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RESEARCH ARTICLE

Valuing Uncertainty and Information Sharing Among Retailers

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Abstract

The purpose of this paper is to examine the value of information in a vertical supply chain involving a manufacturer selling to Cournot-type retailers that in turn market to consumers. We introduce uncertainty for the retailers and discuss the effects on consumer welfare and general efficiency in the market. Additionally, we investigate whether a retailer operating under certainty would find value in sharing the information with the other retailers. The findings provide a model-based rationale for retail associations.

Keywords: *Retail association, Supply chain, Incentive contracts.*

Introduction

Uncertainty may be costly in retail settings, particularly uncertainty regarding demand for a retailer's products. Because of the potential costs there is value for information that can reduce this uncertainty. The purpose of this paper is to examine the value of information in a vertical supply chain involving a manufacturer selling to Cournot-type retailers that in turn market to consumers. We introduce uncertainty for the retailers and discuss the effects on consumer welfare and general efficiency in the market. Additionally, we investigate whether a retailer operating under certainty would find value in sharing the information with the other retailers.

This potential sharing of information can be viewed as part of the justification for various retail associations. The Retail Industry Retailers Association's (RILA) website lists that the group "…provides a forum where members can conduct discussions aimed at…areas of concern and pragmatic solutions to problems." It goes on to note that one of the areas "…where retailers can collaborate to make a difference…" is in their supply chain. [1] The Retail Merchants Association's website listed its mission is to provide "…information to enhance the image and profitability of member companies." [2] Additionally, the scope of the retail market is considerable. The National Retail Federation states that retailers operate "…more than 3.5 million U.S. establishments that support 1 in 4 U.S. jobs." [3]

The value of information in Cournot markets and in vertical relationships continues to be of interest and has been revived in recent years. Using a Cournot duopoly, Clarke [4] shows that the firm with more accurate information enjoys greater profits and would not wish to share the information. Vives [5], in his results regarding Cournot duopoly, also reports that information sharing is not a profitable strategy. Gal-Or [6] finds that private information is never revealed with multiple firms behaving as Nash competitors in setting output levels. Sakai [7] also uses a duopoly model and finds that if there is a, "…simultaneous and symmetric improvement in information for both firms," then the profit for each increases at the expense of consumers. The duopoly structure is used by Sasaki [8] to investigate the effects of demand uncertainty and the value of information. The results of the Cournot market suggest that information acquisition by one firm decreases the incentive of the other to acquire the same information.

The value of information in a vertical structure, or value chain, generally suggests that information exchange between the manufacturer and retailers improves resource coordination. For example, see Cooper and Kaplan [9], Cooper and Slagmulder [10], and Baiman and Rajan [11]. Radhakrishnan and Srinidhi [12] use a monopoly manufacturer and monopoly retailer vertical structure, and determine that information exchange is a function of relative bargaining power. Additionally, they

find the absence of such an exchange results in lower profits for the value chain.

Our results suggest uncertainty for the retailers regarding demand or cost conditions benefits consumers and the manufacturer, at the detriment of the retailers. Furthermore, the gains to the manufacturer and consumers more than offset the losses to retailers, which results in increased market efficiency and total surplus. This suggests that the manufacturer may not be interested in information exchange with the retailers. We also find that it is beneficial for a retailer, i.e. increased profits, in possession of market information to share this information with the other retailers. This finding may provide a rational for retail associations. Section 2 presents the standard model and incentive contract results. Section 3 presents findings concerning the value of information and scenarios for sharing information between retailers. Section 4 concludes.

Equilibrium Conditions with Profit Maximization and Incentive Contracts

The homogenous product, Q, is manufactured by a monopolist. The monopolist incurs constant unit manufacturing costs, which are denoted C_M. The monopolist sells the products to the retailers at a unit price P_M. There are n retailers that in turn distribute the product to the final market. A fixed proportion production function is assumed at the retailer level. For further simplicity, production is normalized so that one unit produced by the manufacturer equals one saleable unit at the retailer level. Following Fershtman and Judd [13], for reasons of tractability we assume demand in the final market to be linear. Inverse demand for the final product is assumed to be:

$$P_R = A - B(Q), \qquad A, B > 0, \tag{1}$$

where P_R is the retail price and Q is the sum of individual sales of the retailers (q_i) in the final market. The economics of distribution in the above setup can be solved as a two-step process. First, the retailers compete for sales resulting in a subgame equilibrium. Total retailer derived demand from this competition is then used by the manufacturer to determine the optimal manufacturer's markup of price over marginal cost. This price determines both the manufacturer's and retailers' profits.

