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Mitigating bankruptcy propagation through contractual incentive schemes

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ABSTRACT

With the increasing interdependence among supply chain members on material, information and capital, interactions and decisions characterized by operational parameters are important causes of bankruptcy propagation in supply chain. This paper investigates the methods for mitigating bankruptcy propagation through supply chain coordination. Based on a two-stage supply chain network that consists of multiple upstream manufacturers and multiple downstream retailers, the effectiveness of some typical contractual incentive schemes, including revenue sharing, price discount and quantity flexibility contracts, in mitigating bankruptcy propagation among supply chain members is examined. Through agent-based simulation experiments, it has been revealed that: 1) the three typical supply chain contracts with properly designed contract parameters are effective in mitigating bankruptcy propagation, but their effectiveness depends on operational parameters of the supply chain; 2) horizontal competition among retailers is an important factor in determining the effectiveness of these contracts; 3) revenue sharing contract turns out to be more effective in mitigating bankruptcy propagation than the other two contracts. By comparing the optimal contract parameters with and without considering bankruptcy risks, it has also been found that, a set of contract parameters that can maximize the profit of the supply chain may increase the occurrence of bankruptcy in supply chain, leading to the phenomenon of a risk–profit tradeoff.

1. Introduction

With the increasing interdependence of supply chain members on material, information and capital, bankruptcy of a supply chain member may lead other member firms getting into financial difficulties. This phenomenon is termed bankruptcy propagation in network economy [2,9]. An intuitive explanation for bankruptcy propagation is the avalanche of debt chain or credit chain in the supply chain network [2,5,6,9,11]. Recent researches reveal that interactions among supply chain members and decisions made by supply chain members are important causes of the occurrence and propagation of bankruptcy in the supply chain. For a simple three-echelon supply chain that consists of a retailer, a distributor, and a manufacturer, Xu et al. [25] found that demand forecasting methods, market demand characteristics (uncertainty of demand in each period and auto-correlation of demands in consecutive periods) and thus service levels required by the supply chain members, have significant impacts on the occurrence of bankruptcy at each stage of the supply chain. For a two-echelon supply chain network that consists of multiple retailers and manufacturers, Hua et al. [10] investigated impacts of various operational parameters of the supply chain, such as horizontal competition among retailers, order allocation strategies of retailers, wholesale price of manufacturers, characteristics of market demand and number of retailers, on bankruptcy propagation. They found that interactions and decisions characterized by these operational parameters are important causes of the occurrence and propagation of bankruptcy in the supply chain.

Bankruptcy propagation is an important type of financial risk in supply chain operations. However, in the previous literature of supply chain risk management, researches are mainly focused on exposure to adverse events [16] and supply chain disruptions caused by natural disasters, strikes and terrorist attacks [20]. Based on specific methods of risk assessment and identification, risk mitigation is usually achieved through structure redesign of supply chains [12,15]. In these researches, operational risk is the main topic, while financial risk draws little attention. Among the few researches related to financial risk of supply chain, Tsai [22] investigated cash flow risk in a three-tier supply chain, which was measured by the standard deviations of cash inflows. Through simulation experiments, Tsai [22] established the relationship between the physical flow and cash flow, measured the supply chain cash flow risks with respect to a few time related risk factors, and recommended the best policy of using Asset-Backed Securities (ABS) to finance accounts receivable as a means to lower the cash inflow risk. In other words, the risk mitigation policy was suggested from financial perspective, rather from operational perspective.

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This paper investigates the methods for mitigating bankruptcy propagation through supply chain coordination. Hua et al. [10] reveal that, 1) horizontal competition among retailers could decrease both the average retail price and the average market demand, and thus decrease sales revenue of supply chain, leading to the collapse of supply chain; 2) bankruptcy at retailers could be increased if manufacturers require a high proportion of up-front payment of retailers. Overall, bankruptcy propagation is the result of ineffective control of material flow and capital flow along the supply chain. Therefore, it may be possible to mitigate the risk of bankruptcy propagation through vertical coordination between supply chain members. In supply chain management, many contractual incentive schemes (also termed as *supply chain contracts*, or simply termed as *contracts*) have been proposed to coordinate the operations of member firms in a supply chain (e.g., quantity discount contract [24], revenue sharing contract [8], quantity flexibility contract [23], buy back contract [18], sales rebate contract [21], and price discount contract [4]). These contracts have been proven to be effective in improving operational performance of supply chain members under various problem backgrounds [7], whereas, the effectiveness of these contracts in mitigating bankruptcy risks in supply chains has yet been examined. Xu et al. [25] made a pioneering attempt to verify the effectiveness of two collaborative mechanisms in reducing the probability of bankruptcy occurrence at each stage of a supply chain. However, the occurrence of bankruptcy at each stage of a supply chain does not imply the tendency of bankruptcy propagation along the supply chain.

