STIVEN CATALYST

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MANAGEMENT REVIEW

Management without theatre.



STRATEGY

THE BULLWHIP EFFECT: SMALL WAVES, BIG SWINGS

A board game where demand changes once, how the swing grows link by link, four rational causes and a human one, what shared stock data does, how to measure the swing, and a card.

700% amplification at the factory in the Beer Game: customer orders rose from 4 to 8 cases a week, factory orders peaked at 32 on average.

STERMAN, 1989

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NO. 88 · STRATEGY

In this issue

A shop sells a little more, and weeks later the warehouse is short, the plant runs overtime, and then everyone sits on stock. Each link blames the one below. The pattern has a name, the bullwhip effect, and decades of research on where it comes from.

In John Sterman's Beer Game, four players run a chain from shop to factory, and customer demand steps up once. Orders and stock still swung in every trial kept, and grew with each link. Lee, Padmanabhan and Whang showed that rational managers create the same pattern through forecasts, batches, promotions and shortages. Sterman's players added a human cause: they forgot what was already on order. Croson and Donohue took the other causes away, and the swing stayed; shared stock data helped most upstream. A ratio and a card measure the swing at one link.

Stiven Janaqi EDITOR · STIVEN CATALYST

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HOW TO READ THIS ISSUE

Figure
Every figure has its source and year at the foot of its page.

Our reading
Where the editor interprets rather than the research, it says so.

Practice
The steps and the card are proposals to try, not research results.

COVER STORY

Demand changed once

The Beer Distribution Game was developed at MIT to teach management. Four players run a retailer, a wholesaler, a distributor and a factory. Each week the only decision is how much to order, and an order takes at least four weeks to arrive. The goal is the lowest total cost for the team.

Weeks 1–4

Customers buy 4 cases a week; everyone holds 12 and orders 4.

Week 5

Demand rises to 8 and stays there. No one is told.

Weeks 20–25

The largest backlog, 35 cases on average.

Weeks 25–30

Stock peaks at 40 cases on average, and orders collapse.

Every one of the 11 trials analysed oscillated. Recovering the starting stock took 21 weeks on average, and team costs were about ten times a simulated benchmark. Asked afterwards to draw customer demand, most players drew a wave.

OUR READING

The wave was made inside the chain. The players saw it outside, in the customer.

Source: John D. Sterman, Management Science 35(3), 1989

Sterman (1989): 11 trials (44 players) kept from 48 played over four years, by MIT students and executives; figures are averages of the 11. A board game, not company data.

THE NUMBERS

Further from the customer, wilder

Sterman measured how the swing grew from link to link. Customer orders rose from 4 to 8 cases a week. By the time the change reached the factory, its orders peaked at 32 on average, more than twice the retailer's peak.

PEAK ORDERS, CASES A WEEK, BEER GAME (1989)



The variance of orders grew the same way: 1.6 for the customer, 13 at the retailer, 72 at the factory. The peaks also came later upstream: week 16 at the retailer, week 20 at the factory.

OUR READING

No one upstream sees the customer. Each link sees only the orders of the link below, and those already carry the swings of everyone in between.

Source: John D. Sterman, Management Science 35(3), 1989

Averages of the 11 trials (Sterman 1989, Table 3). Sterman's amplification compares the rise at the factory, 4 to 32, with the rise in demand, 4 to 8: 700%.

THE MODEL

Four causes and a fifth

Lee, Padmanabhan and Whang (1997) defined the effect: orders to the supplier vary more than sales to the buyer, and the distortion grows upstream. Their models show it arises even when every member orders rationally, from four causes.

01	**Demand signal processing**	A good week is read as a new forecast, and the order overshoots; long lead times make it worse.
02	**Rationing game**	When supply is short, buyers order more than they need to secure their share.
03	**Order batching**	Ordering costs and periodic reviews bunch many weeks into one order.
04	**Price variations**	Promotions bring buying forward, then a lull follows.

Sterman's players added a fifth: they underweighted the supply line, the goods ordered but not yet received. The mean weight they gave it was 0.34, where 1 would be right; only 5 of 44 counted more than two-thirds of it.

OUR READING

Four causes sit in how the chain is built, the fifth in how people read it. A manager can work on both.

Sources: Hau L. Lee, V. Padmanabhan & Seungjin Whang, Management Science 43(4), 1997; John D. Sterman, Management Science 35(3), 1989

Causes as Lee et al. (1997) name them; calling Sterman's finding a fifth is the editors'. Forrester (1961) showed the effect in case studies, as Lee et al. note. S&OP is in No. 59, forecasting in No. 77.

