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The impact of hybrid push–pull contract in a decentralized assembly system ☆

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ABSTRACT

This paper investigates the pricing and production game in a decentralized assembly system that consists of one assembler and two independent suppliers. One supplier is able to exert the *push* contract on the assembler so as to transfer all his inventory risk, while the other supplier has to accept the *pull* contract from the assembler and consequently bears the overstock risk. Under this hybrid push–pull contract scheme, we show that the firms' equilibrium strategies lead to a two-layer decentralization occurring exclusively from the vertical relationships. The supplier's, the assembler's and the channel's profits are highly influenced by the balance between two suppliers' production costs. We also examine the impacts of three different contracts, push, pull and hybrid, on the firm's and the channel's performances. The pull contract always leads to the highest channel profit, while the hybrid contract dominates the push contract only if the supplier's cost under push contract is sufficiently high. From the firm's perspective, we show that a supplier may be worse off under push contract than that under pull contract, which implies that carrying zero inventory risk does not necessarily raise the firm's profitability.

1. Introduction

In most supply chains, the allocation of inventory risk is determined by how the channel members negotiate at their business/transaction contract. For example, before the selling season, a manufacturer may force his supplier to make the capacity reservation first and then purchase the appropriate product quantities after realizing the actual demand. In contrast, sometimes the supplier can reversely require the manufacturer to order and pay for his production in advance of the selling season. In an influential paper, Cachon [3] first classifies different ways of risk allocation into two categories: pull contact that the downstream manufacturer facilitates the upstream supplier to take charge of the entire inventory risk, and push contract that the supplier delegates the inventory risk to the manufacturer. Followed by, Granot and Yin [10] incorporate these two classic contracts into a decentralized assembly system. They examine under either the pull or push contract scheme, how the equilibrium pricing and production/procurement strategies vary when taking the suppliers' coalition into account.

In this paper, we aim to extend this promising research stream by studying the *hybrid push–pull contract*. Under this contract scheme, the assembler is able to partially transfer the inventory risk to some suppliers by exerting the pull contract but meanwhile to accept the push contract from some other suppliers. To our knowledge, this hybrid contract has never been adequately investigated before; however, its implementation is prevalent in practice. Consider the following two real world examples. Shenlong (http://www.dpca.com.cn) is one of the largest auto joint-ventures in China, whose capacity nearly reaches one million cars per year. Given its huge demand of components, Shenlong requires most of the suppliers to locate near its factory and accept the VMI (vendor-managed-inventory) policy. That is, Shenlong would share his demand information to its local suppliers and require these suppliers to independently determine how many components to produce each period and to personally afford the related inventory holding cost. In this sense, VMI policy can be viewed equally as the pull contract, because by doing so the assembler delegates the entire inventory risk to his suppliers.[1]

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[1] Bernstein et al. [1] indicate that VMI partnerships transfer all of the carrying costs from the assembler's inventories to the suppliers, along with the responsibility for the supply chain wide replenishment strategy.

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Nonetheless, for some other foreign suppliers, such as Cummins (http://www.cummins.com) and Aisin (http://www.aisin.com/), Shenlong can no longer exert the VMI policy. Because the components from these suppliers (e.g., motors and engine) are so important that normally require high cost devotion and long production lead times, Shenlong has to reserve and pay for them ahead of the selling season. This subsequently leads to the push contract because Shenlong shall take the corresponding inventory risk of these components. Another example lies in the small appliances industry (e.g., computer, camera and mobile). Malata (http://www.malata.com) is one leading DVD manufacturer in China; however, like other reputational DVD companies he also has to purchase the slugs from Sony, Samsung or Toshiba under the push contract scheme. While for the other common components, such as case and power, they are normally produced by the local factories. Thus, Malata is able to require these suppliers to deliver their components under the pull contract [15].

The above two examples illustrate that in practice the assembly system can operate under the push and pull contracts simultaneously. However, its related questions have never raised enough attention from the prior literature. Motivated by this gap, this paper seeks to examine the impact of hybrid contract in a decentralized assembly system with demand uncertainty. In particular, we are interested in the following issues. First, we try to identify the firms' strategic behaviors under the hybrid push–pull contract. What are the assembler's and suppliers' equilibrium pricing, production and procurement decisions? How do the firms' production costs influence their equilibrium payoffs? Second, we look into the comparison among different contract types: push, pull and hybrid contracts in the assembly system. Which contract type leads to the highest channel performance and how different contracts influence the firm's profitability?

