Demand Information Distortion and Bullwhip Effect

Chopra: Chap. 17
Lessons of the Game

• Such oscillations are common
  – Bullwhip effect (demand distortion)

• Everyone blames others - but problem is with the structure
Bullwhip effect: increased demand variability up the SC
Bullwhip effect in the US PC supply chain

Annual percentage changes in demand (in $s) at three levels of the semiconductor supply chain: personal computers, semiconductors and semiconductor manufacturing equipment.
HP Laser: L – Series

HP- Shipment

Wholesaler-see-thru
• **Causes for Poor SC Performance**

- Demand uncertainty (how to cope with it?)
  - Safety stock
  - Better forecast.
- Product variety (---)
  - Better plan.
- Information distortion along the SC -- bullwhip (---)
Curses of Bullwhip Effect

• Curses
\[ \mu = 350 \]

\[ X = ? \]

\[ \sigma = 10 \]

\[ \text{Svc Level} = 0.95 \]

\[ \text{P(Stockout)} = 0.05 \]

\[ \text{Safety Stock} = X - \mu \]
Causes of Bullwhip Effect

• Key causes
  – Demand forecasts update (by different parties)
    • “information distortion”
  – Leadtimes
  – Price promotion - forward buying
  – Order synchronization
  – Batch ordering practice
  – Shortage “Gaming”

Psychological effect?
Some observations

- Roughly speaking, average in = average out
- But, the standard deviations of “in”/”out” can be diff.
- CV & bullwhip effect

Order-up-to level (OUT):
- If all retailers use OUT policy (with a constant $S$), then the Stdev of the retailer’s orders per period equals the Stdev. Of consumer demand per period – no bullwhip effect

If there is no need to update demand information at the retailer level
If Ordering is Based on Forecasts

• In reality, the retailer may not know the demand to fluctuate around an “average”
• Moreover, each location along the supply chain may forecast demand to determine order sizes

Note that in the previous classes on “Inventory Management”, it was assumed that the control policy parameter values do not vary over time – demand stable. With forecast updating, we may change their values based on forecasts.
Gerard Cachon
(The Wharton School)

• I worked with Campbell Soup to evaluate their VMI system in which they decided what to ship to their client retailers. They were able to lower their retailers’ inventories by about 2/3rds and raise their fill rates at the same time. What made that achievement remarkable was that their system was quite simple, painfully simple – forecast sales for the next few days based on a rolling average of sales in the previous weeks, choose an order up-to level that would achieve a given fill rate assuming a reasonable level of demand volatility.
## Forecast Updating - 121 SC:
An Example – Order-up-to Level

<table>
<thead>
<tr>
<th>Period</th>
<th>t</th>
<th>t-1</th>
<th>t-2</th>
<th>t-3</th>
<th>t-4</th>
<th>t-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>64</td>
<td>40</td>
<td>45</td>
<td>35</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Forecast</td>
<td>64</td>
<td>40</td>
<td>45</td>
<td>35</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Order Upto</td>
<td>128</td>
<td>80</td>
<td>90</td>
<td>70</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Order q</td>
<td>112</td>
<td>30</td>
<td>65</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assumptions: retailer uses $D_{t-1}$ to forecast future demand $D_t$, as $F_t = D_{t-1}$; order-up-to-level 2 $F_t$.

No Safety stock?
Impact of Forecasting on BE

• The BE is due, in part, to the need to forecast demand & hold safety stock
• Moving ave and exponential smoothing are “bad”
• The fancier the method, the worse the BE
• Smoother demand forecasts can reduce the bullwhip effect (MA & ES methods)
• The longer the leadtime, the higher the BE
• Centralised information sig reduces the BE
Forecast Updating - 121 SC

Mkt Demand: \( D_T : (\mu, \sigma^2) \). Retailer: Order up-to-level

\[ S_T = z F_T \]

and follows a naive forecasting method:

\[ F_T = D_{T-1} \cdot \]

