Int. J. Production Economics 175 (2016) 213–225

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

# Families of supply chain coordinating contracts in the presence of retailer effort

Xinghao Yan *, Gregory S. Zaric

*Ivey Business School, Western University, Canada*

ARTICLE INFO

*Article history:*
Received 4 March 2015
Accepted 16 January 2016
Available online 25 January 2016

*Keywords:*
Supply chain coordination
Promotional effort
Supply contracts
Contract family
Incentives

ABSTRACT

In this paper we study supply chain coordination in the presence of promotional effort. A single retailer chooses the level of promotional effort to increase demand and the quantity ordered from a single supplier, who may also exert demand promotional effort. This paper is the first to study all possible coordinating contracts for the model with demand promotional effort(s). Specifically, we classify all coordinating contracts as belonging to one of five mutually exclusive and collectively exhaustive families. For each family we find the necessary conditions and/or the sufficient conditions for the existence of a coordinating contract, as well as the minimum number of parameters required for a contract in that family. We show that different contract families have different levels of efficiency, flexibility, and required information for coordination. In addition, we show that no linear combination of "simple-format contracts", defined as wholesale price contract, buy-back contract, and revenue sharing contract, can achieve coordination except the extreme case where the retailer obtains zero profit. We also investigate two extensions: one in which the retailer has other decisions besides order quantity and effort, and one in which both parties exert demand promotional efforts (hence the decisions structure is changed). We find that coordinating contract design is not significantly influenced by the number of the retailer's decisions or demand function formats, but by the decision structure.



## 1. Introduction

In this paper we study supply chain coordination in the presence of promotional effort. A single retailer chooses the quantity ordered from a single supplier, and the retailer and/or the supplier choose the level of promotional effort to increase demand. These represent common demand promotion scenarios. For example, a retailer may run its own advertising campaign focusing on a particular product, a large name-brand manufacturer may invest heavily in its own advertising campaigns while selling through multiple retailers, or the retailer and the manufacturer may both promote simultaneously since the increased demand benefits both parties. It is well known that in a decentralized supply chain the party that makes the effort will, in general, not have its incentives aligned with the supply chain as a whole because not all parties obtain all benefits related to efforts but each has to pay the associated cost. This results in a suboptimal level of promotional effort. Attempts to address this through contract design are complicated by the fact that promotional effort may not be observable.

There is limited literature on supply chain coordination in the presence of promotional effort. Two common goals in this literature are: (1) Identifying coordinating contracts, and (2) Finding the most parsimonious contract (i.e., with the smallest possible number of parameters). If the effort can be verified, then an effort cost-sharing contract achieves coordination. Netessine and Rudi (2004) presented a coordinating contract that involved sharing advertising costs. Wang and Gerchak (2001) studied a model in which the retailer's shelf space was treated as the retailer's inventory-holding effort. They developed a contract that allowed the supplier to share the retailer's effort cost to coordinate the supply chain. There are also cases where effort itself is not verifiable, but some other quantity that is a function of effort is verifiable. For example, Chu and Desai (1995) allowed the supplier to compensate the retailer by paying the retailer based on the outcome of the effort, which, in this case, was a bonus for high customer satisfaction scores. Zhu et al. (2007) studied a case where retailer can make effort to improve product quality and the resulting quality is verifiable.

The case where the retailer's promotional effort (or an effort-related quantity) and the associated costs are not verifiable has also been studied. Taylor (2002) investigated a model in which demand was a random variable and mean demand was a linear function of the promotional effort. In this model, the retailer must

* Corresponding author. Tel.: +1 519 661 3229.
*E-mail address:* xyan@ivey.uwo.ca (X. Yan).

http://dx.doi.org/10.1016/j.ijpe.2016.01.011
0925-5273/

make the effort decision before demand is realized. Taylor (2002) found that a four-parameter contract consisting of target rebate and buy-back contract achieved coordination. Other contracts, such as a linear rebate and buy-back or a target rebate alone, cannot achieve coordination in this setup. Cachon and Lariviere (2005) extended Taylor's model (Taylor, 2002) but with a more general format for the revenue function. They identified a coordinating contract that required only two parameters.

Krishnan et al. (2004) investigated a similar model but they assumed that the retailer's promotional effort was made after the realization of demand. They found that a buy-back contract alone cannot coordinate the supply chain. Coordination can occur by combining a buy-back contract with promotional cost-sharing agreements (if effort cost is observable), or by offering constraints on the buy-back contract (if demand is observable but not verifiable), or by placing additional constraints on the buy-back (if demand is observable and verifiable). Each of the three coordinating contracts in Krishnan et al. (2004) required three parameters.

In this context, there are two significant shortcomings of the existing literature. First, the existence of a coordinating contract for a given problem structure is often undetermined or unclear. If a particular contract is unable to achieve coordination we do not know whether it is a shortcoming of that particular contract or whether the supply chain or contract structure itself does not allow a coordinating contract. Second, if a coordinating contract is identified, we do not know whether the proposed coordinating contract is the most parsimonious.

