The Bullwhip Effect In Supply Chains[1]

Hau L Lee, V Padmanabhan, and Seungjin Whang;

Sloan Management Review, Spring 1997, Volume 38, Issue 3, pp. 93-102

Abstract:

The bullwhip effect occurs when the demand order variabilities in the supply chain are amplified as they moved up the supply chain. Distorted information from one end of a supply chain to the other can lead to tremendous inefficiencies. Companies can effectively counteract the bullwhip effect by thoroughly understanding its underlying causes. Industry leaders are implementing innovative strategies that pose new challenges: 1. integrating new information systems, 2. defining new organizational relationships, and 3. implementing new incentive and measurement systems.

> *Distorted information from one end of a supply chain to the other can lead to tremendous inefficiencies: excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, inactive transportation, and missed production schedules. How do exaggerated order swings occur? What can companies do to mitigate them?*

Not long ago, logistics executives at Procter & Gamble (P&G) examined the order patterns for one of their best-selling products, Pampers. Its sales at retail stores were fluctuating, but the variabilities were certainly not excessive. However, as they examined the distributors' orders, the executives were surprised by the degree of variability. When they looked at P&G's orders of materials to their suppliers, such as 3M, they discovered that the swings were even greater. At first glance, the variabilities did not make sense. While the consumers, in this case, the babies, consumed diapers at a steady rate, the demand order variabilities in the supply chain were amplified as they moved up the supply chain. P&G called this phenomenon the "bullwhip" effect. (In some industries, it is known as the "whiplash" or the "whipsaw" effect.)

When Hewlett-Packard (HP) executives examined the sales of one of its printers at a major reseller, they found that there were, as expected, some fluctuations over time. However, when they examined the orders from the reseller, they observed much bigger swings. Also, to their surprise, they discovered that the orders from the printer division to the company's integrated circuit division had even greater fluctuations.

What happens when a supply chain is plagued with a bullwhip effect that distorts its demand information as it is transmitted up the chain? In the past, without being able to see the sales of its products at the distribution channel stage, HP had to rely on the sales orders from the resellers to make product forecasts, plan capacity, control inventory, and schedule production. Big variations in demand were a major problem for HP's management. The common symptoms of such variations could be excessive inventory, poor product forecasts, insufficient or excessive capacities, poor customer service due to unavailable products or long backlogs, uncertain production planning (i.e., excessive revisions), and high costs for corrections, such as for expedited shipments and overtime. HP's product division was a victim of order swings that were exaggerated by the resellers relative to their sales; it, in turn, created additional exaggerations of order swings to suppliers.

In the past few years, the Efficient Consumer Response (ECR) initiative has tried to redefine how the grocery supply chain should work.[1] One motivation for the initiative was the excessive amount of inventory in the supply chain. Various industry studies found that the total supply chain, from when

