Decision Support

Transshipment incentive contracts in a multi-level supply chain

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ABSTRACT

Transshipments within a supply chain can be difficult to implement as the costs and benefits are often incurred by different parties. This difficulty becomes even more problematic when the costs and benefits are not completely known by all parties. The primary purpose of this paper is to introduce the role of asymmetric information into the design of supply chain transshipment contracts. Using a representative supply chain from within the soft drink industry as an example, a multi-level contracting framework is developed that aligns incentives to encourage transshipments and improve performance in the absence of all parties having full information. Analysis of the proposed framework suggests that, even if a transshipment is likely to be unprofitable to the transshipping dyad, it may still be best for the entire supply chain. Moreover, overall supply chain inventories with transshipments do not necessarily increase relative to the no-transshipment case.

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1. Introduction

Consider a standard soft drink supply chain. The beverage concentrate manufacturer, for instance The Coca-Cola Company or Pepsico, Inc., sells its product to individual bottlers who, in turn, supply wholesalers and retailers. These bottlers have exclusive distribution rights within a territory and vary in size from larger, more national firms, such as Coca-Cola Refreshments and Pepsi Beverages Co. (both now wholly-owned by their parent companies), to smaller, more regional, and independently-owned ones, such as Swire Coca-Cola, USA (a Coca-Cola bottler in Utah and Idaho) and Brown Bottling Group, Inc. (a Pepsi bottler in Mississippi). On occasion, the bottlers exchange product amongst themselves in order to meet specific demands, according to industry insiders.

This transfer of inventory among entities at the same level of a supply chain is commonly referred to as a transshipment. The design and impact of transshipments has attracted the attention of a large number of researchers. A majority of this work has focused on improving the operational efficiency under centralized decision-making and having full information, with the underlying assumption that supply chain partners are willing to share data and inventories.

In the soft drink industry, transshipments offer the manufacturer an opportunity to increase sales volume by improving customer service through risk pooling. From an individual bottler's perspective, incoming transshipments also offer this same opportunity but are potentially complicated by the additional transfer costs incurred. On one hand, the receiver would like to pay only the landed cost of the transshipped product; on the other, the shipper would like to profit beyond simply covering the cost of bottling and holding inventory for another bottler. This complication is heightened by the fact that the underlying costs involved may not be known to all parties and are subject to obfuscation, leading to missed transshipment opportunities that could have benefited the overall supply chain. For instance, the receiving bottler is often responsible for arranging the transportation of the transshipped product. As the actual transportation cost is known only to the receiver, it could claim (truthfully or not) that this cost is high in an attempt to get a lower transfer price.[3] If the shipping bottler refuses to reduce its transfer price, the receiver might cancel the transshipment request and stock out the demand. Under such circumstances, a coordination mechanism is needed to provide incentives that encourage transshipments in order to take full advantage of their benefits. Of course, this arrangement is not unique to the soft drink industry—a very well-known example was Saturn Corporation's design of its after-sales parts supply chain to support emergency transshipments between automobile dealerships (Cohen et al., 2000). In Saturn's case, the out-of-stock retailer would place a transshipment request with a "pooling group" comprised of all other dealers within the region.

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[3] In a similar vein, costs related to production and capital enhancements, for example, could also be concealed; since these other costs would have comparable effects, they are not considered herein.

While the standard approach to transshipments is such that transfers can go in either direction between two locations, Lien et al. (2011) emphasize that there are numerous reasons associated with system complexity (such as communication and distribution issues) as to why two-way transshipments may not be appropriate. As a result, an alternative arrangement has gained in prominence recently: one-way transshipments. Axsäter (2003) argues that one-way transshipments are reasonable when the costs of a stock-out at two locations are substantially different—transfers flow from the low stockout location to the high stockout location, but not vice versa (see also Olsson, 2010). A documented example of this arrangement is found in the semiconductor spare parts industry (Kranenburg and van Houtum, 2009). ASML, a photolithography machine supplier to the semiconductor industry, has implemented a system within the US whereby a handful of main warehouses transship parts to other, local warehouses as needed, but product does not flow in the reverse direction. Similar arrangements are also observed in the machine tools and maintenance, repair and operating supplies industries (Narus and Anderson, 1996).

Establishing contractual agreements to coordinate transshipments amongst supply chain members is particularly helpful with today's ever-increasing product proliferation given that most companies have limited financial resources, sell only narrow and specialized product lines, and possess limited service capabilities. Moreover, transshipments have received growing attention as supply-chain-wide efficiency has become increasingly important due to competition and as the length of supply chains has increased due to outsourcing. The implementation of a transshipment policy, however, is not as easy as it seems (Narus and Anderson, 1996). The eagerness of supply chain members to be involved in transshipments is not always a given as the party that benefits the most from transshipments may not be the one that does most of the work; likewise, the party that incurs the transshipment-related costs might not be adequately compensated for its effort. The need for incentive contracts is especially important when the costs and benefits for supply chain parties involved in transshipments are not clear *a priori*. Written contracts may be an effective way to motivate all parties to participate in transshipments that benefit the entire supply chain. Thus, the design of effective transshipment-coordination mechanisms is a major concern.