For simplicity, we assume that the only cost to the retailers is the price of the manufactured product to be resold. Product distribution costs can be assumed for the retailer without altering the substance of the analysis. However, if such costs are introduced they must be restricted to be less than any marketing costs incurred by the manufacturer directly marketing the product. If this is not the case then the profit maximizing decision for the manufacturer would be to vertically integrate, bypassing the use of retailers altogether.

We first examine the standard model of vertical structure of a monopolist selling to n Cournot retailers that strictly profit maximize. Given demand of $P_R = A - BQ = A - B\sum q_i, i = 1,...,n$ the profits of the i^{th} retailer are:

$$\Pi_i = [A - BQ]q_i - P_M q_i. \tag{2}$$

The solution to (2) is well known, and yields the following retailer output, market output, and equilibrium retail price:

$$q_i = \frac{A - P_M}{B(n+1)}, \tag{3}$$

$$Q = \frac{n(A - P_M)}{B(n+1)}, \tag{4}$$

$$P_R = \frac{A + nP_M}{n+1}. \tag{5}$$

Use of (4) in the manufacturer's profit function obtains:

$$\Pi_{MFG} = \frac{n(A - P_M)(P_M - C_M)}{B(n+1)}. \tag{6}$$

Maximizing (6) results in the manufacturer price

$P_M = (A + C_M)/2$. Use of this price results in the following individual and total retailer profits and the manufacturer profits of:

$$\Pi_i = \frac{(A - C_M)^2}{4B(n+1)^2}, \tag{7}$$

$$\Pi_{Retailers} = \frac{n(A - C_M)^2}{4B(n+1)^2}, \tag{8}$$

$$\Pi_{MFG} = \frac{n(A - C_M)^2}{4B(n+1)}. \tag{9}$$

We use incentive contracts, from the owner to the manager of the retailer, to model the behavior of a retailer operating under uncertainty. These contracts are presented in Fershtman and Judd [13], who note that a "…crucial element of our model will be the assumption that there is uncertainty about crucial market parameters describing demand and costs at the time the

incentives are determined." These authors also point out that, "…uncertainty is necessary to make the use of linear contracts in profits and sales reasonable and superior to contracts which yield the usual oligopoly outcomes." Now consider the situation in which n Cournot retailers compete under incentive contracts. The simplified objective function is[1]:

$$OBJ_i = [A - BQ]q_i - \lambda_i P_M q_i. \quad (10)$$

Maximization of (10) results in the i^{th} retailer's reaction function:

$$q_i = \frac{A - B\overline{Q}_i - \lambda_i P_M}{2B}, \quad (11)$$

where $\overline{Q}_i = Q - q_i$. Summing over all retailers yields:

$$\Sigma q_i = Q = \frac{nA - B(n-1)Q - \Sigma\lambda_i P_M}{2B}. \quad (12)$$

Solving (12) results in the market output:

$$Q = \frac{nA - \Sigma\lambda_i P_M}{B(n+1)}. \quad (13)$$

Use of the definition $\overline{Q}_i = Q - q_i$ and substitution of (13) into (12) yields the individual retailer's output while the retail price is obtained from the inverse demand curve and (12). These are, respectively:

$$q_i = \frac{A + P_M(\sum_{j \neq i}\lambda_j - n\lambda_i)}{B(n+1)}, \quad (14)$$

$$P_R = \frac{A + P_M\Sigma\lambda_i}{n+1}. \quad (15)$$

The retailer price-cost margin $(P_R - P_M)$ with equations (14) and (15) can be used to derive the i^{th} retailer's realized profits in terms of the parameters λ_i:

$$\Pi_i = \frac{[A + P_M(\Sigma\lambda_i - (n+1))][A + P_M(\sum_{j \neq i}\lambda_j - n\lambda_i)]}{B(n+1)^2}. \quad (16)$$

Differentiating (16) with respect to λ_i, and noting that because of symmetry of response $\lambda_i = \lambda_j$, yields the profit maximizing value of λ_i:

$$\lambda_i = \frac{n(n+1)}{n^2+1} - \frac{(n-1)A}{(n^2+1)P_M}. \quad (17)$$

Substituting (17) into (14) and (15) results in the retailer output, market output, and retail price:

$$q_i = \frac{n(A - P_M)}{B(n^2+1)}, \quad (18)$$

$$Q = \frac{n^2(A - P_M)}{B(n^2+1)}, \quad (19)$$

$$P_R = \frac{A + n^2 P_M}{n^2+1}. \quad (20)$$

Equations (19) and (20) can be used in an analog of (6) to derive the manufacturer's profit expressed in terms of its price-cost margin. This yields the optimal manufacturer price $P_M = (A + C_M)/2$.[2] Use of this price results in the retailer and manufacturer profits when retailers compete under incentive contracts of