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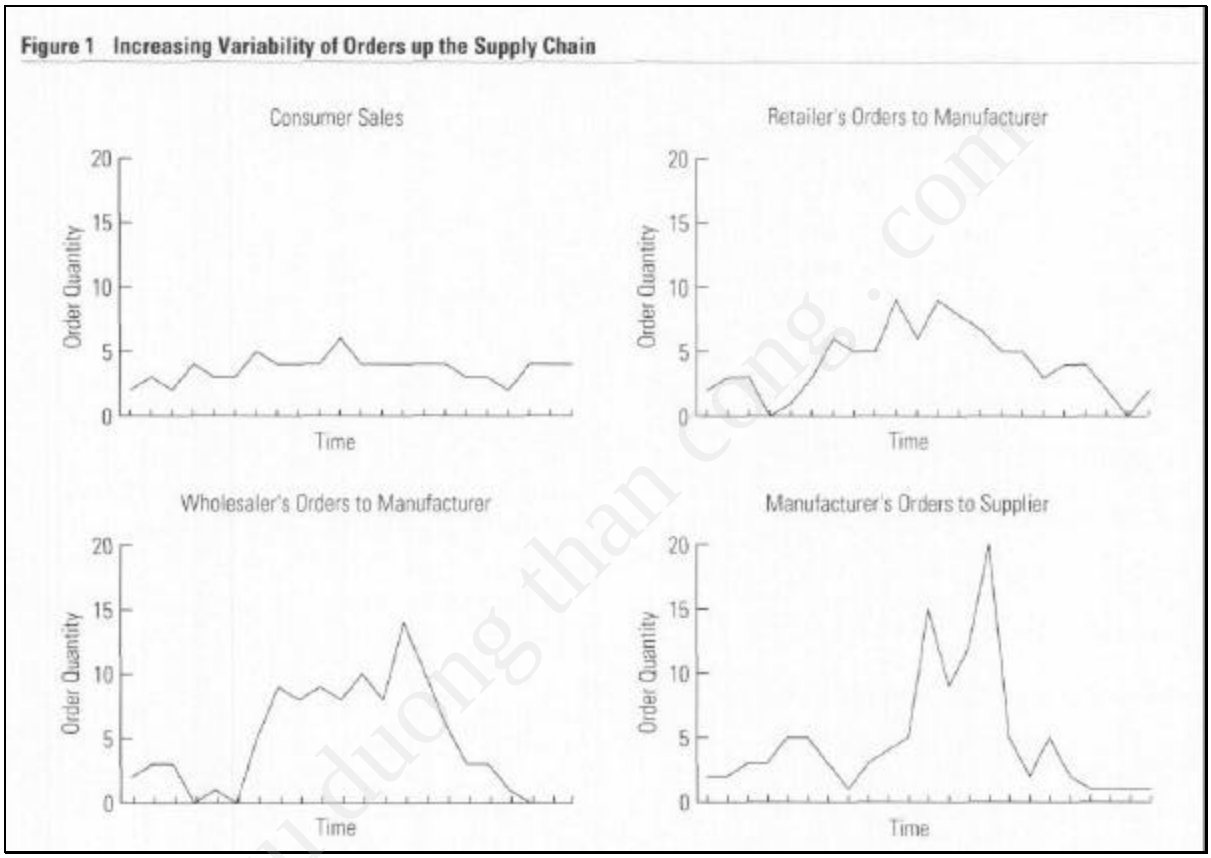
products leave the manufacturers' production lines to when they arrive on the retailers' shelves, has more than 100 days of inventory supply. Distorted information has led every entity in the supply chain - the plant warehouse, a manufacturer's shuttle warehouse, a manufacturer's market warehouse, a distributor's central warehouse, the distributor's regional warehouses, and the retail store's storage space - to stockpile because of the high degree of demand uncertainties and variabilities. It's no wonder that the ECR reports estimated a potential $30 billion opportunity from streamlining the inefficiencies of the grocery supply chain.[2]

Figure 1 Increasing Variability of Orders up the Supply Chain



Other industries are in a similar position. Computer factories and manufacturers' distribution centers, the distributors' warehouses, and store warehouses along the distribution channel have inventory stockpiles. And in the pharmaceutical industry, there are duplicated inventories in a supply chain of manufacturers such as Eli Lilly or Bristol-Myers Squibb, distributors such as McKesson, and retailers such as Longs Drug Stores. Again, information distortion can cause the total inventory in this supply chain to exceed 100 days of supply. With inventories of raw materials, such as integrated circuits and printed circuit boards in the computer industry and antibodies and vial manufacturing in the pharmaceutical industry, the total chain may contain more than one year's supply.

In a supply chain for a typical consumer product, even when consumer sales do not seem to vary much, there is pronounced variability in the retailers' orders to the wholesalers (see Figure 1). Orders to the manufacturer and to the manufacturers' supplier spike even more. To solve the problem of distorted information, companies need to first understand what creates the bullwhip effect so they can counteract it. Innovative companies in different industries have found that they can control the bullwhip effect and improve their supply chain performance by coordinating information and planning along the supply chain.

Causes of the Bullwhip Effect

Perhaps the best illustration of the bullwhip effect is the well-known "beer game."[3] In the game, participants (students, managers, analysts, and so on) play the roles of customers, retailers, wholesalers, and suppliers of a popular brand of beer. The participants cannot communicate with each other and must make order decisions based only on orders from the next downstream player. The ordering patterns share a common, recurring theme: the variabilities of an upstream site are always greater than those of the downstream site, a simple, yet powerful illustration of the bullwhip effect. This amplified order variability may be attributed to the players' irrational decision making. Indeed, Sterman's experiments showed that human behavior, such as misconceptions about inventory and demand information, may cause the bullwhip effect.[4]

In contrast, we show that the bullwhip effect is a consequence of the players' rational behavior within the supply chain's infrastructure. This important distinction implies that companies wanting to control the bullwhip effect have to focus on modifying the chain's infrastructure and related processes rather than the decision makers' behavior.

