Coordination contracts in the presence of positive inventory financing costs

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A R T I C L E   I N F O

A B S T R A C T

Numerous studies have offered diverse contractual forms of alliance, in which the supply chain partners coordinate their decisions for greater joint performance in an entirely self-interested way. Prior literature implicitly assumes free inventory financing. However, this assumption is questionable in the real marketplace. Firms frequently finance their working capital from a variety of credit sources, such as banks, and incur positive costs of the funds for inventory. Surprisingly, the impact of inventory financing costs on supply chain coordination has not been sufficiently investigated by supply chain academics. We address this issue by explicitly assuming capital-constrained agents and positive inventory financing costs. Specifically, we consider four extensively discussed coordination mechanisms for investigation: (i) all-unit quantity discount, (ii) buybacks, (iii) two-part tariff, and (iv) revenue-sharing. We show that, under the assumption of positive inventory financing costs, these contracts fail to achieve joint profit maximization if each agent relies on direct financing from a financial institution. Positive financing costs call for trade-credit in order to subsidize the retailer's costs of inventory financing. Using trade-credit in addition to the contracts, the supplier fully coordinates the supply chain for the largest joint profits. Moreover, positive inventory financing costs make revenue-sharing less profitable than the other three contracts. We present three different schemes for coordination in a decentralized supply chain, using buybacks, quantity discount, and two-part tariff, respectively. We also derive the optimal trade-credit rate not only for the supplier's profit, but also for joint supply chain profit.

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1. Introduction

A supplier and its retailers are independent decision makers. Facing different cost structures and uncertainties in either the wholesale or retail market, each makes strategic decisions in order to maximize its own individual profit. Such independent profit maximizations often lead to poor performance of the entire supply chain. Integrating supply chain agents through merger and acquisition eliminates this problem, and improves performance in the supply chain (Langabeer and Seifert, 2003). However, it is an arduous task to align the localized objectives of channel participants with diverse self-serving orientations (Brouwers et al., 2005). Moreover, this form of vertical integration frequently results in structural inflexibilities and organizational rigidities.

Numerous studies have recently focused on a more flexible form of contractual alliance, in which the supply chain partners coordinate their decisions for greater performance in an entirely self-interested way. These include buybacks (Pasternack, 1985;

Emmons and Gilbert, 1998; Lee, 2001; Tsay, 2001; Lee and Rhee, 2007); quantity discounts (Dada and Srikanth, 1987; Weng, 1995; Chen et al., 2001; Cachon, 2003); revenue-sharing (Cachon, 2003, Cachon and Lariviere, 2005); two-part tariffs (Lariviere, 1999); quantity flexibility contracts (Tsay, 1999); wholesale and retail price protections (Lee et al., 2000); target-level sales rebates (Taylor, 2002); capacity reservation contracts (Barnes-Schuster et al., 2002), etc. These coordination schemes enable the retailer to share the demand uncertainty with its supplier, and make the retailer order the optimal quantity for joint profit maximization. In other words, the schemes coordinate the channel participants' decisions by alleviating the problem in the agents' independent profit maximizations, and yield the same profit as in a fully integrated supply chain. See Lariviere (1999) and Cachon (2003) for detailed discussions of diverse coordination contracts.

The prior literature on supply chain coordination does not take inventory financing costs into account, and implicitly assumes that a supplier and its retailers incur zero cost of the funds for inventory. This assumption is problematic in the real marketplace. Firms frequently finance their working capital from a variety of credit sources, such as banks, and incur positive financing costs. Lenders ask interest for the loans they grant, facing uncertainty regarding what may happen if the loan is in default. Even in the case of zero credit default risk, such as with US Treasury bills, lenders still demand positive financing costs, not only due to market risk, which is the risk of changes in the overall financial

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market, but also due to liquidity risk, which is the risk of being unable to sell the collateral for cash without significant cost.

Immediate questions are, then, (i) whether the contracts in previous studies still fully coordinate the supply chain for joint profit maximization, in the presence of positive inventory financing costs; (ii) if not, how the terms for coordination should be adjusted and what other incentives should be offered to retailers; and (iii) whether one type of contract is better for the supply chain than others. We attempt to address these issues by explicitly assuming capital-constrained agents and positive inventory financing costs.

Inventory financing costs have been assumed as a part of inventory holding cost in an EOQ framework. Beranek (1967) assumes a firm's financial arrangement for inventory and derives the optimal lot size. Harley and Higgins (1973) assume trade-credit financing and examine both lot size and payment time of the trade-credit to minimize total inventory costs. Harley and Higgins' model has been extended to cases of discounted cash flow (Rachamadugu, 1989), inventories subject to deterioration (Aggarwal and Jaggi, 1995), and possible shortage of inventory (Jamal et al., 1997). Unlike prior studies that analyze the retailer's stocking policies at positive inventory financing costs, Gupta and Wang (2009) have recently taken the supplier's viewpoint as well, and conjecture that finance charges for inventory may be used to improve efficiency in the supply chain. They show the effect of finance charges on the supplier's as well as the retailer's profits by changing the size of the finance charge in numerical simulations.

