Contents lists available at GrowingScience

Journal of Future Sustainability

homepage: www.GrowingScience.com/jfs

The bullwhip effect in supply chains: Review of recent development

Elham Rafati[a*]

[a]*Department of Mechanical & Industrial Engineering, Toronto Metropolitan University, Canada*

C H R O N I C L E

Article history:
Received: January 2, 2022
Received in revised format: June 18, 2022
Accepted: August 15, 2022
Available online: September 15, 2022

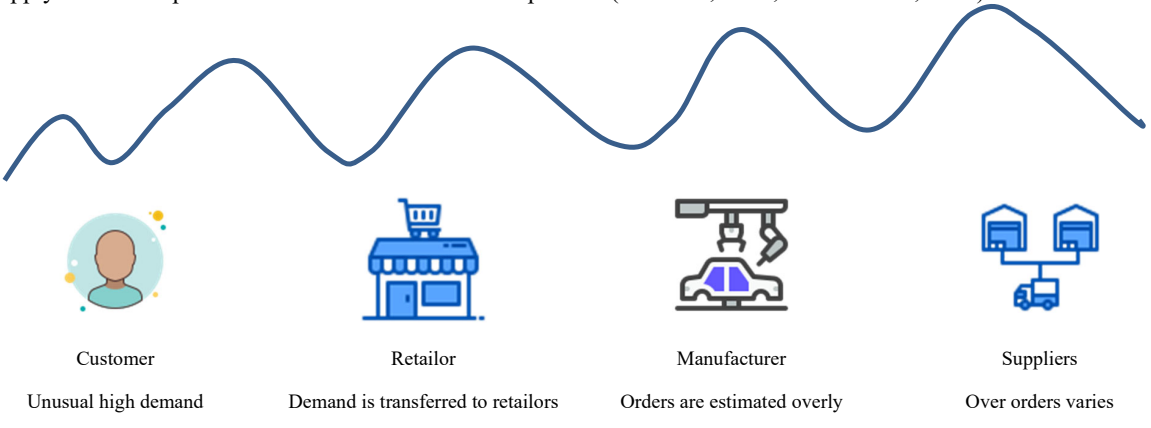
Keywords:
Bullwhip effect
Supply chain
Demand variability
Supply chain disruption

A B S T R A C T

The bullwhip effect happens whenever the demand order fluctuations in the supply chain (SC) escalate as they are transferred up the SC. In fact, a small change in point-of-sale demand may be interpreted by SC participants as a much bigger variability in demand. This looks like a cracking a whip, where a small flick of the wrist may yield a large motion at the end of the whip. Misstate data from one side of a SC to the other part may yield substantial sloppiness. This includes increase in inventories, shortage of cash flow, weak customer satisfaction, etc. Enterprises may efficiently reduce the bullwhip effect by completely learning its root causes. This paper presents an overview on the concept and recent development of the bullwhip effect.

1. Introduction

During the past few years, supply chain disruption has become a main reason for global recession. The shortage of chip demand has created chaos in many industries such as automakers, hardware producers, etc. On the other hand, the zero-covid policy in China has interrupted shipment of goods from this country to all over the world. An immediate consequence of supply chain disruption is associated with the bullwhip effect (Forrester, 1961; de Kok et al., 2005).



Logistics experts in an American firm, Procter & Gamble (P&G), studied the order policy for one of their best-selling commodities, Pampers, whose sales figures were fluctuating. They looked at the distributors' orders and were surprised by the degree of fluctuation. When they looked at the orders of materials to their suppliers, they realized that the trends were

* Corresponding author.
E-mail address: erafati@ryerson.ca (E. Rafati)

ISSN 2816-8151 (Online) - ISSN 2816-8143 (Print)

doi: 10.5267/j.jfs.2022.9.007

even larger. While the variabilities were small, the demand order variabilities in the SC were bigger as they moved up the SC and this phenomenon was later called the "bullwhip" effect (Lee et al., 1997; Giard & Sali, 2013).

Fig. 1. Increasing volatility or orders up to suppliers

Fig. 1 shows the volatilities of demand and bullwhip effects in the supply chain. As we can observe from the figure, there are some high volatilities in the middle of the time span. When an order is placed by customers, there may be a small change on customers' orders. The orders are then sent from retailers to manufacturers. The volatilities are shown bigger when orders are transferred from wholesalers to manufacturers and from manufacturers to suppliers (Ouyang & Li, 2010). Moving up the SC from end-consumer to raw materials supplier, each SC participant has a bigger variation in demand and therefore bigger requirement for safety stock. When demand rises, down-stream participants also add to their orders and, vice versa, in the event of demand reduction, orders go down, thereby not reducing inventory (Hoberg & Thonemann, 2014).