We have identified four major causes of the bullwhip effect:

1. Demand forecast updating
2. Order batching
3. Price fluctuation
4. Rationing and shortage gaming

Each of the four forces in concert with the chain's infrastructure and the order managers' rational decision making create the bullwhip effect. Understanding the causes helps managers design and develop strategies to counter it.[5]

Demand Forecast Updating

Every company in a supply chain usually does product forecasting for its production scheduling, capacity planning, inventory control, and material requirements planning. Forecasting is often based on the order history from the company's immediate customers. The outcomes of the beer game are the consequence of many behavioral factors, such as the players' perceptions and mistrust. An important factor is each player's thought process in projecting the demand pattern based on what he or she observes. When a downstream operation places an order, the upstream manager processes that piece of information as a signal about future product demand. Based on this signal, the upstream manager readjusts his or her demand forecasts and, in turn, the orders placed with the suppliers of the upstream operation. We contend that demand signal processing is a major contributor to the bullwhip effect.

For example, if you are a manager who has to determine how much to order from a supplier, you use a simple method to do demand forecasting, such as exponential smoothing. With exponential smoothing, future demands are continuously updated as the new daily demand data become available. The order you send to the supplier reflects the amount you need to replenish the stocks to meet the requirements of future demands, as well as the necessary safety stocks. The future demands and the associated safety stocks are updated using the smoothing technique. With long lead times, it is not uncommon to have weeks of safety stocks. The result is that the fluctuations in the order quantities over time can be much greater than those in the demand data.

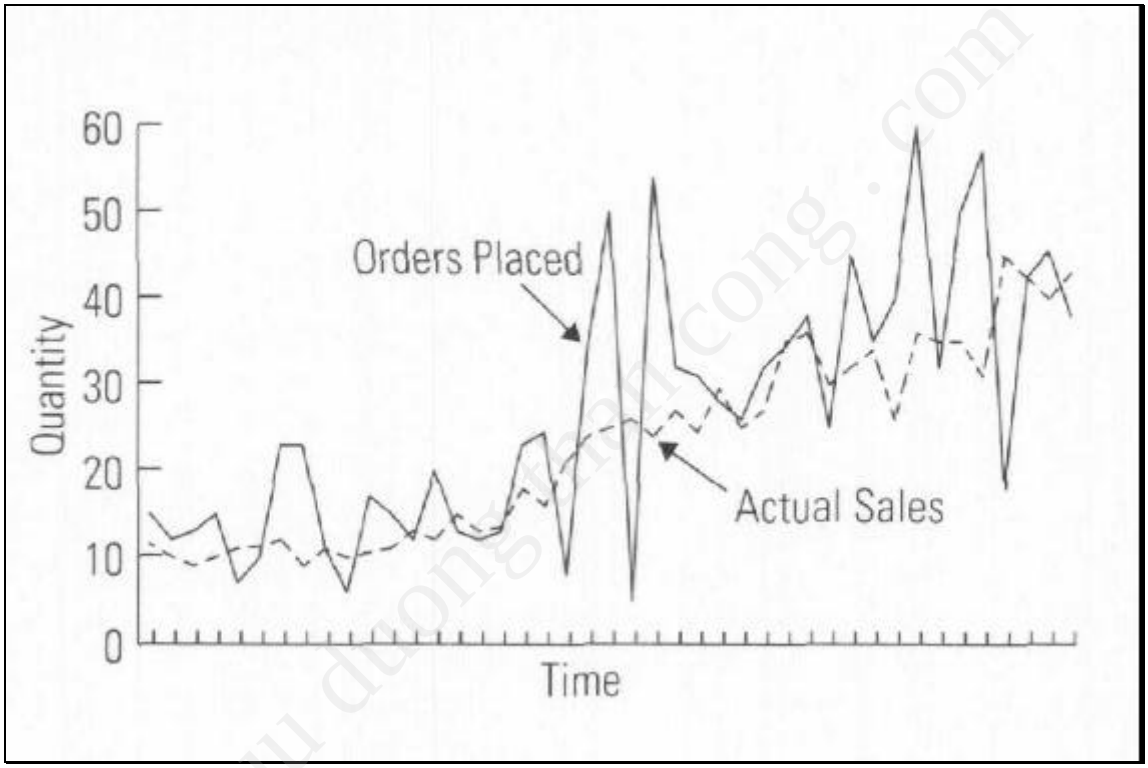
Now, one site up the supply chain, if you are the manager of the supplier, the daily orders from the manager of the previous site constitute your demand. If you are also using exponential smoothing to update your forecasts and safety stocks, the orders that you place with your supplier will have even bigger swings. For an example of such fluctuations in demand, see Figure 2. As we can see from the figure, the orders placed by the dealer to the manufacturer have much greater variability than the

consumer demands. Because the amount of safety stock contributes to the bullwhip effect, it is intuitive that, when the lead times between the resupply of the items along the supply chain are longer, the fluctuation is even more significant.

