The Value of Flexibility from Opaque Selling

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Introduction

An opaque product is a product where some secondary attribute is not revealed to the customer until after purchase. Selling opaque products has become popular on e-commerce platforms where the hidden attribute is often color or style, thanks to its obvious advantage in risk pooling the demand. The objective of this study is to quantify the value of consumer flexibility that underlies opaque selling.

Main Theorem

- The relative cost savings of k-opaque selling is \( \Omega \left( \frac{\log N}{\sqrt{S}} \right) \) for any \( k \geq 2 \) and any \( q = \Omega \left( \frac{\log N}{s^{1-\epsilon}} \right) \) for some fixed \( \epsilon > 0 \).
- A minimal degree of opacity achieves the same order of cost savings as the fully flexible scheme (1, N).
- The balancing policy is sub-optimal, but asymptotically optimal.
- The savings of holding costs are on the same order as that of ordering costs.

Degree of Opacity (q, k)

- k-opaque product: customers select k products from which the seller allocates one to the customer.
- q fraction of the customers select the k-opaque option

Traditional Strategy

- N horizontally differentiated products
- customers dynamically arrive with symmetric preference
- no lead time, no backlogging/lost sales
- holding cost and joint replenishment cost
- joint order-up-to policy (0, S)

Add a k-opaque option

- N products and a k-opaque product
- same inventory setting and same replenishment policy (0, S)
- opaque products allocated by a Balancing Policy

Goal: to quantify the savings in long run holding and ordering costs induced by opaque selling with degree of opacity (q, k)

Numerical Experiments

Figure 2: For fixed q value, compare different k

Table 1: Compare 2-opaque with N-opaque on profitability

Table 2: Extend to inventory settings with positive lead time, backlogging or lost sales

Table 1. N-opaque v.s. 2-opaque in Profitability (N = 7)

<table>
<thead>
<tr>
<th>Valuation Distribution</th>
<th>Discount N-opq</th>
<th>2-opq</th>
<th>q</th>
<th>Increase in Profit N-opq</th>
<th>2-opq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>7.05%</td>
<td>1.07%</td>
<td>9.52%</td>
<td>27.15%</td>
<td>1.43%</td>
</tr>
<tr>
<td>Normal</td>
<td>6.54%</td>
<td>2.05%</td>
<td>13.75%</td>
<td>39.66%</td>
<td>2.46%</td>
</tr>
<tr>
<td>Logistic</td>
<td>5.74%</td>
<td>1.68%</td>
<td>11.68%</td>
<td>33.96%</td>
<td>2.09%</td>
</tr>
</tbody>
</table>

Table 2. Relative Cost Savings with Extension to General Inventory Settings

<table>
<thead>
<tr>
<th>Inventory Settings</th>
<th>Lead Time</th>
<th>2-opq</th>
<th>N-opq</th>
<th>N-opq with re-optimized ordering policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlogging</td>
<td>1</td>
<td>3.27%</td>
<td>5.65%</td>
<td>5.85%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.76%</td>
<td>8.03%</td>
<td></td>
</tr>
<tr>
<td>Lost Sales</td>
<td>1</td>
<td>4.05%</td>
<td>6.50%</td>
<td>6.50%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.15%</td>
<td>6.96%</td>
<td>6.96%</td>
</tr>
</tbody>
</table>