$$\pi_i = \frac{n(A - C_M)^2}{4B(n^2+1)^2}, \quad (21)$$

$$\pi_{Dealers} = \frac{n^2(A - C_M)^2}{4B(n^2+1)^2}, \quad (22)$$

$$\pi_{MFG} = \frac{n^2(A - C_M)^2}{4B(n^2+1)}, \quad (23)$$

Given the results above, it is a straightforward exercise to calculate producer surplus, consumer surplus, and total surplus. These are listed in table 1 according to the nature of competition for the retailers.

The introduction of uncertainty and use of incentive contracts clearly increases producer and consumer surplus, and therefore total surplus. However, it is not necessarily clear from table 1 the nature of the benefits according to the size of the retail structure. We investigate this by looking at the percentage change due to the introduction of uncertainty and the corresponding use of incentive contracts by owners of the retail outlets. Along with the surplus calculations given in table 1,

[1] The linear contract between profit and sales is the objective function $OBJ_i = \lambda(P_R - P_M)q_i + (1-\lambda)q_i$. A simple algebraic manipulation results in equation (10). In the previous case of strict profit maximization λ=1, which is the case with equation (2).

[2] Note that, whether retailers profit maximize or use incentive contracts, the manufacturer price is not a function of the nature of retailer competition or the number of retailers.

Table 1: Efficiency under profit maximization and incentive contracts

	Producer Surplus	Consumer Surplus	Total Surplus
Profit maximization	$\frac{n(n+2)(A-C_M)^2}{4b(n+1)^2}$	$\frac{n^2(A-C_M)^2}{8b(1+n)^2}$	$\frac{n(3n+4)(A-C_M)^2}{8b(n+1)^2}$
Incentive contracts	$\frac{n^2(n^2+2)(A-C_M)^2}{4b(n^2+1)^2}$	$\frac{n^4(A-C_M)^2}{8b(1+n^2)^2}$	$\frac{n^2(3n^2+4)(A-C_M)^2}{8b(n^2+1)^2}$

we investigate differences in manufacturer and retailer profits. Table 2 lists the changes in profitability and surplus in terms of the number of retailers in the market.

Table 2: Changes in profitability and surplus from profit maximization to incentive contracts

Mfr. Profit	Retailer Profit	Producer Surplus	Consumer Surplus	Total Surplus
$\frac{n-1}{n^2+1}$	$\frac{-n^4+n^3+n-1}{(1+n^2)^2}$		$\frac{n^3+n-2}{(n+2)(1+n^2)^2}$	$\frac{2n^3-n^2-1}{(1+n^2)^2}$
$\frac{2n^4+n^3+n-4}{(4+3n)(1+n^2)^2}$				

Multiplying each formula in table 2 by one hundred gives the percentage change. Table 3 provides the percentage changes for values of n, i.e. the number of retailers, of 1 through 10. Note the large effect the use of incentive contracts has on consumer surplus, particularly with fewer retailers in the market. Even with ten retailers the consumer surplus is more than 18 percent greater with uncertainty in the market.

Furthermore, the manufacturer's profits are noticeably larger in percentage terms when retailers compete with incentive contracts. The losers from the introduction of uncertainty and the resulting competition with incentive contracts are the retailers. In percentage terms, the profits are considerably lower as the number of retailers increases. However, total surplus is always greater with incentive contracts as the gains to the manufacturer and consumers offset the lower profits of the retailers.

Table 3: Percentage differences with incentive contracts versus profit maximization

n	Manufacturer Profit	Retailer Profit	Producer Surplus	Consumer Surplus	Total Surplus
1	0.00	0.00	0.00	0.00	0.00
2	20.00	-28.00	8.00	44.00	15.20
3	20.00	-52.00	5.60	44.00	14.46
4	17.65	-65.40	3.81	38.41	12.46
5	15.38	-73.37	2.70	33.14	10.71
6	13.51	-78.52	2.01	28.85	9.33
7	12.00	-82.08	1.55	25.44	8.24
8	10.77	-84.66	1.23	22.70	7.36
9	9.76	-86.62	1.00	20.46	6.65
10	8.91	-88.14	0.82	18.62	6.06

The increase in profitability for the manufacturer, with a given number of retailers, has implications regarding the nature of information the manufacturer wants the owners of retail outlets to acquire. One piece of information that the manufacturer has that can possibly be hidden from retailers is the cost of manufacturing the good, C_M. To the extent that uncertainty regarding acquisition costs for the retailers leads to the use of incentive contracts, the manufacturer has a clear incentive to increase uncertainty regarding manufacturing costs.

