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ABSTRACT

We consider a supply chain with a single manufacturer selling a single product through two competing retailers. The manufacturer sets the wholesale price, and the retailers set the retail margin, simultaneously. The demand information among the members is asymmetric. The main contribution of this paper is extended the results of [5] with two competing retailers under asymmetric demand information. We consider six cases with the manufacturer or the retailers whether owning the information or not, and analyze these six cases in turn solve for a Bayesian equilibrium. Some results are obtained finally.

Keywords: supply chain, Channels of distribution, game theory.

1. INTRODUCTION

New market information technique, such as internet developing, B2C electronic commerce application and POS (point of sale) technique etc., making retailer can obtain the demand information of the end customers easily. But manufacturers have long been able to purchase similar information from the information consults company or by conducting marketing research themselves.

We consider a supply chain with a single manufacturer selling its single product through two competing retailers. The main purpose and contribution of this paper is extended the results of [5] with two competing retailers under asymmetric demand information. We examine this phenomenon through a game of asymmetric information played among a manufacturer and two competing retailers.

We denote a as the market scale (i.e., the maximum possible market demand) and assume that there is uncertainty over a. Let a be a random variable taking values in the finite interval $[a_{\min}, a_{\max}]$, with cumulative distribution function F. The expected value and variance of the variable a are θ, σ^2 respectively. This distribution function is known by all firms. When a firm does not have information about the demand parameter, it only knows F. However, if a firm acquires information, it knows the realization of the random variable, a.

The manufacturer sets the wholesale price w, and the retailers set the retail margin m_1, m_2, simultaneously. The retail price, p_i, is the sum of the wholesale price and the retail margin and is expressed as

$$p_i = w + m_i \qquad (1)$$

Where w is the wholesale price and m_i is the retail margin.

We assume a linear demand function,

$$q_i = a - bp_i + dp_j \qquad (2)$$

$$(i=1,2,\ i \neq j,\ 0<d<b).$$

Where p_i is the price and q_i is the quantity demanded of the retailer i.

We also assume constant average cost of production, and cost of distribution, which are normalized to zero without loss of generality. All decision-makers are profit-maximizers and assumed to be risk-neutral.

The profit functions of the manufacturer (Π) and the retailer i (π_i) are derived by multiplying respective margins by quantity sold. They are, respectively

$$\Pi = \sum_{i=1}^{2} w(a - bp_i + dp_j)$$

$$= w(2a - (b-d)(2w + m_1 + m_2)) \qquad (3)$$

$$\pi_i = m_i(a - b(w+m_i) + d(w+m_j)) \qquad (4)$$

$$i = 1,2,\ i \neq j$$

Note that the two retailers have symmetric profit functions.

2.THE INTEGRATED BENCHMARK AND SYSTEM PROFIT

To establish a performance benchmark, we analyze the problem of an integrated firm. Now, if this supply chain is centrally owned and controlled, a vertically integrated manufacturer obtains the totality of channel profit: therefore, it will seek to maximize channel profit.

$$\Pi_J = p_1 q_1 + p_2 q_2$$

$$= p_1(a - bp_1 + dp_2) + p_2(a - bp_2 + dp_1) \qquad (5)$$

The problem is concave, and table 1 shows the optimal profit.

3. EQUILIBRIUM ANALYSIS UNDER ASYMMETRIC DEMAND INFORMATION

We consider six cases: (1) case 1: None of the members knows the market scale *a*; (2) case 2: All of the members know the market scale *a*; (3) case 3: Only the Manufacturer knows the market scale *a*; (4) case4: Only the Retailers know the market scale *a*; (5) case 5: Both the Manufacturer and the Retailer 1 know the market scale *a*, but Retailer 2 do not know; (6) case6: Only the Retailer 1 knows the market scale *a*. We analyze these six cases in turn solve for an equilibrium.

3.1 Case 1: None of the members knows the market scale *a*

In this case, although none of the channel members knows the exact value of the demand parameter, ***a*,** each maximizes expected profit taking into account the distribution of ***a*.** In particular, the expected profits of the manufacturer is given by

$$E[\Pi] = E[w(2a-(b-d)(2w+m_1+m_2))] \quad (6)$$

Differentiating equation (6) with respect to *w* and taking expectation over ***a*** gives the first-order condition below.

$$2\theta - 4(b-d)w - (b-d)(m_1+m_2) = 0 \quad (7)$$

The expected profits of the retailer *i* is given by

$$E[\pi_i] = E[m_i(a-b(w+m_i)+d(w+m_j))] \; i=1,2, \; i \neq j \quad (8)$$

Differentiating equation (8) with respect to m_i and taking expectation over ***a*** gives the first-order condition below.

$$\theta - b(w+2m_i) + d(w+m_j) = 0 \quad i=1,2, i \neq j \; (9)$$

Since we have a symmetric case $m_1 = m_2$ in equilibrium, (8) and (9) gives

$$w = \frac{\theta b}{(3b-d)(b-d)} \quad (10)$$

$$m_1 = m_2 = \frac{\theta}{3b-d} \quad (11)$$

Substituting (10) and (11) into (6) and (8), we obtain the expected profits of the three members, see table 1.