Order Batching

In a supply chain, each company places orders with an upstream organization using some inventory monitoring or control. Demands come in, depleting inventory, but the company may not immediately place an order with its supplier. It often batches or accumulates demands before issuing an order. There are two forms of order batching: periodic ordering and push ordering.

Figure 2 Higher Variability in Orders from Dealer to Manufacturer than Actual Sales



Instead of ordering frequently, companies may order weekly, biweekly, or even monthly. There are many common reasons for an inventory system based on order cycles. Often the supplier cannot handle frequent order processing because the time and cost of processing an order can be substantial. P&G estimated that, because of the many manual interventions needed in its order, billing, and shipment systems, each invoice to its customers cost between $35 and $75 to process.' Many manufacturers place purchase orders with suppliers when they run their material requirements planning (MRP) systems. MRP systems are often run monthly, resulting in monthly ordering with suppliers. A company with slow-moving items may prefer to order on a regular cyclical basis because there may not be enough items consumed to warrant resupply if it orders more frequently.

Consider a company that orders once a month from its supplier. The supplier faces a highly erratic stream of orders. There is a spike in demand at one time during the month, followed by no demands for the rest of the month. Of course, this variability is higher than the demands the company itself faces. Periodic ordering amplifies variability and contributes to the bullwhip effect.

One common obstacle for a company that wants to order frequently is the economics of transportation. There are substantial differences between full truckload (FTL) and less-than-truckload rates, so companies have a strong incentive to fill a truckload when they order materials from a supplier. Sometimes, suppliers give their best pricing for FTL orders. For most items, a full truckload could be a supply of a month or more. Full or close to full truckload ordering would thus lead to moderate to excessively long order cycles.

In push ordering, a company experiences regular surges in demand. The company has orders "pushed" on it from customers periodically because salespeople are regularly measured, sometimes quarterly or annually, which causes end-of-quarter or end-of-year order surges. Salespersons who need to fill sales quotas may "borrow" ahead and sign orders prematurely. The U.S. Navy's study of recruiter productivity found surges in the number of recruits by the recruiters on a periodic cycle that coincided with their evaluation cycle.[7] For companies, the ordering pattern from their customers is more erratic than the consumption patterns that their customers experience. The "hockey stick" phenomenon is quite prevalent.

When a company faces periodic ordering by its customers, the bullwhip effect results. If all customers' order cycles were spread out evenly throughout the week, the bullwhip effect would be minimal. The periodic surges in demand by some customers would be insignificant because not all would be ordering at the same time. Unfortunately, such an ideal situation rarely exists. Orders are more likely to be randomly spread out or, worse, to overlap. When order cycles overlap, most customers that order periodically do so at the same time. As a result, the surge in demand is even more pronounced, and the variability from the bullwhip effect is at its highest.

If the majority of companies that do MRP or distribution requirement planning (DRP) to generate purchase orders do so at the beginning of the month (or end of the month), order cycles overlap. Periodic execution of MRPs contributes to the bullwhip effect, or "MRP jitters" or "DRP jitters."

Price Fluctuation

Estimates indicate that 80 percent of the transactions between manufacturers and distributors in the grocery industry were made in a "forward buy" arrangement in which items were bought in advance of requirements, usually because of a manufacturer's attractive price offer.[8] Forward buying constitutes $75 billion to $100 billion of inventory in the grocery industry.