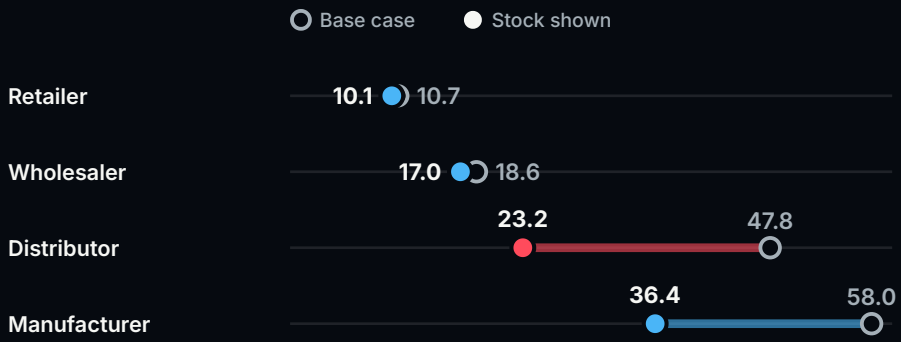
More in the essay Mistakes get lost between departments

WHAT THE RESEARCH SAYS

Even when demand is known

Croson and Donohue (2006) removed the operational causes: no batching, no price changes, and demand known to all: any whole number from 0 to 8 cases, written on the board. 44 students played in 11 teams; 44 more saw all four stocks on screen.

VARIANCE OF ORDERS BY ROLE, TWO EXPERIMENTS (2006)



Customer demand had a variance of 5.33; every role ordered with more. All 44 players in the first study gave less weight to goods on order than to goods in stock. With stock in view, the distributor's variance roughly halved; the retailer's hardly moved.

OUR READING

Knowing demand did not stop the swing. Seeing the stock below helped the links furthest from the customer most.

Source: Rachel Croson & Karen Donohue, Management Science 52(3), 2006

Average variance of orders by role (Table 1), undergraduates in a lab, 2002. Five teams of logistics professionals showed the same pattern, less strongly.

HOW IT IS MEASURED

Orders against demand

Both studies measure the effect the same way: the variance of the orders a link places, against the variance of the demand it receives. A ratio above 1 means the link amplifies.

1. **Same weeks**
   Demand received and orders placed, for one item, over the same period.

2. **Two variances**
   One for demand, one for orders, in the same units.

3. **Divide**
   Orders over demand; repeat at each link where data exist.

HYPOTHETICAL EXAMPLE, ONE ITEM OVER EIGHT WEEKS

Demand	36 to 44 a week, average 40, variance 8
Orders	0, 40 or 80 a week, average 40, variance 1,200
Ratio	1,200 ÷ 8 = 150

The same 40 a week reaches the supplier as a far noisier signal. The item and its figures are invented.

Sources: Hau L. Lee, V. Padmanabhan & Seungjin Whang, Management Science 43(4), 1997; Rachel Croson & Karen Donohue, Management Science 52(3), 2006

The steps and the example are the editors', on the definition of Lee et al. (1997) and the variances of Croson & Donohue (2006). Variances of the eight weeks, divided by 8.

TOOL OF THE ISSUE

The order-swing card

One card per item and link, filled in with the person who places the orders. The inventory tool sorts items by how steady their demand is and sets reorder points from it.

01 Item and link who orders from whom; the weeks compared

02 The ratio variance of orders ÷ variance of demand

03 On order now ordered, not yet received; is it counted before the next order?

04 Which cause forecast update, batching, promotion, shortage gaming, supply line ignored

05 One change, and when we measure again e.g. share sales data, order smaller and more often, allocate by past sales

Sources: Hau L. Lee, V. Padmanabhan & Seungjin Whang, Management Science 43(4), 1997; John D. Sterman, Management Science 35(3), 1989

Our proposal, built on the causes and counter-measures in Lee et al. (1997) and the supply line in Sterman (1989).

Open the tool: ABC/XYZ Inventory stivencatalyst.com/tools/inventory-abc/

SOURCES AND METHOD

Every figure has a source.

The figures in this issue come from the sources below. The year shows how recent each one is.

Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment
John D. Sterman, Management Science 35(3), 1989
https://doi.org/10.1287/mnsc.35.3.321

Information Distortion in a Supply Chain: The Bullwhip Effect
Hau L. Lee, V. Padmanabhan & Seungjin Whang, Management Science 43(4), 1997
https://doi.org/10.1287/mnsc.43.4.546

Behavioral Causes of the Bullwhip Effect and the Observed Value of Inventory Information
Rachel Croson & Karen Donohue, Management Science 52(3), 2006
https://doi.org/10.1287/mnsc.1050.0436

EDITORIAL METHOD

Each figure was checked for its year, its publisher and what it measures, in the full text where it could be opened. A source read only in a summary, an abstract or excerpts is marked “via”. A figure not confirmed in what was read is marked so on its page, or left out. The editor's interpretation is marked “Our reading”.



MANAGEMENT REVIEW

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Every issue, one management question, checked against the best research.

ALL ISSUES

stivencatalyst.com/magazine/management-review.html

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Edited by Stiven Janaqi, who answers for it; “the editors” in this publication means him. Its texts, translations, layout and the checking of figures against their sources are done in working sessions with Claude, an AI model by Anthropic.
stivencatalyst.com/how-this-is-made.html