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Dual sourcing strategy in cost-oriented and flexibility-oriented suppliers environment

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For a buyer, a multiple sourcing strategy can be adopted to take advantages of different suppliers with their different capabilities. This research studies how a retailer determines its ordering quantities when it has a cost-oriented supplier providing discount and a flexibility-oriented supplier providing backup products. From the analysis results, although adopting dual sourcing strategy may increase retailer’s expected sales by satisfying customer’s demand, the expected profit with a duple sourcing strategy is not necessarily higher than that with one discount vendor. The profit depends on the ordering quantities from the cost-oriented vendor and from the flexibility-oriented vendor and the expected value of demand function. However, order quantity is affected by related parameters factors. Therefore, a retailer has to allocate its orders to each vendor under deliberate consideration about influential parameters.

Key words: Dual sourcing, discount supply, emergent supply.

INTRODUCTION

The demand becomes uncertain because of the higher competition in the market, shorter product life cycle and fast change of customers’ preference. Unless a firm can deal the uncertain demand with flexible response to adjust inventory level, it may face low service level or high inventory cost (Kristianto and Helo, 2009; Mieghem, 2007; Yu et al., 2009). A dual sourcing policy may help to reduce the uncertainty of demand (Khouja, 1998; Rong et al., 2008; Tomlin and Wang, 2005). For example, Giordano applies dual sourcing policy. Before several months of the sales season, Giordano has to forecast demand and assigns orders to its cost-oriented supplier, factories in Mainland China, which provide low-cost products due to their cheaper production cost. Once the market is booming, Giordano assigns orders to flexibility-oriented vendors, Taiwan vendors, which could deliver goods quickly but at a high cost. Doing so, Giordano could take advantages of both vendors’ supply properties and satisfy customers by reducing the impacts of demand variability (Ghemawat et al., 2003).

This research studies a situation where a retailer adopts a dual sourcing strategy to fulfill uncertain demand. A retailer may order its inventory from the discount supplier, cost-oriented supplier. Because of the product always drops rapidly, a retailer will not order a large amount from discount vendor before observing actual demand. It has the second source. The retailer can place order to an emergent vendor, flexibility-oriented supplier, after observing real demand. It, therefore, can postpone ordering decision. When the retailer wisely uses the reorder opportunity, higher profit can be generated with higher fulfillment and lower inventory. In this research, an emergent vendor is able to supply goods before the end of sales season. A discount vendor provides goods and price discount before the beginning of the sales season. Therefore, the objectives of study are to establish a mathematical model of single sourcing with discount vendor, and a dual sourcing model allowing retailers to allocate orders between two vendors (a discount vendor and an emergent vendor), to conduct parameters analysis and compare the results of these two models, and to provide managerial insights of dual sourcing policy accordingly. Some researchers focus on quantity discount. Eppen and Iyer (1997) study the value of upstream flexibility with a back up agreement. For example, an emergent supplier is used to model retailer’s flexibility and obtains a retailer’s optimal operational decision.

However, they don’t consider a discount vendor. On the other hand, some researchers find the optimal order
quality when a retailer have discount vendor with different
discount policies such as Khouja (1995, 1996); Khouja
and Mehrez (1996). Unfortunately, these researches simply
consider discount vendor but no emergent vendor.
Lau and Lau (1998) develop a two stage dynamic
programming model and conduct a numerical simulation
to study reorder strategy. They assume normal deman d,
programming model and conduct a numerical simulatio n
(2001) study a newsboy problem with reactive produc tion
much to order and when to order. Chung and Flynn
construct an inventory decision model and address h ow
emergent supplier, and provide managerial insights. 

NOTATION
The product considered in this study is the end-product
which is ready to be consumed by customers. However, the
actual demand is unknown. The retailer will have to
estimate the demand of the coming season and decide
on the order amount and retailer has two choices to place
order. It can order from a discount vendor in the
beginning of a period. And the retailer also has an option
to place a second order from an emergent vendor.
To determine the contribution from the emergent
vendor, two different models are formulated. The retailer simply has a discount vendor in single sourcing
but has one discount and one emergent model in dual sourcing model. The notations used in the two
proposed model are as follows:

\[ \pi_1 \] retailer’s expected profit in single sourcing model

\[ \pi_2 \] retailer’s expected profit in dual sourcing model

MODELS FORMULATION
Single sourcing model
In single sourcing model, a retailer simply has one vendor and it
provide quality discount to encourage the retailer ordering more
products. However, the risk of overstocking inventory and
decreasing salvage value will deter a retailer from maintaining high
inventory level. On the other hand, under-stocking inventory implies
that the retailer will lose the future opportunity to serve customers.
Order quantity, hence, determines retailer’s profit. When actual
demand is less than order quantity, the retailer will sell exactly the
demand quantity while amount of product, \( q_1 - x \), will be left; and
the salvage value of unsold goods is \( v(q_1 - x) \). When demand
exceeds order quantity, the retailer will sell all inventories and do
nothing to alleviate the shortage. In each case, the retailer’s cost
depends on the supplier’s discount policy. The total cost is the
product of discounted price and order quantity, but discounted price
is the function of order quantity, \( g(q) = \frac{a}{q} + c \). The discount rate
of price is \( \frac{a}{(a + c)} \). \( c \) is lowest price possibly offered by the vendor and \( a \) is the maximal discount magnitude.
The retailer’s profit function under single discount vendor can be
formulated as follows:

\[
\pi_1 = \int_0^{q_1} \left[ px + v(q_1 - x) - g(q_1)q_1 \right] f(x) dx + \int_0^{\infty} \left[ pq_1 - g(q_1)q_1 \right] f(x) dx
\]

(1)

\[
\pi_1 = \int_0^{q_1} \left[ px + v(q_1 - x) \right] f(x) dx + \int_0^{\infty} pq_1 f(x) dx
\]

To obtain retailer’s optimal condition, Equation (1) is restructured as:

\[
\pi_1 = pq_1 -(p-v) \int_0^{q_1} F(x) dx - g(q_1)q_1
\]

(2)

Since the decision variable is order quantity \( q_1 \), we differentiate
Equation (2) with \( q_1 \) to obtain necessary condition of optimality.

\[
\frac{d \pi_1}{dq_1} = 0 \Rightarrow g'(q_1)q_1 + g(q_1) = p - (p-v)F(q_1)
\]

(3)

Equation (3) is the optimal condition for one discount vendor
problem if equation (2) satisfies the concavity condition. Because
the discount function in this research is assumed to be
\( w(q_1) = \frac{a}{q_1} + c \). Equation (2) satisfies the concavity condition.

Optimal ordering quantity can be obtained by Equation (4)

\[
\left( -\frac{a}{q_1*} + \frac{a}{q_1} + c = p - (p-v)F(q_1) \right) \Rightarrow \frac{a}{q_1} = F^{-1}(\frac{p-c}{p-v})
\]

(4)

Equation (4) shows that if lowest price, \( c \), increases and other
parameters hold constant, a retailer will decrease order quantity.
The optimal ordering quantity with the specific discount function $g(q^*_2) = \frac{a}{q^*_2} + c$ is obtained.

$$(-\frac{a}{q^*_2} + \frac{a}{q^*_2} + c) = p_2 - (p_2 - v)F(q^*_2) \Rightarrow q^*_2 = F^{-1}\left(\frac{p_2 - c}{p_2 - v}\right) \quad (9)$$

From Equation (9), there are some observations. First, when the lowest price, $c$, offered by discount vendor increases and other parameters keep the same, a retailer will decrease order quantity, owing to that a retailer will buy less when purchasing cost increases. Second, the lower the discrepancy between the salvage value and the lowest price is, the more quantities a retailer purchases. The optimal ordering quantity of the discount vendor also shows that if the price charged by the emergent vendor goes up, a retailer will purchase more goods from the discount vendor.

**COMPARISONS BETWEEN SINGLE AND DUAL SOURCING MODELS**

Adopting different sourcing strategies may result in different performance. We compare ordering quantities from the discount vendor and expected profits between single and dual sourcing strategies here.

**Comparisons on ordering quantity**

Traditional newsboy problem is served as the basis to make the comparison. Classic newsboy problem considers only one vendor that provides no discount policy and the optimal ordering quantity of a newsboy problem ($q^*_1$) can be obtained as $F^{-1}\left(\frac{p - (a + c)}{p - v}\right)$. Lemma 1 and 2 illustrates the relationships of the optimal ordering quantities between the proposed models and newsboy problem.