Thus, for period \( t-1 \):

\[ S_{t-1} = z F_{t-1} = z D_{t-2} \]

and for period \( t \):

\[ S_t = z F_t = z D_{t-1} \]

ordering quantity:

\[ q_t = S_t - S_{t-1} + D_{t-1} \geq z(D_{t-1} - D_{t-2}) \]

\[ \text{Var} (q_t) > z^2 \text{Var} (D_{t-1} - D_{t-2}) \]

\[ = z^2 [2 \sigma^2 - \text{Cov} (D_{t-1}, D_{t-2})] \geq z^2 \sigma^2 \]

\[ \frac{\text{Var} (q_t)}{\text{Var} (D_t)} = \frac{\text{Var} (q_t)}{\sigma^2} \geq z^2 \]

For example, \( \text{Cov}(D_{t-1}, D_{t-2}) = 0 \), \( z = 1.5 \):

\[ \text{Var} (q_t) / \text{Var} (D_t) = 1.5^2 = 2.25. \]
Avoiding Demand Forecast Updates

• BE resulted from the chain effect along the SC
  – Repetitive multiple forecast updating

• Share demand information so that every one can
  obs demand shifts without distortions:
  – Demand forecasts should be based on final sales to
    consumers
Avoiding Demand Forecast Updates

- **Channel Alignment**
  - VMI - vendor managed inventory scheme
  - Consumer direct
  - Discount for information sharing, including plan of promotion activities
Bullwhip can occur within a firm

Volvo Green Cars

<table>
<thead>
<tr>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>We need to promote and get rid of these green cars</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>All green cars are sold out, time for replenishment</td>
</tr>
</tbody>
</table>
Order Synchronization

• Synchronized ordering occurs when retailers tend to order at the same time:
  – end of the week orders
  – beginning of the month orders
  – end of the quarter orders
Figure 3: Orders from Automobile Manufacturers to Their Supplier: a Tubing Manufacturer: Spikes Coinciding with MRP Runs by Automobile Manufacturers

Order Quantity in Millions of Meters

Time

MRP/Push Lean/JIT/Repetitive
Order batching

- Retailers may be required to order in integer multiples of some batch size, e.g., case quantities, pallet quantities, full truck load, etc.

- The graph shows simulated daily consumer demand (solid line) and supplier demand (squares) when retailers order in batches of 15 units, i.e., every 15\textsuperscript{th} demand a retailer orders one batch from the supplier that contains 15 units.
50 Retailers Order from A Supplier
Supplier demand: Retailer Batches = 10
Order batching solutions

- Smaller min order quantity (lower Q), so retailers order more frequently
- Unsynchronize retailer order intervals
  - Retailers may order every T periods
  - Min batch size Q=1, so no min order Q restriction
  - Retailers are placed on balanced schedules s.t. average demand per period is held constant
    - e.g., 100 identical retailers and T=5 implies 20 retailers may order each period
Trade Promotion

• Why trade promotion?

• Consequences of trade promotion?
Trade promotions and forward buying

- Supplier gives retailer a temporary discount, called a trade promotion.
- Retailer purchases enough to satisfy demand until the next trade promotion.

Example: Campbell’s Chicken Noodle Soup over a one year period:

Total shipments and consumption

One retailer’s buy
Shortage game

- Retailers submit orders for delivery in a future period
- Supplier might not be able to fill all orders
  - He might not get enough components
  - His production yield might not be as high as expected
- Phantom orders
  - Retailers order more than they think they need to make sure they get a good allocation if demand is high or if capacity is tight
When is shortage game likely?

- Supplier allows retailers to cancel order or accepts returns
- High retailer profit margin, i.e., costly to not have goods
- Retailer demand expectations positively correlated (i.e., if one retailer has high demand expectation, the other retailers probably do too.)
- Retailer competition (if retailer A takes more inventory, retailer B has less to sell)
- Capacity is expensive, so the supplier will not build unlimited cap

- Perception: Demand for semiconductors would have a tremendous increase
- Result: Customers, worried about a supply shortage, tripled their orders
- Reality: Semiconductor companies scrambled to meet demand, realized information was inflated and suffered huge losses
How to stop phantom ordering

- Don’t let retailers cancel orders
- Don’t offer retailers generous return policies
- Share cap. And inventory data prevent false scares
- Prioritize retailers (customers, e.g., by past sales)
Summary

• **Three major causes for Poor SC Performance**
  – Demand uncertainty
  – Product variety
  – Information distortion along the SC -- bullwhip

• **Several (root) causes for B.E.**
  – Ordering decision based on demand forecast updating
  – Order synchronization and batch ordering
  – Promotion deals
  – Shortage gaming