This research considers the role of asymmetric information in the establishment of a design framework for efficient transshipment contracts in a multi-level supply chain to align conflicting supply chain interests and firm behaviors. As such, it establishes a groundbreaking path for future work by marrying two previously independent research streams: asymmetric information and transshipment mechanisms. More significantly, findings from this study provide several important messages for managers. First, well designed transshipment contracts can be used to guide the allocation of resources and the pooling of risk in a multi-level supply chain, even when cost information is asymmetric. Second, direct transshipment profitability is found not to be necessary for two parties to engage in transshipment activities. Rather, supply-chain-wide contracts can be designed to provide motivation for the dyad to transship even when it is *not* directly profitable for the two parties to do so, because it would be beneficial to the whole supply chain. Third, with the presence of information asymmetry, not only should supply chain decisions be made differently when a transshipment is not directly profitable, but the impact of a transshipment on supply chain performance should be different as well.

This exploratory work paves the way for the design of more general incentive mechanisms in the future with the ultimate goal of helping supply chain managers better understand and implement transshipment policies and compensation plans to coordinate supply chain operations. In the next section, the related literature is summarized and discussed. Section 3 presents the transshipment model and examines the characteristics of the transshipment contracting mechanism as well as the grand contract. Section 4 analyzes the implications of information asymmetry and the contracting structures. The paper concludes with a summary of main findings, managerial implications, limitations, and future research directions.

2. Research motivation and related literature

The preponderance of prior research on transshipments has centered on establishing proper ordering and transshipment policies to improve either operating efficiency or service levels under various demand and supply structures through a centralized decision maker. Dong and Rudi (2004), Köchel (1998), Paterson et al. (2011), and Wee and Dada (2005) review a number of these studies. But while the presence of a central decision maker for the whole supply chain allows for the maximum possible benefits to be derived from transshipments by assuming full, public information (c.f., Herer and Rashit, 1999; Kim and Benjaafar, 2002; Tagaras and Vlachos, 2002; Herer et al., 2002, 2006; Wee and Dada, 2005), it is rarely the case in reality. Recent studies, most notably Anupindi et al. (2001), Dong and Rudi (2004), Grahovac and Chakravarty (2001), Granot and Sošić (2003), Hezarkhani and Kubiak (2010), Rudi et al. (2001), Shao et al. (2011), Sošić (2006), Zhang (2005), Zhao et al. (2005), and Ziya (2004), have begun to evaluate the role of decentralized decision makers on the behavior of such a system, though they, too, assume full information between all parties. As one of the early studies in this direction, Rudi et al. (2001) examine the impact of decentralized versus centralized transshipment decision-making on supply chain profits. They show that the optimal order quantity in a decentralized environment is increasing with prices of transshipments in and out and, thus, transshipment prices can be used to achieve supply chain coordination. In contrast, the research presented in this paper shows that supply chain coordination via transshipments cannot always be optimally achieved when information asymmetry exists and can never be achieved through the transshipment payment alone.

More recently, Dong and Rudi (2004) and Hu et al. (2007) have studied the role of wholesale pricing mechanisms in supply chains with transshipments, since the supplying manufacturer and its wholesale price are not explicitly considered in the traditional transshipment literature. Zhang (2005) extends the results of Dong and Rudi (2004) to general demand distributions and uses a novel approach to demonstrate the equivalence of the retailer's problem with transshipment to a newsvendor problem without transshipment but with an adjusted demand. Zhang (2005) also examines the impact of transshipments on order quantity and retailer profit. Shao et al. (2011) extend several of the above works by studying transshipment and wholesale pricing and quantity decisions in vertically and horizontally decentralized supply chain under full (public) information. In comparison, the research presented herein finds that the order quantity based on transshipments and asymmetric information is typically closer to the standard no-transshipment quantity than to the order quantity based on transshipments and full information and that the manufacturer does not necessarily charge a higher wholesale price.

Based on a game theoretic approach, Anupindi et al. (2001), Granot and Sošić (2003), and Sošić (2006) propose a general framework for a decentralized supply chain with transshipments, but focus on the stability of the transshipment coalition structure. In particular, Anupindi et al. (2001) emphasize that transshipments can only happen with a process to allocate relevant costs and revenues in a way that is consistent with the self-interests of relevant parties. This point is explored considerably more in this paper's research.