To address these limitations we develop a general supply chain model with promotional effort, using generalized revenue, cost and payment functions. A single retailer chooses the level of promotional effort as well as the quantity ordered from a single supplier (we refer to this model as a "retailer-effort" model). We classify all contracts as belonging to five contract families, which are defined by the structure of the payment term between the parties in contracts. For each family we find the necessary conditions and/or the sufficient conditions for the existence of a coordinating contract as well as the minimum number of parameters required in a coordinating contract. We show that the literature cited earlier can be seen as special cases of our general model, and that our model can be used to explain why the results of previous studies – in particular, the ability or inability of a particular contract to achieve coordination – are expected. In addition, we find that some contract forms cannot achieve coordination.

We also investigate two extensions of the model framework. In the first extension, the retailer makes other decisions in addition to order quantity and effort, which could include retail prices, return policies, shipping rates, quality of customer service or anything else that would have an impact of revenue or cost. In the second extension, which we refer to as a "dual-effort" model, the retailer continues to determine order quantity but the supplier and the retailer both determine promotional effort, resulting in a change in the overall decision structure.

We summarize the main contributions as follows. 1) We classify all possible coordinating contracts as belonging to one of five mutually exclusive and collectively exhaustive families. For each family we find the necessary conditions and/or the sufficient conditions for the existence of a coordinating contract, as well as the minimum number of parameters required for a contract in that family. 2) Through a comparison of the retailer-effort vs. the dual-effort models, we find that in the dual-effort model it is critical to coordinate the supplier's demand promotional effort, while coordination of the retailer's promotional effort may not be required. This is seen from payment structure in coordinating contracts which must depend on the supplier's promotional effort. Any contract with payment depending only on the retailer's promotional effort cannot achieve coordination for the dual-effort model. 3) We show that the coordinating contract design is not significantly influenced by the number of decisions made by the retailer or the demand function formats. 4) We compare the levels of efficiency, flexibility, and required information of coordinating contracts in different contract families. These comparisons provide us with clear managerial insights of the applicability of coordinating contracts in different families.

## 2. General model framework and contract families

We use the same general basic model setup as in Cachon and Lariviere (2005) to study a supply chain with two risk-neutral firms, a supplier (she) and a retailer (he). The retailer orders quantity $q$ from the supplier at a wholesale price $w$ and chooses the demand-increasing promotional effort $e$. The supplier obtains $w$ for each unit of product sold to the retailer and pays $c$ as the unit production cost. Let $R(q,e)$ be the retailer's expected revenue, including any salvage benefit. Let $g(e)$ be the retailer's cost of effort, which we assume to be increasing and convex in $e$ with $g(0)=0$. Note that this basic model includes the special cases where the effort is made either before the realization of demand (e.g., Taylor, 2002) or after the realization of the basic or underlying demand (e.g., Krishnan et al., 2004). We assume that the retail price is fixed in the basic model. In Section 4 we consider an extended model where the retailer may make additional decisions including the retail price. In this extension demand may be price-dependent. In Section 5 we consider another extended model where both parties exert efforts (i.e., dual-effort model).

The retailer's expected profit, $\Pi_R(q,e)$, the supplier's expected profit, $\Pi_S(q,e)$, and the total system profit, $\Pi_T(q,e)$, under the basic retailer-effort model, are written as follows:

(RE) $\Pi_R(q,e)=R(q,e)-g(e)-qw$,
$\Pi_S(q,e)=(w-c)q$,
$\Pi_T(q,e)=R(q,e)-g(e)-qc$.

We study contracts that can coordinate (RE). We classify all contracts into different families according to the payment (s) between the supplier and retailer. For generality, model (RE) includes the wholesale price. Thus, the important feature of each contract family is the additional payment, denoted by $A$, from the retailer to the supplier ($A<0$ would indicate a payment form the supplier to the retailer). This additional payment may depend on the retailer's decision variables $q$ and/or $e$. We construct five mutually exclusive and collectively exhaustive families of contracts, depending on which decision variables affect the payment term $A$:

1. Family 1: $A$ is a constant that does not depend on $q$ or $e$.
2. Family 2: $A$ does not include constant part and depends only on $q$, i.e., $A=P(q)$.
3. Family 3: $A$ does not include constant part and depends only on $e$, i.e., $A=P(e)$.
4. Family 4: $A$ depends on both $q$ and $e$, i.e., $A=P(q,e)$ but does not include any payments from Families 1–3.
5. Family 5: "Hybrid" contracts in which $A$ is a linear combination of contracts from the other four families with at least two different contract types.

## 3. Coordinating contracts in the presence of retailer effort

### 3.1. Centralized case and conditions for coordination

We first analyze the centralized case as the benchmark and then consider coordinating contracts in each family. In the