International Journal of Industrial Organization 27 (2009) 625–631

Contents lists available at ScienceDirect

International Journal of Industrial Organization

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

Distribution contracts to support optimal inventory holdings under demand uncertainty

Howard P. Marvel [a,*], Hao Wang [b,1]

[a] Department of Economics, The Ohio State University, 1945 North High Street, Columbus, OH 43210-1172, United States
[b] China Center for Economic Research, Peking University, Beijing, 100871, China

ARTICLE INFO

Article history:
Received 30 May 2008
Received in revised form 31 January 2009
Accepted 9 February 2009
Available online 13 February 2009

JEL classification:
L1
M2

Keywords:
Distribution
Inventories
Demand uncertainty

ABSTRACT

When suppliers produce products for which demand is uncertain, they face a problem of inducing downstream distributors to stock inventory levels that the suppliers prefer. This paper considers a wide array of alternative supply contracts, each of which consists of a mixture of constant per-unit wholesale prices, buy-back arrangements, and post sale payments contingent on sales made, such as revenue sharing or buybacks. We show that linear supply contracts specifying any combination of two of these three instruments can implement the vertical integrated outcome for a monopoly, thereby generating the supplier's preferred inventory configuration and price distribution. We extend our results to differentiated product oligopoly, demonstrating that each supplier obtains its preferred inventory configuration and price distribution, given the choices of its rival. Distributors choose optimal inventories from the suppliers' standpoint, even if suppliers do not know the distribution of demand uncertainty, and, given the perfect competition among distributors, all profits in the supply chain are captured by suppliers. Thus, suppliers are able to deal with demand uncertainty with remarkably little information about demand, and without the need to control dealer actions in detail. In particular, suppliers need not specify either dealer inventories or resale prices, but instead encourage distributors to order based on information in their possession and to set prices that generate desirable resale price dispersion.

1. Introduction

Suppliers and the distributors of their products exist in quasi-independent and yet symbiotic relationships with one another. Suppliers determine the amount and composition of their output and then announce contractual terms, which can include, among other terms, wholesale prices, returns policies or buyback allowances, and additional remittances payable contingent on retailer revenues. Distributors, acting in accordance with their knowledge of their local markets, then chose the size and composition of their inventories. These inventories are then priced to consumers, who are subjected to promotion of the supplier's products both by the supplier itself and by its distributors. As both the supplier and its distributors pursue their own interests, contracts can serve to improve the alignments of those interests. Most analysis of such vertical contracts has focused on the promotional issue by considering how vertical restraints can ameliorate free riding. Here, however, we consider contracts to structure inventory holdings. The selection of inventories is perhaps the central function of retailers, whose close proximity to ultimate consumers provides them with insights about what and how much to stock. Using a general model of linear supply contracts, we establish that several commonly observed supply contracts are special cases of our model and thereby establish the equivalence of two common contract variants, revenue sharing and returns policies.

Our model emphasizes the central role of demand uncertainty in motivating suppliers to employ supply contracts that are related to inventories. We consider contracts that place the responsibility for choosing appropriate inventories in the hands of retailers, but which provide incentives to hold the level of inventories that the supplier would choose if it possessed the same level of information about demand as that held by its dealers. The contracts in question are contingent on realized demand—they mitigate the dealers' predicament when low demand results in unsold inventories, thereby encouraging larger *ex ante* orders. The contracts we consider are linear functions of retail inventories, retail sales (quantities or revenues) and unsold inventory. Retailing is taken to be perfectly competitive, so inventories are held and retail prices established so that the expected profits of each retailer are zero.

In an earlier paper, (Marvel and Wang, 2007), we have shown that a constant wholesale price together with a buy-back credit for unsold inventories is sufficient to coordinate retailer inventory holdings, generating the distribution of prices and availability that suppliers prefer, even when suppliers do not have access to the information about demand held by their retailers. Perhaps most surprisingly, we demonstrated that buy-backs operate in the same fashion when there are

* Corresponding author. Tel.: +1 614 292 1020.
E-mail addresses: marvel.2@osu.edu (H.P. Marvel), hwang@ccer.edu.cn (H. Wang).
[1] Tel.: +86 10 6275 8934.

