisions such that the rivals usually can react immediately. Due to these distinctions, the vast part of the literature has concentrated on the impact of one group of competitive characteristics for estimating the market shares of rivals. For details, we refer the readers to the work done by Farahani et al. (2014) in which the literature of competitive SCs is classified based on aforementioned competitive characteristics. Also, this conceptual distinction has some effects on the formulation of competition which is the third question raised above (i.e. how the rival SC reacts to the competitor?).

There are three general types of competitions as follows (Farahani et al., 2014):

(1) **Static competition**: A new player enters the market considering the current situation of its competitors (e.g. Fernández et al., 2007; Zhang and Rushton, 2008). It is assumed that the existing competitors will not react to the entrance of the new player in the near future. This type of competition typically includes long-term (i.e. strategic) decisions such as facility location (FL) in SCs.
(2) **Competition under foresight**: A new player enters the market while anticipating possible reactions of its existing competitor(s)