Int. J. Production Economics 142 (2013) 179–193

Contents lists available at SciVerse ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Stability issues in supply chain networks: Implications for coordination mechanisms

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ARTICLE INFO

Article history:
Received 14 July 2011
Accepted 26 October 2012
Available online 19 November 2012

Keywords:
Network stability
Coordination
Competition
Game theory

ABSTRACT

Stability is essential for long term sustainability of supply chain networks. The literature on supply chain coordination focuses on enhancing network efficiency, and stability issues are largely unexplored. In this paper, we consider a two-tier supply chain network with a marketing agent coordinating activities among the network players using a price and profit sharing based coordination mechanism. Our non-cooperative game theoretic model shows that a unique subgame perfect Nash equilibrium exists that facilitates development of structural results characterizing network stability from the perspectives of costs, number of players and parameters of the coordination mechanism. In particular, we obtain ranges for cost, number of players and the profit sharing parameter over which the network is internally and/or externally stable. Our results suggest that cooperation among the network players is not always necessary; network efficiency can be achieved in some situations with the coordination mechanism adopted here.

1. Introduction

During the past two decades, supply chains have evolved into complex networks involving diverse players, each with its own rights and individual interests. In this environment, supply chain coordination with focus on mechanisms to align decisions of members for improving the overall effectiveness of the network has emerged as a key management capability (see Cachon, 2003; Li and Wang, 2007). For long-term sustainability, it is important that such networks remain stable with little incentives for players to alter their existing alliances. The issue is particularly important in networks with exclusive participation constraints due to restrictions on network players from competing simultaneously outside the network. Franchises, exclusive dealerships, captive facilities (such as manufacturing plants, distribution units, etc.) and cooperatives are typical examples of supply chain networks that exhibit such restrictions. The presence of competing supply chains often provides players in the network with alternate avenues that may undermine stability of the network. While coordination issues have received much attention in supply chain management literature (see Whang, 1995; Tsay et al., 1998; Kouvelis et al., 2006), implications of coordination mechanisms for network stability have not been studied in detail. In this paper, we aim to bridge this gap and develop a modeling approach to examine the impact of coordination mechanisms on stability of supply chain networks.

The motivation for our work comes from mixed results in the cooperative sector of India. Over the last seven decades, *AMUL*, a milk producers' cooperative, has led a dairy revolution that has resulted in India becoming one of the largest producers of milk in the world (Bellur et al., 1990). The success of AMUL is achieved within the framework of a network of cooperatives organized in a hierarchical manner. The network structure has been subsequently replicated in various other sectors—such as oil, sugar, wheat, fertilizer, etc. However, similar success has eluded many of these cooperatives, and in some cases the networks have disintegrated (Bandyopadhyay, 1996; Das et al., 2006). Recently, the AMUL network has also come under strain with competition from private players with alternate avenues for the players in the network that include changing supply chain alliances, terminating network membership, establishing independent production units, etc. (Chandra and Tirupati, 2003). In particular, in 2006, the Mehsana union, the largest of the 17 members in GCMMF, and in 2010, the Kaira union, the oldest producer in the network threatened to pull out of the network in self interest (see Sriram, 2010; PTI, 2010). As a result sustainability of the India's largest and most admired brand had become uncertain. In a competitive environment such as that in the Indian dairy industry, network formation by the competing players may counteract individual objectives of the network players causing instability in the network. A clear understanding of the interplay between

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http://dx.doi.org/10.1016/j.ijpe.2012.11.003

objectives of the individual players and the parent network is necessary in order to eliminate any incentives threatening network stability and to ensure network sustainability. The literature examining stability issues in the context of supply chains is primarily based on cooperative networks which do not adequately capture the AMUL environment (elaborated in Sections 2 and 3). Hence, our objective in this paper is to bridge this gap and develop a model based approach to understand stability issues. It may be noted that similar competitive setting may be observed in network structures such as Independent Grocers Association (IGA)—a group of independent retailers (www.iga.com), Unified Western Grocers Inc.—a purchasing cooperative of independent grocers (www.unifiedgrocers.com) and European Social Franchising Network, CAP Market in Germany—cooperatives of sheltered workshops (www.socialfranchising.coop, www.cap-markt.de).