0167-7187/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijindorg.2009.02.003

multiple competing suppliers serving the market in question. In this paper, we consider a wide array of alternative supply contracts, each of which consists of a mixture of constant per-unit wholesale prices, buy-back arrangements, and post sale payments contingent on sales made, such as revenue sharing or buybacks. We show that supply contracts that are linear combinations of two of these three categories of contract terms are capable of generating suppliers' preferred inventory holdings and price distributions. We thereby establish that a wide variety of contracts, some of which do not entail buy-backs or returns credits, are equivalent to our original wholesale price plus returns credit contract. Distributors choose optimal inventories from the suppliers' standpoint, even if suppliers do not know the distribution of demand uncertainty, and, given the perfect competition among distributors, all profits in the supply chain are captured by suppliers.

We characterize fully three types of optimal contracts available to a monopoly supplier, each of which implements exactly the outcome that would occur if the supplier were integrated forward into distribution. These types include a revenue sharing contract, a generalized consignment sale plan, and a buyback plan. We then extend our results to oligopoly suppliers. We demonstrate that any one of the optimal plans, each supplier is able to obtain its preferred inventory configuration and price distribution, given the choices of its rivals, and we fully characterize the modifications necessary for each of the optimal supply contracts in the oligopoly setting.

After presentation of our results, we place them in context, comparing our approach to previous papers such as the Dana, Jr. and Speir (2001) revenue sharing model and the Marvel and Peck (1995) returns model. Our setting differs from these papers, allowing consumers to choose from an array of retailers and analyzing somewhat general demand conditions. In addition to demonstrating in our setting the equivalence of the monopoly supply contracts in these papers, we provide the extension to oligopoly. Suppliers are able to deal with demand uncertainty with remarkably little information about demand, and without the need to control dealer actions in detail. In particular, suppliers need not specify either dealer inventories or resale prices, but instead encourage distributors to order based on information in their possession and to set prices that generate desirable resale price dispersion.

Our approach relies on competition among retailers that causes them to select prices that yield zero profits in retail equilibrium. As a result of this competition, retailers that anticipate the possibility that their inventories will turn relatively slowly (that is, that their inventories will not sell if realized demand is low) will only offer their products to the market at comparatively high prices. This effect naturally results in price dispersion in the marketplace. The supplier's problem is to induce its desired degree of price discrimination. The lowest prices are set by retailers who expect to sell out in all demand realizations. When these prices are too low, the supplier throws away surplus and sees insufficient inventory holding for high demand states. But with positive marginal cost of production, the supplier will not wish to provide inventories for very unlikely states of demand. We show that a monopoly supplier can induce its preferred distribution of prices and inventories by relying on retailers to use their superior knowledge of the distribution of demand. We show that the insight extends to the case of oligopoly suppliers.

Section 2 analyzes the model when there is a single supplier selling through competitive retailers. We establish the equivalence of revenue sharing, returns, and generalized consignment contracts, and show that with appropriate contracts for competitive retailers, the supplier does not need to know the distribution of demand facing those retailers. In Section 3, we show that the results also apply when oligopoly suppliers compete with one another. The contract equivalence we establish suggests that different supply contracts can coexist in the marketplace, and that, as for the monopoly supplier, oligopoly suppliers do not need to know the distribution of demand, but can instead rely on retailers to use their superior knowledge of the marketplace to set appropriate prices and inventory levels.