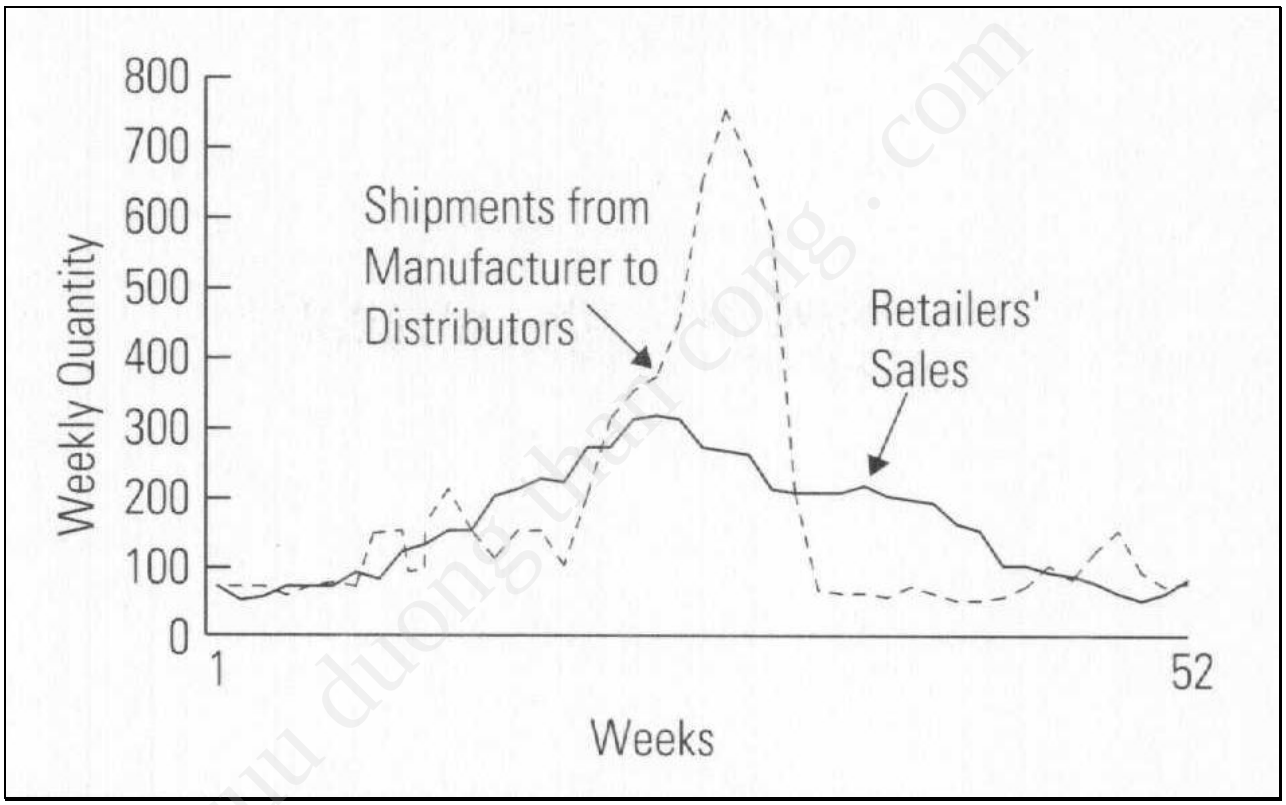
Forward buying results from price fluctuations in the marketplace. Manufacturers and distributors periodically have special promotions like price discounts, quantity discounts, coupons, rebates, and so on. All these promotions result in price fluctuations. Additionally, manufacturers offer trade deals (e.g., special discounts, price terms, and payment terms) to the distributors and wholesalers, which are an indirect form of price discounts. For example, Kotler reports that trade deals and consumer promotion constitute 47 percent and 28 percent, respectively, of their total promotion budgets.[10] The result is that customers buy in quantities that do not reflect their immediate needs; they buy in bigger quantities and stock up for the future.

Such promotions can be costly to the supply chain.[11] What happens if forward buying becomes the norm? When a product's price is low (through direct discount or promotional schemes), a customer buys in bigger quantities than needed. When the product's price returns to normal, the customer stops buying until it has depleted its inventory As a result, the customer's buying pattern does not reflect its consumption pattern, and the variation of the buying quantities is much bigger than the variation of the consumption rate - the bullwhip effect.

When high-low pricing occurs, forward buying may well be a rational decision. If the cost of holding inventory is less than the price differential, buying in advance makes sense. In fact, the high-low pricing phenomenon has induced a stream of research on how companies should order optimally to take advantage of the low price opportunities.

Although some companies claim to thrive on high-low buying practices, most suffer. For example, a soup manufacturer's leading brand has seasonal sales, with higher sales in the winter (see Figure 3). However, the shipment quantities from the manufacturer to the distributors, reflecting orders from the distributors to the manufacturer, varied more widely. When faced with such wide swings, companies often have to run their factories overtime at certain times and be idle at others. Alternatively, companies may have to build huge piles of inventory to anticipate big swings in demand. With a surge in shipments, they may also have to pay premium freight rates to transport products. Damage also increases from handling larger than normal volumes and stocking inventories for long periods. The irony is that these variations are induced by price fluctuations that the manufacturers and the distributors set up themselves. It's no wonder that such a practice was called "the dumbest marketing ploy ever."[12]

Figure 3 Bullwhip Effect due to Seasonal Sales of Soup



Using trade promotions can backfire because of the impact on the manufacturers' stock performance. A group of shareholders sued Bristol-Myers Squibb when its stock plummeted from $74 to $67 as a result of a disappointing quarterly sales performance; its actual sales increase was only 5 percent instead of the anticipated 13 percent. The sluggish sales increase was reportedly due to the company's trade deals in a previous quarter that flooded the distribution channel with forward-buy inventories of its product.[13]