Manufacturing costs are a directly incorporated into the price the manufacturer charges the retailers, P_M. The results in table 3 also indicate that the value of information is high. The positive value of certainty for the retailers is obvious, while the value of uncertainty clearly favors the manufacturers and consumers.

An interesting question is whether there is value to a particular retailer to sharing information with or eliminating uncertainty for another retailer. Or more specifically, what is the value or cost associated with information sharing between retailers?

Information Sharing between two Retailers

In this section we consider the case where one of the retailers has acquired information allowing it to be sure of market conditions and costs while the other retailers operate under uncertainty, i.e. with incentive contracts. We initially consider two retailers (n=2) and then investigate the situation with n retailers. We will look at 2 cases with n=2: (1) the certain retailer believes the other retailer has the same information yet the other retailer believes both are operating under uncertainty, and (2) the certain retailer knows that the other retailer is uncertain yet the other retailer believes both are operating under uncertainty.

Consider the first case. The certain retailer will choose the output given in equation (3) while the uncertain retailer will choose the output in equation (18). The equilibrium retail price and the profits for each retailer are

$$P_R = \frac{19A + 11C_M}{30}, \tag{24}$$

$$\pi_{Certain} = \frac{(A - C_M)^2}{45B}, \tag{25}$$

$$\pi_{Uncertain} = \frac{(A - C_M)^2}{37.5B}. \tag{26}$$

Note that both retailers earn greater profits in this scenario rather than if both are operating under uncertainty (see equation (22) with n=2). However, the retailer that knows with certainty the market conditions does not earn as much as the retailer operating under the assumption that both firms are using incentive contracts. In this case the certain retailer would be better off not only in terms of its own profit but also in matching the profit level of the other retailer by sharing the information and allowing each retailer to earn a profit of

$$\Pi_i = \frac{(A - C_M)^2}{36B}. \tag{27}$$

Now consider the second case where the certain retailer knows that the other retailer is uncertain yet the other retailer believes both are operating under uncertainty. Here the certain retailer will choose an output of $q_{Certain} = \frac{3(A - C_M)}{20B}$. while the other retailer will choose $q_{Uncertain} = \frac{(A - C_M)}{5B}$. This leads to a retail price and profits of

$$P_R = \frac{13A + 7C_M}{20}, \tag{28}$$

$$\pi_{Certain} = \frac{(A - C_M)^2}{44\frac{4}{9}B}, \tag{29}$$

$$\pi_{Uncertain} = \frac{(A - C_M)^2}{33\frac{1}{3}B}. \tag{30}$$

Once again the retailer operating under uncertainty with an incentive contract earns higher profits than the retailer with market information. This occurs even though the certain retailer incorporates the other retailer's output into its profit maximizing output decision. Additionally, a comparison of equations (29) and (25) reveals that the retailer with information does only slightly better when correctly anticipating the other retailer's output and using it to make its output decision. And a comparison of equations (30) and (26) reveals that the other retailer does even better than before when the competitor correctly anticipates that it does not possess the information. Therefore it is in the interest of the retailer in possession of market information to share this with the other retailer. This increases the profits of the certain retailer and, to the extent that market share is important, allows it an equal share of the market rather than a smaller share.

We now extend the previous results such that one of the n retailers has acquired information allowing it to be sure of market conditions and costs and the remaining (n-1) retailers do not have the information. We will again investigate 2 cases: (1) the certain retailer believes the other retailers have the same information yet the other retailers believe all are operating under uncertainty, and (2) the certain retailer knows that the others retailers are uncertain yet the other retailers believe all are operating under uncertainty.

In the first case the certain retailer will sell the quantity given in equation (3) and each of the uncertain retailers will sell the quantity given in equation (18). This leads to following retail price and profits for the certain and each of the uncertain retailers.

$$P_R = \frac{A\left(n^3+n^2+3n+1\right)+C_M\left(n^3+n^2-n+1\right)}{2(n+1)\left(n^2+1\right)}, \quad (31)$$

$$\pi_{Certain} = \frac{n\left(A-C_M\right)^2}{2B\left(n^2+1\right)(n+1)^2}, \quad (32)$$

$$\pi_{Uncertain} = \frac{n^2\left(A-C_M\right)^2}{2B(n+1)\left(n^2+1\right)^2}. \quad (33)$$

In this case the profit for each of the uncertain retailers is greater by a factor of $\frac{n(n+1)}{\left(n^2+1\right)}$ over the certain firm. If the certain firm shares the information with the other retailers in the market then the certain firm's profit will increase by a factor of $\frac{(n+1)\left(n^2+1\right)}{2n}$, as all of the retailers will now act as profit maximizers and each earns profits given in equation (7). It is clearly in the interest of the certain firm to share the information to increase its own profits, and this will also increase its market share to 1/n of the market.