2. A monopoly supplier with competitive retailers

We begin by analyzing a market in which a single upstream firm sells a product or service (which must be inventoried prior to sale) to consumers through competitive retailers.[2] We assume that the good or service in question is valuable for one period only, and that it has no scrap value, so that we can consider a single period in isolation. The upstream firm's marginal cost of production is given by c. The retailers have a common marginal cost of selling, denoted d, and, in addition, each retailer must acquire an inventory prior to the market period. Retailers are assumed not to have fixed costs or holding costs in addition to the acquisition costs for their inventories.[3] These simplifying assumptions are linked to our perishable product assumption, together allowing us to focus on a single period. The result is a model in which retailer differences in expected inventory turnover lead to differences in prices across retailers. Retailers may choose to be high-turn, low price retailers or, conversely, may choose a strategy in which they sell at high prices with a lowered probability of making a sale in a particular period. Retailer profit seeking yields equal returns for each category of retailer, resulting in an inverse relationship between turn and price. We assume that all firms, whether supplier or retailer, are risk neutral.

We assume that each active consumer has a demand function, $D(p)\geq 0$, with $D'(\cdot)\leq 0$ and $D(c+d)\geq 0$. But while all active customers are identical, there is uncertainty over the number of such customers who will participate in the market during a given period. The number of active customers, e, is a random variable with a discrete distribution over possible values $\{e_1, e_2,\ldots, e_m\}$ and associated positive probabilities $\{f_1, f_2,\ldots f_m\}$, where $0<e_1<e_2<\ldots<e_m$ and $\sum_{j=1}^{m} f_j = 1$.[4] Thus realized market demand is multiplicative and is given by $eD(p)$ Following Deneckere, Marvel and Peck (1996), there are m "demand pockets," denoted 1,2,…, m, respectively. Demand pocket i, which has measure $e_i - e_{i-1}$ (with $e_0 \equiv 0$) enters the market with probability $\sum_{j=i}^{m} f_j$.

Retailers order inventory and set prices prior to the resolution of demand uncertainty. Thus, given this demand uncertainty and a retailer's inability to slash prices to unload excessive inventory holdings, for some demand realizations, a retailer may fail to sell its entire inventory. Retailers will be willing to accept this possibility if they anticipate sales at high prices when realized demand is strong, but, as Deneckere, Marvel and Peck (1996) demonstrate, the resulting price variation may exceed that which the supplier prefers. Retail inventories may be too low and prices may differ from those that the supplier would prefer. Accordingly, the supplier may offer a supply contract that ties retailer outcomes either to realized demand or to inventory holdings, or both. We consider supply contracts denoted $\{w, \rho, \kappa\}$, where w denotes the supplier's transfer price to retailers of its inventory, ρ is a royalty rate, and κ is the credit offered for an unsold unit of inventory (the supplier's buyback price).[5] We allow for the possibility that $\kappa<0$, in which case the supplier imposes a charge for unsold units. We expect implementation

[2] Our market is similar to those studied in Marvel and Wang (2007).

[3] See Marvel and Peck (2008) for a model that highlights the importance of holding costs.

[4] We here follow Dana, Jr. (1999), who provides a monopoly model with demand uncertainty characterized by a random variable with a discrete distribution. Our analysis is essentially the same if we follow Marvel and Wang (2007) in considering a more general distribution.

[5] We treat a royalty as a state-contingent payment made by retailers to the supplier, as distinguished from inventories that must be ordered and paid for in advance of the resolution of demand uncertainty. Our royalty is a per unit payment for units actually sold, not an ad valorem royalty such as that modeled by Dana, Jr. and Spier (2001). An ad valorem royaltymay be desirable when the supplier wishes to condition returns on the prices that retailers set, but this is not an issue in our setting. Competition pins down prices so that the addition of a price-sensitive term does not fundamentally alter the outcome and the choice between specific and ad valorem royalties can bemade on the basis of convenience. An appendix that describes equivalent contracts for ad valorem royalties is available on request. While retailer competition fixes prices and all parties are risk neutral, our model, given the combination of demand uncertainty and a positive marginal cost for provision of the good, is more complex than those typically analyzed in patent licensing. See, e.g., (Bousquet et al., 1998).