Rationing and Shortage Gaming

When product demand exceeds supply, a manufacturer often rations its product to customers. In one scheme, the manufacturer allocates the amount in proportion to the amount ordered. For example, if the total supply is only 50 percent of the total demand, all customers receive 50 percent of what they order. Knowing that the manufacturer will ration when the product is in short supply, customers exaggerate their real needs when they order. Later, when demand cools, orders will suddenly disappear and cancellations pour in. This seeming overreaction by customers anticipating shortages results when organizations and individuals make sound, rational economic decisions and "game" the potential rationing.[14] The effect of

"gaming" is that customers' orders give the supplier little information on the product's real demand, a particularly vexing problem for manufacturers in a products early stages. The gaming practice is very common. In the 1980s, on several occasions, the computer industry perceived a shortage of DRAM chips. Orders shot up, not because of an increase in consumption, but because of anticipation. Customers place duplicate orders with multiple suppliers and buy from the first one that can deliver, then cancel all other duplicate orders.[15]

More recently, Hewlett-Packard could not meet the demand for its LaserJet III printer and rationed the product. Orders surged, but HP managers could not discern whether the orders genuinely reflected real market demands or were simply phantom orders from resellers trying to get better allocation of the product. When HP lifted its constraints on resupply of the LaserJets, many resellers canceled their orders. HP's costs in excess inventory after the allocation period and in unnecessary capacity increases were in the millions of dollars.[16]

During the Christmas shopping seasons in 1992 and 1993, Motorola could not meet consumer demand for handsets and cellular phones, forcing many distributors to turn away business. Distributors like AirTouch Communications and the Baby Bells, anticipating the possibility of shortages and acting defensively, drastically over ordered toward the end of 1994.[17] Because of such overzealous ordering by retail distributors, Motorola reported record fourth-quarter earnings in January 1995. Once Wall Street realized that the dealers were swamped with inventory and new orders for phones were not as healthy before, Motorola's stock tumbled almost 10 percent.

In October 1994, IBM's new Aptiva personal computer was selling extremely well, leading resellers to speculate that IBM might run out of the product before the Christmas season. According to some analysts, IBM, hampered by an overstock problem the previous year, planned production too conservatively. Other analysts referred to the possibility of rationing: "Retailers - apparently convinced Aptiva will sell well and afraid of being left with insufficient stock to meet holiday season demand -- increased their orders with IBM, believing they wouldn't get all they asked for."" It was unclear to IBM how much of the increase in orders was genuine market demand and how much was due to resellers placing phantom orders when IBM had to ration the product.

How to Counteract the Bullwhip Effect

Understanding the causes of the bullwhip effect can help managers find strategies to mitigate it. Indeed, many companies have begun to implement innovative programs that partially address the effect. Next we examine how companies tackle each of the four causes. We categorize the various initiatives and other possible remedies based on the underlying coordination mechanism, namely, information sharing, channel alignment, and operational efficiency. With information sharing, demand information at a downstream site is transmitted upstream in a timely fashion. Channel alignment is the coordination of pricing, transportation, inventory planning, and ownership between the upstream and downstream sites in a supply chain. Operational efficiency refers to activities that improve performance, such as reduced costs and lead-time. We use this topology to discuss ways to control the bullwhip effect (see Table 1).

Avoid Multiple Demand Forecast Updates

Ordinarily, every member of a supply chain conducts some sort of forecasting in connection with its planning (e.g., the manufacturer does the production planning, the wholesaler, the logistics planning, and so on). Bullwhip effects are created when supply chain members process the demand input from their immediate downstream member in producing their own forecasts. Demand input from the immediate downstream member, of course, results from that member's forecasting, with input from its own downstream member.

One remedy to the repetitive processing of consumption data in a supply chain is to make demand data at a downstream site available to the upstream site. Hence, both sites can update their forecasts with the

same raw data In the computer industry, manufacturers request sell-through data on withdrawn stocks from their resellers' central warehouse. Although the data are not as complete as point-of-sale (POS) data from the resellers' stores, they offer significantly more information than was available when manufacturers didn't know what happened after they shipped their products. IBM, HP, and Apple all require sell-through data as part of their contract with resellers.