Specifically, in this paper, we examine stability issues in a two-tier supply chain network comprising several producers operating in a competitive market. While some of the producers operate independently and supply their product in the market directly, the rest form a cooperative network (hereafter referred to as network) and supply through a marketing agent that acts as a coordinator. Production decisions by the network producers are driven by self interest and are influenced by the coordination mechanism used for sharing the revenues generated. In this paper, we analyze a profit sharing based mechanism that is popular both in practice (see Azfar and Danninger, 2001; Heywood and Jirjahn, 2009) and literature (see Chen et al., 2001; Foros et al., 2009). The coordination mechanism involves procurement price paid by the marketing agent to the network producers and surplus sharing. We develop a game theoretic model to describe the problem context and characterize the decisions of both network and independent producers. Our development involves integration of (i) principles of coordination from supply chain management literature, and (ii) literature on network stability from economics and industrial organization. We derive response functions for the players involved and show that optimal decisions lead to a Nash equilibrium for the supply chain. In addition, we show that there exists a range of procurement prices in which both network and independent producers compete together, i.e., optimal production quantities are non-zero for both types of producers. For procurement price below a threshold value, the network producers do not produce. Similarly, for procurement price beyond an upper bound, the independent producers do not produce. We also develop structural results to characterize stability of the network. Our results show that the profit sharing parameter has no impact on network surplus; however, it has implications for network stability. Also, cooperation among network producers is not always necessary to obtain efficient performance and the coordination mechanism considered in this paper is adequate for this purpose. The results bring out relationship between the factors of interest and provide insights for determining the decision parameters of the coordination mechanism. Our main contribution in the existing literature is linking stability and efficiency of supply chain networks within the framework of supply chain coordination.

The remainder of the paper is organized as follows. In Section 2, we describe the problem context in our motivating example. We review the relevant literature in Section 3 and position the work described in this paper. We build the game theoretic model in Section 4. Section 5 covers model analysis. Section 6 discusses network stability. We conclude in Section 7 with a summary of the key findings of the paper. All proofs are relegated to appendix.

2. Problem context: AMUL

In this section, we provide a brief description of the evolution of the AMUL milk cooperative that motivated this work. (The description has been prepared based on the discussions between one of the authors and the members of the AMUL organization and also the information provided in Heredia, 1997; Chandra and Tirupati, 2003; Goldberg et al., 1998.) The first cooperative, later renamed AMUL, was founded in 1946 in Anand, Gujarat, India, with the objective of providing fair prices to the milk producers who were being exploited by the middlemen. The local markets for milk and milk products at the time were underdeveloped and it was necessary to transport the perishable commodity to reach the market. The producers, on the other hand, were tiny, often at or below subsistence level and did not have the ability or resources for the purpose (Heredia, 1997). The cooperative was set up with the aim to (i) collect milk from several small producers in the region, and (ii) sell the product in the market to assure fair price to the producers. Thus the cooperative acted as the marketing arm of the producers and derived significant scale economies due to the large number of producers involved. From its inception, the cooperative was required to accept all the produce offered by the producers. (However, the restriction was one-sided and the producers were free to sell part or all of their products elsewhere.) Besides providing marketing support, the cooperative enabled the producers' growth through financial assistance, technology and educational support. During 1960s and 1970s, the AMUL cooperative grew rapidly through a combination of growth and expansion of both consumer and producer market and there was a need to find new markets beyond the region (Goldberg et al., 1998; Chandra and Tirupati, 2003).

Consequently, Gujarat Cooperative Milk Marketing Federation (GCMMF) was established in 1974 as the marketing and coordinating agent in the AMUL network with the specific objectives that include the following (Heredia, 1997): "(i) to establish a strong and extensive marketing system, ... and allowing member producers to concentrate on procurement, processing and packaging, ... (ii) to coordinate the operations covering all member producers, ... and (iv) ... to accept and utilize all the produce of its producer-members." Accordingly, the objectives of GCMMF are aligned with the interests of the entire network, rather than those of the individual network producers or GCMMF itself. Today, AMUL is one of the biggest brands in the country, and GCMMF is the marketing arm and coordinator for 17 district level cooperatives in Gujarat. It provides for over 3.2 million individual producers and its per day average milk collection is 10.5 million liters (http://www.amuldairy.com/index.php?option=com_content&view=article&id=49&Itemid=172).

In recent years the network has experienced severe stress with both internal and external pressures. First, well-developed markets and increased competition present ready alternative avenues for the member producers with higher prices. Second, with expansion, regional differences are more pronounced (Damodaran, 2006). Encouraged by growth in volumes the network members are no longer content to accept the quotas assigned by GCMMF and are ready to exercise their rights. For instance, in 2006, Mehsana, the largest of the 17 members in GCMMF threatened to pull out of the network (Sriram, 2010). More recently, the Kaira union, the oldest producer in the network threatened to withdraw from the network on the basis of failure of the other network producers in meeting the product quality standards (PTI, 2010). Thereby, sustainability of the network has been a major concern for the member producers.

3. Related literature

The literature related to the problem context described above is very extensive and it comes from two streams: (i) operations and supply chain management, in particular, on coordination, and (ii) network formation and stability in economics and industrial