**Lemma 1**

The optimal ordering quantity in the discount vendor problem is higher than that of the classic newsboy problems.

$$\frac{p - (a + c)}{p - v} < \frac{p - c}{p - v}$$

and the Cumulative Density Function (C.D.F) of demand function is monotonous increasing function, the inverse function of C.D.F of demand function is also monotonous increasing function, therefore, $F^{-1}\left(\frac{p - (a + c)}{p - v}\right) < F^{-1}\left(\frac{p - c}{p - v}\right)$, which implies $q^*_1 < q^*_2$.

Thus, the optimal ordering quantity in one discount vendor model is greater than the optimal order quantity in a newsboy problem.
Table 1. Summary of performance index.

<table>
<thead>
<tr>
<th>Performance Index</th>
<th>Single Sourcing Model</th>
<th>Dual Sourcing Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Ordering Quantity</td>
<td>$q_1^* = F^{-1}\left(\frac{p - c}{p - v}\right)$</td>
<td>$q_2^* = F^{-1}\left(\frac{p_2 - c}{p_2 - v}\right)$</td>
</tr>
<tr>
<td>Expected Profit</td>
<td>$\pi_1 = pq_1^* - (p - v) \int_0^{q_1^<em>} F(x)dx - a - cq_1^</em>$</td>
<td>$\pi_2 = (p - p_2)E(x) + v \int_0^{q_2^<em>} F(x)dx$ + $p_2[q_2^</em> - \int_0^{q_2^<em>} F(x)dx] - a - cq_2^</em>$</td>
</tr>
</tbody>
</table>

Lemma 2: The optimal ordering quantity in dual sourcing model is less than that of the classic newsboy problem. Since

$$\frac{p - (a + c)}{p - v} - \frac{p_2 - c}{p_2 - v} - \frac{pp_2 - (a + c) p_2 - v p + v (a + c) - pp_2 + c p + v p_2 - cv}{(v - v)(p - v)} > 0$$

and the C.D.F. of demand function is monotonous implies the inverse function of C.D.F. of demand function is also monotonous increasing function, $F^{-1}\left(\frac{p - (a + c)}{p - v}\right) > F^{-1}\left(\frac{p_2 - c}{p_2 - v}\right)$, which implies $q_1^* > q_2^*$. According to Lemma 1 and 2, $q_1^* > q_1^* > q_2^*$. The relationship matches intuition since a retailer will order more when it has only one supplier while adopt a wait-and-see policy when it has re-order opportunity.

Comparisons on expected profit

After obtain optimal ordering quantity, the expected profits in each model can be derived as follows:

(1) A retailer’s expected profit in single sourcing model ($\pi_1$)

$$\pi_1 = \int_0^{q_1^*} \left[ px + v(q_x - x) - \frac{a}{q_1^*} \right] f(x)dx + \int_0^{q_1^*} \left[ pq_1^* - \frac{a}{q_1^*} \right] f(x)dx$$

$$= pq_1^* - (p - v) \int_0^{q_1^*} F(x)dx - a - cq_1^*$$

(2) A retailer’s expected profit in dual sourcing model ($\pi_2$)

$$\pi_2 = \int_0^{q_2^*} \left[ px + v(q_x - x) - \frac{a}{q_2^*} \right] f(x)dx$$

$$+ \int_0^{q_2^*} \left[ px - p_2(x - q_x) - \frac{a}{q_2^*} \right] f(x)dx$$

$$= (p - p_2)E(x) + v \int_0^{q_2^*} F(x)dx + p_2[q_2^* - \int_0^{q_2^*} F(x)dx] - a - cq_2^*$$

The difference of expected profit between two models is calculated as follows:

$$\pi_1 - \pi_2 = p(q_1^* - \int_0^{q_1^*} F(x)dx) - p_2 q_2^* - \int_0^{q_2^*} F(x)dx$$

$$+ v \left( \int_0^{q_1^*} F(x)dx - \int_0^{q_2^*} F(x)dx \right) - (p - p_2)E(x)$$

From (10), the difference could be a positive or negative and it depends on different value of parameters. Parameter analysis will be conduct in Section 5. The optimal ordering quantity and expected profit of two sourcing models are summarized in Table 1.

Parameters analyses

The impacts of environment factors, $c$, $v$, $p$ (or $p_2$), are explored. The impacts of environmental factors on these three measures are studied first and the impacts across different models are then compared.