Supply chain partners can use electronic data interchange (EDI) to share data. In the consumer products industry, 20 percent of orders by retailers of consumer products was transmitted via EDI in 1990.[1] In 1992, that figure was close to 40 percent and, in 1995, nearly 60 percent. The increasing use of EDI will undoubtedly facilitate information transmission and sharing among chain members. Even if the multiple organizations in a supply chain use the same source demand data to perform forecast updates, the differences in forecasting methods and buying practices can still lead to unnecessary fluctuations in the order data placed with the upstream site. In a more radical approach, the upstream site could control resupply from upstream to downstream. The upstream site would have access to the demand and inventory information at the downstream site and update the necessary forecasts and resupply for the downstream site. The downstream site, in turn, would become a passive partner in the supply chain. For example, in the consumer products industry, this practice is known as vendor-managed inventory (VMI) or a continuous replenishment program (CRP). Many companies such as Campbell Soup, M&M/Mars, Nestle, Quaker Oats, Nabisco, P&G, and Scott Paper use CRP with some or most of their customers. Inventory reductions of up to 25 percent are common in these alliances. P&G uses VMI in its diaper supply chain, starting with its supplier, 3M, and its customer, Wal-Mart. Even in the high-technology sector, companies such as Texas Instruments, HP Motorola, and Apple use VMI with some of their suppliers and, in some cases, with their customers.

Inventory researchers have long recognized that multi-echelon inventory systems can operate better when inventory and demand information from downstream sites is available upstream. Echelon inventory - the total inventory at its upstream and downstream sites - is key to optimal inventory control."

Another approach is to try to get demand information about the downstream site by bypassing it. Apple Computer has a "consumer direct" program, i.e., it sells directly to consumers without going through the reseller and distribution channel. A benefit of the program is that it allows Apple to see the demand patterns for its products. Dell Computers also sells its products directly to consumers without going through the distribution channel.

Finally, as we noted before, long resupply lead times can aggravate the bullwhip effect. Improvements in operational efficiency can help reduce the highly variable demand due to multiple forecast updates. Hence, just-in-time replenishment is an effective way to mitigate the effect.

Break Order Batches

Since order batching contributes to the bullwhip effect, companies need to devise strategies that lead to smaller batches or more frequent resupply. In addition, the counterstrategies we described earlier are useful. When an upstream company receives consumption data on a fixed, periodic schedule from its downstream customers, it will not be surprised by an unusually large batched order when there is a demand surge.

One reason that order batches are large or order frequencies low is the relatively high cost of placing an order and replenishing it. EDI can reduce the cost of the paperwork in generating an order. Using EDI, companies such as Nabisco perform paperless, computer-assisted ordering (CAO), and, consequently, customers order more frequently. McKesson's Economost ordering system uses EDI to lower the transaction costs from orders by drugstores and other retailers." P&G has introduced standardized ordering terms across all business units to simplify the process and dramatically cut the number of invoices.[22] And General Electric is electronically matching buyers and suppliers throughout the company.

It expects to purchase at least $1 billion in materials through its internally developed Trading Process Network. A paper purchase order that typically cost $50 to process is now $5.23

Table 1 A Framework for Supply Chain Coordination Initiatives

Causes of Bullwhip	Information Sharing	Channel Alignment	Operational Efficiency
Demand Forecast Update	• Understanding system dynamics • Use point-of-sale (POS) data • Electronic data interchange (EDI) • Internet • Computer-assisted ordering (CAO)	• Vendor-managed inventory (VMI) • Discount for information sharing • Consumer direct	• Lead-time reduction • Echelon-based inventory control
Order Batching	• EDI • Internet ordering	• Discount for truckload assortment • Delivery appointments • Consolidation • Logistics outsourcing	• Reduction in fixed cost of ordering by EDI or electronic commerce • CAO
Price Fluctuations		• Continuous replenishment program (CRP) • Everyday low cost (EDLC)	• Everyday low price (EDLP) • Activity-based costing (ABC)
Shortage Gaming	• Sharing sales, capacity, and inventory data	• Allocation based on past sales	

Another reason for large order batches is the cost of transportation. The differences in the costs of full truckloads and less-than-truckloads are so great that companies find it economical to order full truckloads, even though this leads to infrequent replenishments from the supplier. In fact, even if orders are made with little effort and low cost through EDI, the improvements in order efficiency are wasted due to the full truckload constraint. Now some manufacturers induce their distributors to order assortments of different products. Hence a truckload may contain different products from the same manufacturer (either a plant warehouse site or a manufacturer's market warehouse) instead of a full load of the same product.

The effect is that, for each product, the order frequency is much higher, the frequency of deliveries to the distributors remains unchanged, and the transportation efficiency is preserved. P&G has given discounts to distributors that are willing to order mixed-SKU (stock-keeping unit) loads of any of its products." Manufacturers could also prepare and ship mixed SKUs to the distributors' warehouses that are ready to deliver to the stores.

