Supply chain coordination under budget constraints

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ABSTRACT

Budget constraints are commonly considered in real decision frameworks; however, the literature has rarely addressed the design of contracts for supply chains with budget-constrained members and in which capital costs are considered. In this article, we study supply chain coordination of budget-constrained members when a financial market is unavailable. We propose a revenue-sharing-and-buy-back (RSBB) contract that combines revenue-sharing (RS) and buy-back (BB) contracts. We compare the performance of RS, BB, and RSBB contracts under a coordinated two-stage supply chain in which members experience budget constraints. Results show that the RS and BB contracts are not feasible under certain budget scenarios, whereas the RSBB contract can always be used to coordinate the supply chain and arbitrarily divide profits. We propose a profit allocation approach to address information symmetry created by undisclosed budget thresholds. Our analytical and numerical results provide insight into how managers select an appropriate contract based on their budget scenarios and capital costs.

1. Introduction

In existing studies on supply chain contracts, it has been commonly assumed that all of the supply chain members have infinite budgets. Under this assumption applied to a conventional market setting, the retailer orders fewer products than the channel-wide optimal quantity (Spengler, 1950). In developed economies, such as those in the United States or the European Union, a powerful supplier (or retailer) has enough access to the financial market to obtain a sufficient budget. However, in many developing countries that do not have an advanced financial market, supply chain members, even the most powerful, may be unable to obtain sufficient money to order optimal quantities. In these cases, supply chain managers must make decisions under strict budget constraints such that they order fewer products than the channel-wide optimal quantity. The motivation for considering absolute budget constraints is illustrated by examples from China.

Li Jun Orchard (LJO) plants and supplies peaches and watermelons to retailers in Beijing. The retailers pay a deposit when sending orders to LJO and pay the balance when they receive the products. LJO cannot obtain bank loans because fruit growing is a high-risk industry that can be significantly influenced by natural disasters, and the company does not have the cash flow to satisfy bank

requirements. In another example, from Moon, Feng, and Ryu (2015), an electronics distributor in China cannot secure a bank loan because neither its fixed assets nor cash flow amounts satisfy financing requirements. The managers of LJO and the electronics distributor must make decisions under absolute budget constraints.

Many companies with budget constraints attempt to improve their financial management. A survey of more than 170 firms showed that 39% of small companies were inhibited from maximizing their global trade opportunities by the costly and complex proof of financial stability for conducting an imports/export operation (Enslow, 2006). However, to the best of our knowledge, most of the contracts studied have been used to achieve supply chain coordination under the assumption that the members have sufficient budgets to make a range of decisions.

Some studies have focused on budget constraints by firms that can secure loans from a financial market, but do not address supply chain coordination. For example, Dada and Hu (2008) discussed a supply chain model in which budget-constrained retailers can borrow funds from a bank. Caldentey and Haugh (2009) proposed a contract through which a budget-constrained retailer can hedge its budget constraint in the financial market. Chen and Cai (2011) studied a supply chain model in which a budget-constrained retailer can borrow funds from a bank or logistics firm. The literature describes situations in which the financial market loans money to the budget-constrained members and joins into finance

contracts, an efficient approach if the borrowers can satisfy the requirements of the financial market and if the negotiation is not costly. However, especially for those with small companies, some supply chains may find involving the financial market an infeasible or inefficient option. First, the financial market may be unavailable to small companies, which usually do not have high credit ratings. Second, involving the financial market may create new contract parameters, such as specifications for an interest rate that depends on the members' default risk (e.g., Dada & Hu, 2008; Lee & Rhee, 2010). In this case, all of the supply chain members and those in the financial market must agree to the parameters, which can lead to a costly negotiation process (Moon et al., 2015). Consequently, it is important to study the coordination of supply chains with budget-constrained members for whom the financial market is unavailable.

Contracts have been popular for coordinating supply chains. The buy-back (BB) contract was first studied by Pasternack (1985). Under a BB contract, the manufacturer charges the retailer a unit wholesale price and pays the retailer a buyback price per unit unsold. Cachon and Lariviere (2005) proposed a revenue-sharing (RS) contract, under which the manufacturer charges the retailer a unit wholesale price and shares a proportion of the retailer's total revenue. RS contracts have also been extended to coordinate supply chains with more than two members (e.g., Jiang, Wang, & Yan, 2014). See Hou, Zeng, and Zhao (2010) and Feng, Moon, and Ryu (2014) for detailed surveys on BB and RS contracts. Recently, Nosoohi and Nookabadi (2014) developed an option contract for coordinating a manufacturer and its component supplier. Arya, Löffler, Mittendorf, and Pfeiffer (2015) discussed simple cost-based contracts with a middleman for supply chain coordination. Several composite contracts have been developed for new supply chain problems (Chen, 2011; Jörnsten, Nonås, Sandal, & Ubøe, 2013; Taylor, 2002; Wang & Webster, 2007; Xiong, Chen, & Xie, 2011). Each of these composite contracts consists of two subcontracts. All of these studies focused on supply chain coordination with members operating without budget constraints.

