Incentive-Driven Bilateral Transshipment in Inventory Competition

A key challenge in supply chains is matching supply with demand, especially when facing high demand variability and long ordering lead times. In practice, customers and firms approach this challenge in various ways. Encountering stock-out, a customer may switch suppliers for a substitutable product. This substitution both poses challenges and provides opportunities to competing firms. A firm with excess inventory may transship its remaining inventory to another firm with a shortage. Bilateral transshipment is widely practiced to improve inventory management beyond a single location/organization. The incentive to transship among independent firms is inventory pooling.

When multiple firms sell identical products in non-overlapping markets in which customer switching is rare due to high switching costs, transshipment is regarded as the main way to solve the mismatch problem. One scenario well studied is when multiple stores or warehouses are owned by a single "parent firm". Intra-firm transshipment can occur and can be coordinated centrally. Transshipment in this case is conducted at some internal transfer price. It acts essentially as an inventory pooling scheme, allowing firms to achieve higher service levels while reducing inventory investment. When each of a group of independent firms that sell identical products serves a distinct geographic region, there is no direct competition, and interfirm transshipment can occur. The key issue is to have a sharing mechanism to induce joint-profit maximization and allocate the additional profit reaped from cooperation. This requires setting appropriate transshipment prices, and it has been well studied (see, for instance, Rudi et al. 2001, Anupindi et al. 2001, Dong and Rudi 2004, Hu et al. 2007, Huang and Sošić 2010, Shao et al. 2011).

When independent firms serve the same or overlapping markets, customer switching can occur when their demands are not met at their first-choice firm. The key issue arising from customer flow is competition in terms of product availability, which has been studied extensively in the literature without considering transshipment. Palar (1988) studies a competitive version of the newsvendor problem of two retailers selling substitutable products. He proves the existence and uniqueness of the Nash equilibrium.
of a pair of competitive order quantities. Many extensions of the problem in varying settings have been studied, and a common finding is a tendency toward "competitive overstocking" (see, for example, Lippman and McCardle 1997 and Mahajan and van Ryzin 2001).

This raises the question of whether independent distributors/retailers who compete for customers in overlapping markets should transship to each other. Industry practices suggest that perhaps they should. For example, in Hong Kong, many independent retailers selling consumer electronics usually cluster in nearby shopping malls. When a customer encounters a stock-out at one store, the retailer will request a transshipment from a nearby store. When transshipment is not successful, the unsatisfied customer may leave and go to other sellers. The independent automobile dealerships of a particular car brand in an extended region usually do not have mutually exclusive markets. They compete for buyers and often accept transshipment requests from their competitors. In the above examples, bilateral transshipment may appear unreasonable because by customer switching, a competitor's loss in sales due to stock-out could be one's own gain. Although the literature on transshipment and customer switching is substantial, there has been no work on their joint effect in overlapping markets except for Çömez et al. (2012). In Çömez et al. (2012), customer demands arrive sequentially, and a transshipment request and the acceptance/rejection decision are made when demand encounters a stock-out. The focus is on the optimal transshipment policy of the selling side as characterized by inventory holdback levels. However, some important questions remain unexplored. (1) How can transshipment in this competitive environment be beneficial to firms? (2) How do customer switching behavior and the problem parameters affect firms' decisions and profits? (3) How does the availability of subsequent transshipment affect competitive inventory decisions? (4) Is there a pair of coordinating transshipment prices that can result in the first-best ordering and transshipment decisions in this decentralized system?

To answer the above questions, we consider a model with two retailers selling identical products in overlapping markets. The two retailers decide their order quantities before the selling season. Demands are then realized, and each firm satisfies its demand with on-hand inventory. If one retailer has a shortage and the other has surplus inventory, the
stock-out retailer will request transshipment, based on which the retailer with surplus inventory decides the transshipment quantity. A fraction of unsatisfied customers at the stock-out retailer, after taking the initial stock and the transshipment (if there is any) into account, will switch to the other retailer. The rest of the residual demand will be lost. In this environment, the two retailers, although competing with each other in product availability, may improve their individual profit by reducing the lost sales and enlarging the total pie if they can cooperate. We call this the "co-opetition" game, and we use it to investigate the above key managerial issues.

We make four main contributions in this paper. (1) The seller's transshipment policy in non-overlapping markets is essentially to meet the shortage to the extent possible with the on-hand inventory (i.e., Full-Transshipment); but it is no longer optimal in overlapping markets. With customer switching, when the surplus is not too large relative to the shortage, the seller prefers either No-Transshipment or Partial-Transshipment (i.e., reserving all or part of its inventory) to benefit from demand spillover. (2) The competitive order quantity decisions are significantly affected by subsequent transshipment policy, and a unique Nash equilibrium exists under some mild demand distribution conditions. Retailers order more to increase their chance of being on the selling side when the transshipment price rises. Unlike customer switching, which always leads to "competitive overstocking", bilateral transshipment can reduce inventory quantities in overlapping markets when the transshipment prices are sufficiently low. (3) We show that competing retailers have an incentive to bilaterally transship when the customer switching probability is relatively low and the transshipment prices are within a certain range. Under these conditions, retailers are better off with transshipment because they can benefit from both inventory pooling via transshipment and less intense inventory competition (i.e., mitigated "competitive overstocking"). (4) By comparing the decentralized system with the centralized case, in which the two firms are managed by a central decision maker whose objective is to maximize the joint profit of the two firms, we explicitly derive the conditions on the existence of coordinating transshipment prices that align the self-interests of independent retailers and induce globally optimal behavior.