"Composite distribution" for fresh produce and chilled products uses the same mixed-SKU concept to make resupply more frequent. Since fresh produce and chilled foods need to be stored at different temperatures, trucks to transport them need to have various temperatures. British retailers like Tesco and Sainsbury use trucks with separate compartments at different temperatures so that they can transport many products on the same truck.[25]

The use of third-party logistics companies also helps make small batch replenishments economical. These companies allow economies of scale that were not feasible in a single supplier-customer relationship. By consolidating loads from multiple suppliers located near each other, a company can realize full truckload economies without the batches coming from the same supplier. Of course, there are additional handling and administrative costs for such consolidations or multiple pickups, but the savings often outweigh the costs.

Similarly, a third-party logistics company can utilize a truckload to deliver to customers who may be competitors, such as neighboring supermarkets. If each customer is supplied separately via full truckloads, using third-party logistics companies can mean moving from weekly to daily replenishments. For small customers whose volumes do not justify frequent full truckload replenishments independently, this is especially appealing. Some grocery wholesalers that receive FTL shipments from manufacturers and then ship mixed loads to wholesalers' independent stores use logistics companies. In the United Kingdom, Sainsbury and Tesco have long used National Freight Company for logistics. As a result of the heightened awareness due to the ECR initiative in the grocery industry, we expect to see third-party logistics companies that forecast orders, transport goods, and replenish stores with mixed-SKU pallets from the manufacturers.

When customers spread their periodic orders or replenishments evenly over time, they can reduce the negative effect of batching. Some manufacturers coordinate their resupply with their customers. For example, P&G coordinates regular delivery appointments with its customers. Hence, it spreads the replenishments to all the retailers evenly over a week.

Stabilize Prices

The simplest way to control the bullwhip effect caused by forward buying and diversions is to reduce both the frequency and the level of wholesale price discounting. The manufacturer can reduce the incentives for retail forward buying by establishing a uniform wholesale pricing policy. In the grocery industry, major manufacturers such as P&G, Kraft, and Pillsbury have moved to an everyday low price (EDLP) or value pricing strategy. During the past three years, P&G has reduced its list prices by 12 percent to 24 percent and aggressively slashed the promotions it offers to trade customers. In 1994, P&G reported its highest profit margins in twenty-one years and showed increases in market share.[27] Similarly, retailers and distributors can aggressively negotiate with their suppliers to give them everyday low cost (EDLC). From 1991 to 1994, the percentage of trade deals in the total promotion budget of grocery products dropped from 50 percent to 47 percent.

From an operational perspective, practices such as CRP together with a rationalized wholesale pricing policy can help to control retailers' tactics, such as diversion. Manufacturers' use of CAO for sending orders also minimizes the possibility of such a practice.

Activity-based costing (ABC) systems enable companies to recognize the excessive costs of forward buying and diversions. When companies run regional promotions, some retailers buy in bulk in the area

where the promotions are held, then divert the products to other regions for consumption. The costs of such practices are huge but may not show up in conventional accounting systems. ABC systems provide explicit accounting of the costs of inventory, storage, special handling, premium transportation, and so on that previously were hidden and often outweigh the benefits of promotions. ABC therefore helps companies implement the EDLP strategy.[28]

Eliminate Gaming in Shortage

Situations When a supplier faces a shortage, instead of allocating products based on orders, it can allocate in proportion to past sales records. Customers then have no incentive to exaggerate their orders. General Motors has long used this method of allocation in cases of short supply, and other companies, such as Texas Instruments and Hewlett-Packard, are switching to it.

"Gaming" during shortages peaks when customers have little information on the manufacturers' supply situation. The sharing of capacity and inventory information helps to alleviate customers' anxiety and, consequently, lessen their need to engage in gaming. But sharing capacity information is insufficient when there is a genuine shortage. Some manufacturers work with customers to place orders well in advance of the sales season. Thus they can adjust production capacity or scheduling with better knowledge of product demand.

Finally, the generous return policies that manufacturers offer retailers aggravate gaming. Without a penalty, retailers will continue to exaggerate their needs and cancel orders. Not surprisingly, some computer manufacturers are beginning to enforce more stringent cancellation policies.

We contend that the bullwhip effect results from rational decision making by members in the supply chain. Companies can effectively counteract the effect by thoroughly understanding its underlying causes. Industry leaders like Procter & Gamble are implementing innovative strategies that pose new challenges: integrating new information systems, defining new organizational relationships, and implementing new incentive and measurement systems. The choice for companies is clear: either let the bullwhip effect paralyze you or find a way to conquer it.

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Reprint 3837

Authors

Hau L. Lee is the Kleiner Perkins, Mayfield, Sequoia Capital Professor in Industrial Engineering and Engineering Management, and professor of operations management at the Graduate School of Business, Stanford University.

V Padmanabhan is an associate professor of marketing, and

Seungjin Whang is an associate professor of operations information and technology, also at Stanford.