Yan and Sun (2013) designed a wholesale-price contract and a finite loan scheme to coordinate supply chains with a manufacturer, a capital-constrained retailer, and a bank. Jing and Seidmann (2014) compared banks and trade credit in a supply chain with a supplier and a budget-constrained retailer. Xu, Cheng, and Sun (2015) discussed the performance of RS, output-penalty, and cost-sharing contracts for coordinating outsourcing supply chains with firms under financial constraints. Jin, Wang, and Hu (2015) analyzed contract type under sales promotion in supply chain coordination with a capital-constrained retailer. These studies assumed that the manufacturer (or supplier) has a sufficient budget. Moon et al. (2015) extended the RS contract for multi-echelon supply chains with budget-constrained members. However, they assumed that the terminal members have sufficient budgets.

Lee and Rhee (2010) studied the performance of RS and BB contracts when the budget-constrained retailer and supplier can borrow as much money as needed from the financial market. Our paper differs from that work in meaningful ways. First, Lee and Rhee (2010) assumed that both retailer and manufacturer must expend their internal budgets, while we study more general budget constraints. Second, we propose a new contract to achieve supply chain coordination without a financial market. The absence of a financial market could influence supply chain coordination more significantly when only one member is budget constrained. Third, Lee and Rhee (2010) studied a special case of open-account financing in which the retailer pays the remainder after the total sales revenue was obtained. However, in practice, the due date for the retailer to pay

the remainder is often set before the sales revenue is collected by the retailer. Delaying the due date may require a new negotiation process and additional administrative costs. In this paper, we study open-account financing in which the due date is set before the retailer obtains the sales revenue as is common practice.

The current RS and BB contracts have limitations. First, RS contracts may necessitate additional costs for the manufacturer who must monitor the retailer's revenue (Cachon & Lariviere, 2005). Consequently, RS contracts can be unfair to the manufacturer. Second, when capital costs are considered, BB contracts also can be unfair to the retailer. Under the BB contract, the wholesale price can be high when the sales price is high or when the profit percentage for the retailer is low. Third, under budget constraints, RS and BB contracts may not allow for supply chain coordination. However, a composite contract consisting of revenue-sharing and buy-back mechanisms may overcome the limitations. We propose a revenue-sharing-and-buy-back (RSBB) contract, which combines RS and BB contracts.

We consider a two-stage supply chain that consists of a retailer and a manufacturer who have budget constraints. This paper contributes to the literature in three ways. First, we analyze supply chain coordination with budget-constrained members when the financial market is unavailable. Second, we propose a flexible contract for supply chain coordination under budget constraints. Third, we show the limitation of RS and BB contracts under budget constraints.

The paper is organized as follows. Section 2 analyzes the decision framework of a supply chain under budget constraints and proposes the RSBB contract. Section 3 discusses three regions of the budget space in which the RS, BB, and RSBB contracts show different performance. Section 4 presents numerical experiments and related discussions. We provide concluding remarks and suggest future avenues for our model in Section 5.

2. The revenue-sharing-and-buy-back contract

2.1. Supply chain model

We consider a supply chain consisting of a retailer (r) and a manufacturer (m). Both members are risk neutral and the retailer faces a newsvendor problem. The uncertain customer demand is represented by the nonnegative random variable D defined over the continuous interval $[0, \infty)$. Unit production costs for the retailer and the manufacturer are c_r and c_m, respectively. Let $c = c_r + c_m$. The retailer sells the products to customers at a retail price, $p(> c)$. The unsold products are salvaged by the retailer with a unit salvage value, s. We take the above parameters as exogenously specified. The retailer decides the order quantity, $q(\geqslant 0)$, and pays the manufacturer a wholesale price, w, for each unit purchased. Before the manufacturer begins production, the retailer pays a proportion of the total trading amount up front as a deposit. The retailer pays the rest of the total amount after a fixed period (e.g., 30 days) that ends before the final sales revenue is obtained. This scheme reflects a typical form of open-account financing that has become popular in recent years. For simplicity, we assume that the retailer pays the balance due and starts to sell upon receiving the products. This assumption will not influence the conclusions presented in the paper. Because the selling season of newsvendor-type products is relatively short, we do not consider the interest income from the revenue collected during the selling season. Fig. 1 shows the funding sequence in the supply chain.

Let β be the percentage of the total trading amount that the retailer pays up-front, defined over the continuous interval $[0, 1]$. The retailer pays $\beta w q$ as a deposit and the manufacturer starts