Supply chain academics have recently examined inventory financing costs in a Newsvendor framework. Babich et al. (2008) study a firm's dual financing strategy. A firm has multiple suppliers offering limited amounts of trade-credit. It can also finance working capital from a bank. The firm will go bankrupt if the return (cash flow) from the business activity is less than the total of the loans. Given differing interest rates from the suppliers and the bank, Babich et al. (2008) investigate the firm's procurement with financing decisions on loan amount from each source. Li et al. (2009) questions the assumption of credit default. In contrast to Babich et al. (2008) and Li et al. (2009) assume that a firm can continue its operation by paying a default penalty even after the firm defaults on the loan for a particular business activity. Hence, going into terminal bankruptcy is also the firm's strategic decision. Under this more realistic assumption, Li et al. (2009) examine a multi-period dynamic model, in which a firm can finance working capital from external as well as internal sources.

Dada and Hu (2008) is the closest to our model. They present a capital-constrained Newsvendor model, in which a vendor has limited internal capital and needs funds from a bank to finance additional procurement. They assume that the bank is strategic and coordinates the vendor's order quantity as a Stackelberg leader. Using a game theoretic approach, Dada and Hu (2008) design a lending rate to induce the capital-constrained vendor to order the optimal quantity for joint profits of the bank and vendor.

Unlike Gupta and Wang (2009), this paper explicitly considers inventory financing cost as a strategic tool. As in Dada and Hu (2008), a retailer is a capital-constrained Newsvendor and needs funds from external sources to finance inventory. This paper, however, differs from Dada and Hu (2008) in that we focus on *inner* supply chain coordination issues. Specifically, we shed light on inventory financing costs from a supplier's perspective. A supplier is strategic and coordinates the supply chain as a Stackelberg leader. We show a supplier's trade-credit as a tool for supply chain coordination. In the presence of positive inventory financing costs, previous coordination contracts fail to achieve joint profit maximization if each agent relies on direct

financing. A supplier's sharing demand uncertainty is not enough for its retailers to order the optimal quantity for the entire supply chain. In addition, positive financing costs call for trade-credit in order to subsidize the retailer's costs of inventory financing. Using these multiple schemes, the supplier fully coordinates the supply chain for the largest joint profits.

Specifically, we consider four extensively discussed coordination mechanisms for investigation: (a) all-unit quantity discount, (b) buybacks, (c) two-part tariff, and (d) revenue-sharing. In quantity discount and two-part tariff, the supply chain is always better off with trade-credit. The supply chain is also better off with trade-credit even in a buyback contract, if the supplier is a credit-worthy borrower or has a sufficiently large internal capital. These three contracts yield the identical joint profits with trade-credit. On the other hand, positive inventory financing costs make revenue-sharing less profitable than the other three contracts. We present three different coordination schemes, using buybacks, quantity discount, and two-part tariff, respectively, for a decentralized supply chain. We also derive the optimal trade-credit rate not only for the supplier's profit, but also for joint supply chain profit.

The rest of the paper is organized as follows. Section 2 presents a model that captures the transactions between a supplier and its independent retailer given the retailer's two financing options: trade-credit and direct financing. Sections 3 and 4 examine two benchmark cases of fully integrated supply chain with trade-credit and direct financing, respectively, and derive the conditions under which trade-credit yields greater joint supply chain profit. Section 5 derives three optimal coordination schemes for a decentralized supply chain. The last section summarizes the findings and implications, and suggests areas for future research.

2. The model

We follow the standard approach in the "Selling to the Newsvendor" framework (Lariviere and Porteus, 2001). The supply chain consists of two risk-neutral agents, a supplier and a retailer. The product has a short life cycle, such as consumer electronics, fashion apparel, or other perishable goods. Consumer price p is constant during the short sale period, and the demand is stochastic at p. Specifically, demand y follows continuous distribution $F(y)$ with density $f(y)$, where $F(y=0)=0$. The retailer procures quantity q given the demand, only once at the beginning of the sale period. We assume zero market value of leftover items. We also omit the long-run impact of poor product availability on revenue (such as loss in goodwill). The supplier incurs a constant marginal cost c in procurement, and wholesales the product to the retailer at w per unit.

We assume capital-constrained agents, following Dada and Hu (2008) and Li et al. (2009). The supplier and retailer have insufficient amounts of internal capital, k_s and k_r, respectively, reserved *a priori* for this particular business. The retailer's invoice, wq, is greater than its internal funds, k_r, and needs additional working capital, $B_r = wq - k_r$, from external sources: (1) directly from a financial institution (direct financing) or (2) through the supplier's trade-credit, if it is granted (trade-credit financing). Specifically, in the case of direct financing, the retailer pays the invoice, wq, to the supplier with the internal capital, k_r, and the capital borrowed from a financial institution, B_r, at the beginning of the sale period. The retailer remits the loan, B_r, with interest back to the lender at the end of the period. In the case of trade-credit financing, the retailer uses the internal capital, k_r, first for the payment, and finances B_r from the supplier by delaying the rest of the payment until the end of the sale period. The retailer