In the second case the certain firm incorporates the fact that each of the uncertain retailers is producing the output listed in equation (18). Using this information in the profit maximizing reaction function leads to the certain firm producing output of $q_{Certain} = \frac{(n+1)(A-C_M)}{4B\left(n^2+1\right)}$. Using this output and the n-1 uncertain retailers output leads to the following retail price and profits for the certain and each of the uncertain retailers.

$$P_R = \frac{3A+C_M+n\left(A-C_M\right)+2n^2\left(A+C_M\right)}{4\left(n^2+1\right)}, \quad (34)$$

$$\pi_{Certain} = \frac{(n+1)^2\left(A-C_M\right)^2}{16B\left(n^2+1\right)^2}, \quad (35)$$

$$\pi_{Uncertain} = \frac{n(n+1)\left(A-C_M\right)^2}{8B\left(n^2+1\right)^2}.$$

(36)In this case the profit for each of the uncertain retailers is greater by a factor of $\frac{2n}{(n+1)}$ over the certain firm. If the certain firm shares the information with the other retailers in the market then the certain firm's profit will increase by a factor of $\frac{\left(n^2+1\right)^2}{4(n+1)^3}$. Once again it is profitable for the certain firm to share the information with the uncertain retailers to ensure that all act as profit maximizers, such that each earns profits in equation (7). And as in the previous case, information sharing allows the certain firm to increase its market share to 1/n of the market.

Note that in both cases sharing the information increases the profitability not only of the certain retailer but of the uncertain retailers as well. This increase in retailer profits due to information sharing is at the expense of the manufacturer and the consumers.

Conclusion

We examined the value of information in a vertical supply chain involving a monopoly manufacturer selling to Cournot-type retailers, where uncertainty is modeled with the retailers competing under incentive contracts as proposed by Fershtman and Judd [13]. Our results reveal that uncertainty increases consumer surplus and manufacturer profits while decreasing retailer profits. However, the gains to consumers and the manufacturer more than offset the losses to the retailers, which leads to an overall increase in total surplus.

We also found that it is profitable for a retailer that possesses accurate information regarding market conditions to share this information with the other retailers. This result holds when the certain retailer: (1) believes the other retailers have the same information yet the other retailers believe all are operating under uncertainty and (2) knows that the other retailers are uncertain yet the other retailers believe all are operating under uncertainty. This finding could provide a rationale for retail associations. The ability to share information regarding market conditions may allow for more consistent evaluations of the market, leading to higher profits for each retailer. It is important to note this information sharing should not be viewed as collusion; the sharing of information to eliminate uncertainty allows the retailers to engage in Cournot-type competition.

References

1. Retail Industry Leaders Association. www.rila.org
2. Retail Merchants Association. retailmerchants.com
3. National Retail Federation. www.nrf.com
4. Clarke Richard N (1983) Collusion and the Incentives for Information Sharing, Bell Journal of Economics, 14(2):383-94.
5. Vives, Xavier (1984) Duopoly information equilibrium: Cournot and bertrand. Journal of Economic Theory 34(1):71-94.
6. Gal-Or Esther (1985) Information Sharing in Oligopoly, Econometrica, v54, n2 March: 329-344.
7. Sakai, Yasuhiro (1985) The value of information in a simple duopoly model. Journal of Economic Theory 36(1):36-54.
8. Sasaki Dan (2001) The Value of Information in Oligopoly with Demand Uncertainty, Journal of Economics (Zeitschrift fur Nationalokonomie) 73(1):1-23.
9. Cooper Robin, Robert Kaplan (1998) Measure Costs Right: Make the Right Decisions, Harvard Business Review, 96-103.
10. Cooper Robin, Regine Slagmulder (1998) Cost Management for internal markets. Management Accounting, 79 (11):16-188.
11. Baiman Stanley, Rajan Madhav V (2002) Incentive issues in inter-firm relationships, Accounting, Organizations and Society, 27(3):213-238(26).
12. Radhakrishnan Suresh, Srinidhi Bin (2005) Sharing demand information in a value chain: Implications for pricing and profitability. Review of Quantitative Finance and Accounting 24(1):23-45
13. Fershtman Chaim, Kenneth Judd (1987) Equilibrium incentives in oligopoly. American Economic Review, 77, (5)927-940.