Behavioral Causes of the "Bullwhip" Effect in Supply Chains

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The “Bullwhip” Effect

- Orders to increase in variation as one moves up a supply chain.
- The effect is costly because it causes excessive inventories, poor customer service, and unnecessary capital investment.
Operational Causes

- There is a great deal of research on operational causes of the bullwhip effect (see for example Lee et al. 1997):
  - demand signal processing,
  - inventory rationing,
  - order batching
  - price variations
Behavioral Causes of the Bullwhip Effect

“...the key to improved performance lies within the policy individuals use to manage the system and not in the external environment. Even a perfect forecast will not prevent a manager who ignores the supply line from over ordering.” (Sterman 1989, p. 336).

- Implication: the Bullwhip effect will persist even if ALL operational causes are removed (even with constant and known demand).
The “Beer Distribution Game”

- A vehicle we use to study the bullwhip effect in the laboratory.

Your Role is: Retailer
This is the beginning of week: 1
Research Questions

- Will the bullwhip effect persist in an environment with constant and known demand?
- If so, then we can separate possible causes into two broad categories
  - Cognitive limitations
  - Inability to coordinate
Experimental Design

- Compares performance of subjects in the same roles in teams with all human participants, to teams with one human participant.
- If we see improved performance in the automated teams, we can conclude that, at least partially, the problem is due to the inability to coordinate.
### Experimental Design

<table>
<thead>
<tr>
<th>Know Optimal Policy</th>
<th>Team Composition</th>
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</thead>
<tbody>
<tr>
<td>YES</td>
<td>I = 12, 5 teams</td>
</tr>
<tr>
<td></td>
<td>I = 0, 5 teams</td>
</tr>
<tr>
<td></td>
<td>I = 12, 20 teams</td>
</tr>
<tr>
<td></td>
<td>I = 0, 20 teams</td>
</tr>
<tr>
<td>NO</td>
<td>I = 12, 5 teams</td>
</tr>
<tr>
<td></td>
<td>I = 0, 5 teams</td>
</tr>
</tbody>
</table>

Customer demand is constant at 4; this is public information.
There are 4 cases in each delay position.

I = Initial Inventory is either 0 or 12, depending on the treatment.
All human team
- On-hand inventory
- Initial inventory = 0
- No information about optimal policy provided
Comparisons by Role

Retailers

Wholesalers

Distributors

Manufacturers

Automated

Human
Overall Performance...

![Bar chart showing overall performance with different initial inventories and cost per team for automated, information, and no information scenarios.](chart.png)

- **Average Cost per Team**
- **Initial Inventory**:
  - 0
  - 12

Legend:
- **Automated**
- **Information**
- **No Information**
Estimating Behavior

From Sterman '89:

\[
Order = \max \left\{ 0, EO + a \left[ (I^* - I) - b (SL^* - SL) \right] \right\}
\]

Where:
- EO = expected order
- I* = target inventory
- SL* = target supply line
- I = actual inventory
- SL = actual supply line
- a and b are adjustment parameters to be estimated
Ignoring supply line...
Conclusions

- The bullwhip effect persists with known and constant demand.
  - Behavioral explanation
- Telling subjects what the optimal ordering policy is does not help them.
- Human subjects do better when other team members are computerized than when the other team members are human.
  - Coordination is part of the story