To answer the above questions, we construct a game-theoretic model in a supply chain setting. Two independent suppliers produce the complementary components to a single assembler who assembles these components into the final product. One supplier (supply-leader) first determines the wholesale price and requires the assembler to pay for his components in advance of the selling season. In response, the assembler decides the order quantity from this supplier and affords the corresponding inventory risk, thereby forming the push contract. Meanwhile, the assembler also offers a pull contract to the other supplier (supply-follower), in which case he determines the wholesale price and purchases the components only after the demand is resolved. Afterwards, the supply-follower chooses the production quantity before seeing the actual demand. Accordingly, he has to bear the entire inventory risk of his components.

We derive several interesting results from the firms' equilibrium pricing and production strategies that provide useful managerial implications. First, we identify a two-layer decentralization that generates exclusively from the *vertical* relationships (between the assembler and the suppliers). This distinguishes our analysis to the vast literature that investigates the assembly system, because horizontal decentralization (among the suppliers) does not exist in such a context.[2] Note that this unique characteristic is driven by the assembler, who takes the role of a linkage between the pull contract (leader) and the push contract (follower). Consequently, he can set the optimal wholesale price and order the appropriate components from either of the suppliers, so as to induce both of them to produce the same amounts of components. This subsequently eliminates the horizontal decentralization in the system.

Second, we show that the firms' and the channel's performances are highly influenced by the balance between two suppliers' production costs. The supply-leader's profit increases when his own cost constitutes a higher proportion of the total production cost. This unintended phenomenon emerges because in this assembly system, the firm's profit is mainly determined by the *bottleneck* of the system: supply-follower. Once the supply-follower's production cost becomes relatively high, he shall cut down his production amount due to the consideration of inventory risk. This subsequently squeezes the supply-leader's profit margin because currently he has no choice but only to reduce his wholesale price to keep the assembler's purchasing incentive. Similar effect applies to the assembler's and channel's sides in which their profits decrease when the supply-follower's production cost becomes higher. Therefore, these results also provide some insights on the firm's procurement strategy, i.e., an assembler should enroll more suppliers under push contract scheme when the overall production cost is fixed, even though he has to endure a higher inventory risk.

Moreover, we find that the impacts of contract types, push, pull and hybrid, vary significantly under different conditions. First, from a channel's perspective the pull contract always leads to the highest payoff since it only contains one vertical decentralization in the system. Once the assembler can endogenously determine the two suppliers' wholesale prices, he can then guarantee these suppliers to produce the same amounts of components and eliminate the decentralization between suppliers. While the other two contracts have two sources of decentralization occurring from either the horizontal (supplier to supplier) or the vertical (assembler to supplier) relationship. Second, hybrid contract is better than push contract only if the supply-follower's production cost is relatively low. This is because a higher proportion of the supply-follower's cost amplifies the degree of decentralization under the hybrid contract and undermines the channel's performance. We also identify the optimal contract type that leads to the highest firm's equilibrium payoff. Interestingly, it shows that delegating the entire inventory risk does not necessarily give rise to a higher payoff, since a supplier may obtain a lower payoff under the push contract than under the pull contract.

Our work originates from the vast literature that studies the push contract and the pull contract. In this stream of line, Cachon [3] first makes a thorough analysis of the pull and push contracts in a supply chain setting. Given their explicit definitions, push contract is somehow similar to the wholesale price contract [13,1,7] and the pull contract can be viewed equally as the consignment contract [20,23,16]. In particular, Dong and Zhu [6] study two-wholesale-price contracts in the supply chain when there are two ordering opportunities in a single selling season. Lai et al. [12] examine the impact of financial constraint under each contract mode. Wang et al. [24] extend the push and pull contracts into a three-tier supply chain, and investigate the equilibrium strategies under all possible outsourcing structures. However, neither of them considers the mixture of push and pull contracts in a decentralized assembly system. Although Özer and Raz [19] also study the optimal push or pull contracting strategy in a system that contains two suppliers, the relationship between these suppliers is competitive rather than complementary.

Since we put our analysis in context of the assembly system, this paper also contributes to the literature that studies the decentralized assembly system with stochastic demand [17]. For example, Bernstein and DeCroix [2] investigate the firms' equilibrium pricing and production decisions, Netessine and Zhang [18] focus on the optimal inventory policy and Wang and Gerchak [22] look into the suppliers' capacity game. All these papers indicate that there are two sources of inefficiency in the decentralized assembly system: one is vertical decentralization between the

[2] Note that extensive literature discusses the horizontal decentralization in the assembly system, e.g., [22,10,9].