3.2 Case 2: All of the members know the market scale *a*.

In this case, all of the channel members know the demand parameter. The first-order condition of the manufacturer is given by

$$2a - 4(b-d)w - (b-d)(m_1+m_2) = 0 \quad (12)$$

The first-order condition of the retailer *i* is given by

$$a - b(w+2m_i) + d(w+m_j) = 0 \quad (13)$$

By symmetry $m_1 = m_2$. Solving (12) and (13) gives

$$w = \frac{ab}{(3b-d)(b-d)} \quad (14)$$

$$m_1 = m_2 = \frac{a}{3b-d} \quad (15)$$

Substituting (14), and (15) into (6), and (8) gives and taking expectation over ***a*** gives the expected profits (table 1)

3.3 Case 3: Only the Manufacturer knows the market scale *a*

This more complex case is a game of asymmetric information in which the manufacturer knows the demand scale, ***a*,** but the retailers only knows the distribution of ***a*.** Accordingly, a strategy for the manufacturer consists of a function ***w(a)*,** where wholesale price is contingent on the realized value of ***a*.** since the retailer does not observe ***a*,** the strategy for the retailer *i* consists of a fixed value of $\boldsymbol{m_i}$**. W**e are solving for a Bayesian equilibrium[5].

Since the manufacturer chooses a ***w(a)*** for each value of ***a*,** it maximizes (6). The first-order condition is given by

$$w(a) = \frac{a}{2(b-d)} - \frac{m_1+m_2}{4} \quad (16)$$

Since the retailers know that the manufacturer's strategy is a function ***w(a)*,** the retailer *i* chooses m_i to maximize expected profit

$$E[\pi_i] = E[m_i(a-b(w(a)+m_i)+d(w(a)+m_j))] \quad .(17)$$

Substituting (16) into (17) and take the first-order condition gives

$$w = \frac{a}{2(b-d)} - \frac{\theta}{2(3b-d)} \quad (18)$$

It is not diffcult to obtain the profits of the three members(table 1).

Similarly, We analyze the other three cases in turn solve for a Bayesian equilibrium and obtain table 1.

Table 1 Individual and System Expected Profits

	$E[\Pi]$	$E[\pi_1]$	$E[\pi_2]$	System profit
Integrated channel	–	–	–	$\frac{\theta^2}{2(b-d)}+\frac{\sigma^2}{2(b-d)}$
Case 1	S	T	T	$S+2T$
Case 2	$S+\frac{2b^2\sigma^2}{(3b-d)^2(b-d)}$	$T+\frac{b\sigma^2}{(3b-d)^2}$	$T+\frac{b\sigma^2}{(3b-d)^2}$	$S+2T+\frac{2b(2b-d)\sigma^2}{(3b-d)^2(b-d)}$
Case 3	$S+\frac{\sigma^2}{2(b-d)}$	T	T	$S+2T+\frac{\sigma^2}{2(b-d)}$
Case 4	S	$T+\frac{b\sigma^2}{(2b-d)^2}$	$T+\frac{b\sigma^2}{(2b-d)^2}$	$S+2T+\frac{2b\sigma^2}{(2b-d)^2}$
Case 5	$S+\frac{\sigma^2}{2(b-d)}$	T	T	$S+2T+\frac{\sigma^2}{2(b-d)}$
Case 6	S	$T+\frac{\sigma^2}{4b}$	T	$S+2T+\frac{\sigma^2}{4b}$

Where $S=\frac{2b^2\theta^2}{(3b-d)^2(b-d)}$, $T=\frac{b\theta^2}{(3b-d)^2}$

4. RESULTS

We denote the expected profit of the manufacture under case i as $E[\Pi]^*_{ci}$, and the expected profit of retailer j under case i as $E[\pi_j]^*_{ci}$. We have following results

Result 1 (1) $E[\Pi]^*_{c1} = E[\Pi]^*_{c4} = E[\Pi]^*_{c6} < E[\Pi]^*_{c2} < E[\Pi]^*_{c5} < E[\Pi]^*_{c3}$

(2) $E[\pi_1]^*_{c1} = E[\pi_1]^*_{c3} < E[\pi_1]^*_{c2} < E[\pi_1]^*_{c5} < E[\pi_1]^*_{c6} < E[\pi_1]^*_{c4}$

(3) $E[\pi_2]^*_{c1} = E[\pi_2]^*_{c3} = E[\pi_2]^*_{c5} = E[\pi_2]^*_{c6} < E[\pi_2]^*_{c2} < E[\pi_2]^*_{c4}$

If retailer i has the full information about a and can report the information to retailer j without any cost, then retailer i desires to tell retailer j about a to increase own profit when the manufacturer has no information concerning a. When the manufacture has the full information about a, retailer i has no incentive to do so.

Result 2 (1) When the manufacturer is unaware of a, its expected profit $E[\Pi]^* = \frac{2\theta^2 b^2}{(3b-d)^2(b-d)}$.

(2) When Retailer i is unaware of a, its expected profit

$$E[\pi_i]^* = \frac{\theta^2 b}{(3b-d)^2}.$$

Result 3 Total channel profits are highest when the supply chain is vertically integrated; the next in order for only the manufacturer knows the market information. While all members do not know the information, the system profit is minimum.

Although the manufacturer is not a leader in the game, Result 2 expresses the manufacturer to be placed in the predominant position in the supply chain.

Result 4 (1) When the supply chain is vertically integrated, the expected distribution quantity is $q_1+q_2=\theta$.Otherwise, the expected distribution quantity is $q_1=q_2=\frac{\theta b}{3b-d}$ (2) When the supply chain is vertically integrated, the expected price is $p_1^* = p_2^* = \frac{\theta}{2(b-d)}$.

Otherwise, the expected price is

$$p_1 = p_2 = \frac{\theta(2b-d)}{(3b-d)(b-d)}.$$

Since $0<d<b$ and $\frac{2\theta b}{3b-d}<\theta$, when the supply chain is vertically integrated, the expected distribution quantity is maximum.

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