Parameters analysis on ordering quantity

After the optimal ordering quantity is obtained, the first derivatives respective to each parameter will provides a good way to understand the impacts on order quantity. Table 2 shows the results of parameters analysis on both models.

Parameter analysis on expected profit

Since the expected profits in different models are derived, the first derivative respective to parameters can be shown on Table 3. Based on Table 3, among all environmental factors, parameter $c$ is still the most important factor at both models. If parameter $c$, $v$ and $p$ are increased by one unit at the same time, the expected profit remains unchanged in single sourcing model. The mean of demand function will influence the expected profit of a retailer when purchasing price from the emergent vendors varies. Especially, higher the expected value of
Table 2. Parameters analysis on ordering quantity.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameters</th>
<th>( c )</th>
<th>( v )</th>
<th>( p ) or ( p_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Sourcing Model</td>
<td>( dq_1^* )</td>
<td>( \frac{-1}{(p-v)f(q_1^*)} )</td>
<td>( \frac{F^2(q_1^<em>)}{(p-c)f(q_1^</em>)} )</td>
<td>( \frac{(1-F(q_1^<em>))^2}{(c-v)f(q_1^</em>)} )</td>
</tr>
<tr>
<td>Dual Sourcing Model</td>
<td>( dq_2^* )</td>
<td>( \frac{-1}{(p_2-v)f(q_2^*)} )</td>
<td>( \frac{F^2(q_2^<em>)}{(p_2-c)f(q_2^</em>)} )</td>
<td>( \frac{(1-F(q_2^<em>))^2}{(c-v)f(q_2^</em>)} )</td>
</tr>
</tbody>
</table>

Relationships

1. \( \frac{dq_1^*}{dc} > \frac{dq_2^*}{dp_2} \) if \( p_2 - c \geq c - v \)
2. \( \frac{dq_1^*}{dc} > \frac{dq_2^*}{dp_2} \) if \( p_2 - c < c - v \)
3. \( \frac{dq_1^*}{dc} > \frac{dq_2^*}{dp_2} \) if \( p_2 - c \geq c - v \)
4. \( \frac{dq_1^*}{dc} > \frac{dq_2^*}{dp_2} \) if \( p_2 - c < c - v \)

Table 3. Parameters analysis on expected profit.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameters</th>
<th>( c )</th>
<th>( v )</th>
<th>( p ) or ( p_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Sourcing Model</td>
<td>( d\pi_1 )</td>
<td>( -q_1^* )</td>
<td>( \int_0^{q_1^*} F(x)dx )</td>
<td>( q_1^* - \int_0^{q_1^*} F(x)dx )</td>
</tr>
<tr>
<td>Dual Sourcing Model</td>
<td>( d\pi_2 )</td>
<td>( -q_2^* )</td>
<td>( \int_0^{q_2^*} F(x)dx )</td>
<td>( -E(x) + q_2^* - \int_0^{q_2^*} F(x)dx )</td>
</tr>
</tbody>
</table>

Conclusions

A smart retailer takes advantages of cost-oriented and flexibility-oriented supplier to fulfill customer demand. A dual sourcing policy helps to reduce the uncertainty of demand. A single sourcing (a discount supplier) and a dual sourcing (a discount and an emergent supplier) model are constructed to derive optimal ordering policy. For a retailer, having an emergent vendor reduces its dependence on the single vendor. However, the expected profit of the dual sourcing model is not necessarily higher than that with a single sourcing model. Retailer’s expected profit depends on the difference between the order quantity for the discount and emergency retailer and the expected value of demand function. Although several environmental factors affect the ordering quantity, the minimum discount price offered by discount vendor is still the most important factor on the expected profit in both models. Therefore, a retailer has to consider the impact of environmental factors on ordering quantity to determine the sourcing strategy to maximize its expected profit. For the future direction of research, researchers might study the following issues. Retailers adjust ordering quantity along with the demand. Therefore, it a firm
two sources of supplies in a price-sensitive demand market could be discussed further based on the proposed models. In addition to demand, retailers might have other concerns except the lowest price of discount function, salvage value of excess inventory and unit price of products from both suppliers. Researchers can include different discount functions or environmental parameters into the proposed models to extend the generalization.

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