For a two-echelon supply chain network that consists of multiple manufacturers and retailers, the effectiveness of some typical contractual incentive schemes, including revenue sharing, price discount and quantity flexibility contracts, in mitigating bankruptcy propagation is examined. Results of agent-based simulation reveal that: the three typical supply chain contracts are conditionally effective in mitigating bankruptcy propagation, whose effectiveness depends on the operational parameters of the supply chain. By comparing the optimal contract parameters with and without considering bankruptcy risks, it has also been found that, a set of contract parameters that can maximize the profit of the supply chain may increase the occurrence of bankruptcy, leading to the phenomenon of a risk–profit tradeoff.

Main contributions of this paper are two folds. First, an agent-based simulation model is built to investigate the relationship between supply chain contracts and the financial status of firms in the supply chain network. Second, the effectiveness of some typical supply chain contracts in mitigating bankruptcy propagation is examined. Impacts of operational parameters on the effectiveness of these contracts are also investigated, which significantly contributes to the research of mitigating financial risks of supply chains from the operational perspective.

The remainder of this paper is organized as follows. In Section 2, we briefly describe the supply chain model. In Section 3, some typical supply chain contracts are described. The simulation model is developed in Section 4. Effectiveness of supply chain contracts in mitigating bankruptcy propagation is examined in Section 5. Section 6 presents the conclusions.

2. The supply chain model

Consider a supply chain network consisting of I ($I \geq 1$) upstream manufacturers and J ($J \geq 1$) downstream retailers. The I manufacturers produce a single product to fulfill orders placed by the retailers, and the J retailers procure the product from the manufacturers to meet the market demand in discrete time periods t ($t = 1, 2, \ldots, T$). Because J retailers sell the same product to the market, demand of each retailer depends not only on the retail price of itself, but also on the retail prices of other retailers. Denote by $\mathbf{p^t} = (p_1{}^t, p_2{}^t, \ldots, p_j{}^t, \ldots, p_J{}^t)$ the price vector of J retailers in period t, and $d_j{}^t(\mathbf{p^t})$ the elastic demand of retailer j, we assume [4]

$$d_j^t = a_j - b_j\left(p_j^t - \sum_{l=1, l\neq j}^{J} \theta_{jl} p_l^t\right) \tag{1}$$

with $a_j > 0$ and $b_j > 0$. Parameter θ_{jl} ($\theta_{jl} \geq 0$ and $\sum_{l=1, l\neq j}^{J} \theta_{jl} \leq 1$; $l, j, \in \{1, 2, \ldots J\}$ and $l \neq j$) describes the degree of competition between retailer j and retailer l. The larger the value of θ_{jl}, the more intensive the competition between retailer j and retailer l [13]. The demand of retailer j ($j = 1, 2, \ldots J$) in period t, $D_j{}^t$, is assumed to be of the additive form

$$D_j^t = d_j^t + \varepsilon_j^t, \tag{2}$$

where parameter $\varepsilon_j{}^t$ is a random term, which represents the uncertainty of the demand market.

2.1. Operation process of the supply chain

At the beginning of each period, retailers receive market demand, review their inventory positions of the product, and make procurement decisions about how much to order from their upstream manufacturers. Similarly, manufacturers receive orders from their downstream retailers at the beginning of each period, review their inventory positions of the material, and make procurement decisions about how much to order from the suppliers outside of the supply chain. In any period, if the realized demand of a supply chain member is larger than its on-hand inventory, the stockouts are backordered. To simplify the description of interactions between manufacturers and retailers in the operation processes, we make the following assumptions: (1) all manufacturers sell the product to the retailers at the same unit price w; (2) different manufacturers (or retailers) have the same production (or replenishment) lead time of one period.

In period t ($t = 1, 2, \ldots, T$), the sequence of events followed by supply chain member x ($x = i$ or j, $i = 1, 2, \ldots, I$; $j = 1, 2, \ldots, J$) is outlined as follows:

(1) At the beginning of period t, member x reviews its inventory position and financial situation, and decides how much to order from its immediate upstream members ($Q_x{}^t$). In case when the cash on hand of member x ($A_x{}^t$) is insufficient for product procurement, it can borrow $B_x{}^t$ from exogenous financial institutions with a constant interest rate $r (r > 0)$.
(2) Member x then receives products or materials ($IR_x{}^t$) from its immediate upstream members, which was ordered at the beginning of period t or before period t (in case of backorders). If member x is a manufacturer, it receives materials from outside suppliers with ample raw material.
(3) At the end of period t, member x observes the realization of demand ($D_x{}^t$) from its downstream members (or from the retail market). If $x = j$, the realized demand of retailer j in period t, $D_j{}^t$, is described by Eq. (2). If $x = i$, the realized demand of manufacturer i in period t, $D_i{}^t$, is the sum of the orders placed by all retailers to manufacturer i at the beginning of period t.
(4) Member x sells product to meet the demand, as well as backorders of the last period ($IB_x{}^{t-1}$) if any, of its downstream members. The quantity of product that member x sells in period t, $IS_x{}^t$, is limited by its total demand ($D_x{}^t + IB_x{}^{t-1}$) and its on-hand inventory.

Note that when member x is the manufacturer ($x = i$), it is possible that a manufacturer cannot meet its total demand. In this case, we assume that the manufacturer distributes the product to retailers in proportion to the total order quantities of retailers.