In search of the bullwhip effect

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The bullwhip effect

- Demand variability increases as you move up the supply chain from the customer towards supply
Campbell’s Chicken Noodle Soup

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The bullwhip at Barilla pasta

Downstream variability at DC: mean demand is about 300, the standard deviation is about 75

Upstream variability at CDC is much higher
Demand Variability --
Bullwhip Effect in LaserJet L Series

Shipments

Sell Thru-To
Reseller Order Bullwhip -- 5L

Constrained Supply

Channel Inefficiencies

Order Std Dev

Sell-To Std Dev

Comp USA

Office Depot

OfficeMax

Staples

Micro Electronics

Tandy Corp

Best Buy

ElekTek

PC Warehouse
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Autos to machine tools

Source: Anderson, Fine and Parker (1996)
Annual percentage changes in demand (in $s) at three levels of the semiconductor supply chain: personal computers, semiconductors and semiconductor manufacturing equipment.
Explanations for the bullwhip effect …


- **Price fluctuations/cost shocks:** LPW (1997)

- **Non-convex production:** Ramey (1991)

- **Demand can be backlogged:** Kahn (1987)

- **Shortage gaming:** LPW (1997), Cachon and Lariviere (1997)

- **Misperception of feedback/irrational behavior:** Sterman (1989)
Empirical evidence of production smoothing

- **Blinder and Maccini (91,92):**
  - Data: 1959-1986, monthly, seasonally adjusted, constant 1982 dollars
  - Production is more variable than sales in 17 of 20 two-digit manufacturing industries
  - “… the basic facts to be explained are … 1) production is more variable than sales in most industries”.

- **Blanchard (1983):**
  - “… in the automobile industry, inventory behavior is destabilizing: the variance of production is larger than the variance of sales.”

- **Miron and Zeldes (1988):**
  - “…The overall assessment of this model … is quite negative: there is little evidence that manufacturers hold inventories of finished goods … to smooth production.”

- **Eichenbaum (1989):**
  - “We find overwhelming evidence against the production-level smoothing model … we conclude that the variance of production exceeds the variance of sales in most manufacturing industries.”

- **Other negative results:**
A measure of the bullwhip effect: the amplification ratio

- Amplification ratio = \( V[Y] / V[D] \).
- If demand is not available, use sales as a proxy for demand.
- We say the bullwhip effect is present in an industry if its amplification ratio is greater than 1.
Our data

- **Sources:**
  - Census Department, Bureau of Economic Analysis.

- **Data:**
  - 50 manufacturing industries: Sales, inventory.
    - In a subset of 23 manufacturing industries: Demand.
  - 16 wholesale industries: Sales, inventory.
  - 6 retail industries: Sales, inventory.

- **Data manipulations:**
  1) Adjust Demand and Sales series for margins and price.
  2) Adjust Inventory series for price.
  3) For each industry evaluate a Production series: \( Y_t = S_t + \Delta I_t \)
  4) Log and first difference the Production, Demand and Sales series.
General merchandise stores – margin and price adjusted
General merchandise stores – margin and price adjusted plus logged and first differenced
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Telecom – margin and price adjusted

Production
Demand

Jan-92 Jan-94 Jan-96 Jan-98 Jan-00 Jan-02 Jan-04 Jan-06
Telecom – margin and price adjusted plus logged and first differenced
Research questions

- To what extent does the bullwhip effect exist in U.S. industry level data?
  - Are amplification ratios greater than 1?
  - Do manufacturers experience the highest demand variability and retailers the lowest?

- Understand variation in the amplification ratios:
  - What explains variation in the amplification ratio across industries?
  - Have amplification ratios been decreasing over time?
Prevalence of the bullwhip effect

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<thead>
<tr>
<th>Aggregate series</th>
<th>Amplification Ratio</th>
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<tbody>
<tr>
<td>Retail</td>
<td>0.50</td>
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<tr>
<td>Wholesale</td>
<td>1.14</td>
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<tr>
<td>Manufacturing</td>
<td>0.55</td>
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Percentage of industries that exhibit the bullwhip effect

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<th>Seasonally unadjusted</th>
<th>Seasonally adjusted</th>
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<tbody>
<tr>
<td>Retail</td>
<td>16% (1 of 6)</td>
<td>100% (6 of 6)</td>
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<tr>
<td>Wholesale</td>
<td>88% (14 of 16)</td>
<td>100% (16 of 16)</td>
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<tr>
<td>Manufacturing</td>
<td>40% (20 of 50)</td>
<td>74% (37 of 50)</td>
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Demand variability at different levels of the supply chain
Trends in amplification ratios

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<tbody>
<tr>
<td>All Industries</td>
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Future research

- Investigate the bullwhip effect at different levels of aggregation – firm, category, sku.

- Investigate the bullwhip effect at different levels of time aggregation – daily, weekly, quarterly.

- Obtain better order and demand data.

- Do firms/supply chains that better manage the bullwhip effect perform better financially?