



# Supply chain coordination with a single supplier and multiple retailers considering customer arrival times and route selection



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## ABSTRACT

We address a novel decentralized supply chain with one supplier and multiple independent retailers based on the practice of several supply chains in the real world. Coordination of such a supply chain has rarely been studied. Despite overcoming the well-known double marginalization, the supplier's route selection can obstruct supply chain coordination. We present a wholesale-price-and-carpooling contract to coordinate such a supply chain. We demonstrate supply chain coordination under such a contract and show that the profit along the supply chain can be arbitrarily allocated. We show that the popular revenue-sharing contract may lose flexibility in profit allocations.

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## 1. Introduction

Managers of many supply chains with a single supplier and multiple retailers face a pricing-and-routing problem. With one vehicle, the supplier distributes newsvendor-type products to different retailers located within different geographic regions. The retailers do not compete with each other and make ordering decisions on the basis of the wholesale prices charged by the supplier. These newsvendor-type products require long lead times and are sold in short selling seasons. The arrival time of products at each retailer depends on the delivery route selected by the supplier, but the arrival times of the customers to purchase the products vary. Suppliers in these supply chains cannot start production too early because of specific constraints. Therefore, some customers visit local retailers before product arrive, and because these customers typically do not look for the products at other retailers, the orders are lost. This problem can be widely found in many supply chains in the real world and our study was motivated by the following real examples.

In China, customers use many traditional food supply chains. In each supply chain, a single supplier distributes food to multiple retailers every day. Each retailer only places one order every day. Because the food must be used shortly after harvested or produced, customers will not purchase food after specific, fixed, time points. A traditional food supply chain, as described, has several unique characteristics. On the supply side, to guarantee product freshness or appropriateness, suppliers cannot start production too early. Because suppliers usually deliver food to retailers with a single vehicle, the route selection influences when retailers can sell the food. On the demand side, consumers of traditional foods in rural China, primarily housewives, visit retailers in the morning to purchase traditional foods and other goods for use at lunch or dinner. The housewife consumers in our example visit at different time points as determined by their own schedules. Those who visit local retailers before product arrival fail to purchase the desired product, but they typically do not search for the product

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at other retailers. In addition, although some retailers have predictably early-arriving clientele, the supplier may not serve them first because of the increased transportation costs, which might exceed the increased revenue gained by delivering early. Some retailers who receive late deliveries complain to the supplier or even quit the supply chain. Their pricing and ordering decisions are more complicated by customer arrival times and supplier route selections. A similar situation is found in the traditional bread supply chains of Argentina.

The second example involves newspaper supply chains. One traveling salesperson, who determines the route, delivers newspapers to several newsstands. In the morning of every business day, workers pass by newsstands near mass transit areas and buy available newspapers. Those who arrive at their local newsstands before the newspapers are delivered typically neither wait for the supply to arrive nor look for the newspapers at other newsstands. This purchasing pattern also characterizes many university campuses where instructors and students try to buy newspapers from local vendors during break times. In these cases, customer arrivals fall within a wide range of time points at different newsstands. However, because of the nature of the news cycle, publishers cannot start production too early.

On the basis of the practice, we developed our model that differs from others in the literature in two aspects. First, the demands at all retailers are generated by customers arriving at different times; in most real cases, customers enter the system at different time points. With the assumption that the products can be delivered to retailers before the selling time (season) starts, many studies on supply chain coordination describe the total demand at each retailer as a probability distribution. In some supply chains, however, the arrival time of each customer needs to be considered. For example, Grubbström (2010) studied the newsvendor problem to show ways to maximize the net present value of the payments involved, and customer demand was considered a compound renewal process. In our supply chain model, we account for the arrival time of customers because the product arrival times are decision variables that affect the overall supply chain profit. Second, the route decided by the supplier influences the profits of all supply chain members. Many studies show that supply chain coordination cannot be achieved because of double marginalization (Spengler, 1950) and the competition between retailers. A well-known phenomenon, double marginalization is found when the retailer's optimal order quantity is smaller than the channel-wide optimal inventory level. A fairly large number of contracts have been developed to align retailers' pricing and ordering decisions. In our supply chain model, the supplier uses a new decision framework and plays a more important role than in existing supply chain models. We show that the supplier's route selection can create a new barrier to supply chain coordination. To the best of our knowledge, this type of supply chain has rarely been studied. Fig. 1 illustrates such a supply chain with  $n$  retailers.

Managers of one food supply chain in China realized supply chain profit losses and raised the following questions: Are the profits of members maximized in a decentralized supply chain? If not, how do we increase the profits of supply chain members? Can existing supply chain contracts improve the supply chain profit? On the basis of these questions, we study the coordination of supply chains. To the best of our knowledge, coordination of such supply chains has been unexplored, and this article is the first to answer these managerial questions. Therefore, our study fills the research gap by coordinating the decentralized supply chain. The specific contributions of this study are as follows:

- (1) We uncover barriers to the coordination of the supply chain, in which the supplier charges each retailer a price for each unit purchased and decides the route. On the basis of prices and route, the retailers decide their own selling prices and order quantities. Double marginalization exists in all of the subsystems, each of which involves a retailer and the supplier. In addition, the supplier may prefer a local optimal route that cannot maximize supply chain profit (this phenomenon is described in detail in Section 3).
- (2) In contrast to combining or extending existing contracts, we developed a wholesale-price-and-carpooling (WPC) contract based on practice in the taxi industry in China to address the unique characteristics of the supply chain, which enhances the feasibility of our contract. The contract suggests use of a carpooling strategy through which retailers pay the supplier wholesale prices for each unit purchased and share the transportation costs of the delivery routes, which they share in part. We demonstrate that the WPC contract can achieve supply chain coordination and arbitrarily allocate supply chain profit. Principles of carpooling have not been used to design a supply chain contract. In traditional carpooling, passengers share a transportation service, usually one vehicle in which several people ride, sacrificing some individual benefits, such as streamlined travel time and privacy, while saving transportation fees, easing traffic

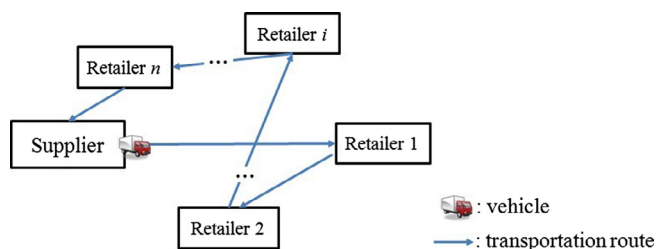


Fig. 1. Supply chain model.

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