2. The causes of bullwhip effects

There are several reasons behind bullwhip effects such as lack of good communication, free return policy, order batching, demand information, etc. (Lee et al., 1997). Human behavior in the supply chain is blamed to be the main reason for the bullwhip effect (Disney, 2008; Hoberg & Thonemann, 2014; Udenio et al., 2017; Yang; Metters, 1997) determined the effect of the bullwhip in the supply chain by building a lower bound on the profitability effect of the bullwhip in the supply chain. The results indicated that the magnitude of the bullwhip effect to a firm varies primarily based on the specific business environment and it can change from 10 to 30 percent. Sucky (2009) reported that the bullwhip effect could be overestimated whenever just a simple supply chain were assumed and risk pooling effects were present. Nevertheless, measuring the bullwhip effect plays an essential role for business development (Fransoo & Wouters, 2000).

Forecasting is normally applied by looking into the historical order data from the firm's present customers (Bhattacharya & Bandyopadhyay, 2011). Once a downstream part of SC sends an order, the upstream part of SC processes that part of data as a signal for future demand. Based on this signal, the upstream manager readjusts the demand forecasts, and, in turn, the orders are dispatched with the suppliers of the upstream side and the demand signal is blamed as a major contributor to the bullwhip effect. For instance, if we plan to decide how much to order from a particular supplier, we normally apply some method to do demand prediction, such as exponential smoothing which updates the future demands continuously as the new daily demand data becomes available. The order we send to the supplier reflects the amount we require to refill the stocks to reach the future demands and the necessary safety stocks. The forecasted demands and the safety stocks are updated using the smoothing technique. When the lead times are long, it is often to face weeks of safety stocks and this yields trouble making a bullwhip effect (Lee et al., 1997). During the past few years, there have been tremendous efforts on proposing new techniques for forecasting demand. Jaipuria and Mahapatra (2014), for instance used discrete wavelet transforms analysis and artificial neural network as a hybrid improved demand forecasting method to reduce bullwhip effect in supply chains. Luong (2007) proposed another method to measure bullwhip effect in SC with autoregressive demand process. Barlas and Gunduz (2011) proposed another technique for demand forecasting and sharing various strategies to reduce demand variations and the bullwhip effect in SC. Duc et al. (2008) provided a tool of bullwhip effect in SC with a mixed autoregressive-moving average demand process. Luong and Phien (2007) discussed different measures of bullwhip effect in SC using the case of high order autoregressive demand process. Hofmann (2017) studied the role of big data and SC decisions in terms of the effects of volume, variety and velocity properties on the bullwhip effect.

The other problem causing the bullwhip effect is associated with order batching, which are in the forms of either periodic ordering or push ordering. Price fluctuation and Forward buying are other important factors causing the bullwhip effect. Every year over 100$ billion dollars of funds are held on forward buying. Amazon is one of the well reputed fortune 500 companies that handles bullwhip effect effectively. The firm normally uses data mining techniques to determine where customers are possibly interested in their products and services and keep some orders in advance. This helps the firm to handle any sudden and uneven demands, promptly.

Dejonckheere et al. (2004) investigated the advantage of information sharing (SI) in multi-echelon SC. They compared a traditional SC, in which only the first stage in the chain considers end consumer demand and upstream stages ought to base

their own forecasts on incoming orders, with an information enriched SC where customer demand data was shared throughout the chain. They explained that SI was essential to reduce order variance at higher levels of the chain. Disney and Lambrecht (2008) provided more comprehensive discussions on replenishment rules, forecasting, and the bullwhip effects in supply chains.

Paik and Bagchi (2007) studied the effect of each of the causes of the bullwhip effect and determined which one has relatively more effects on the variability of orders in SC. They reported six most important factors as demand forecast updating, order batching, material delays, information delays, purchasing delays and level of echelons. Similar to many studies, demand forecast updating, level of echelons, and price variations were the three most important factors. Chen et al. (2000) studied the effects of forecasting, lead times, and information on bullwhip effects. Dominguez et al. (2015) studied the effects of the supply chain structure on bullwhip effect. They explained that under an immediate shock in market demand, the number of nodes and the divergence of the SC network may influence the SC performance. Ouyang (2007) investigated the impact of SI on SC stability and the bullwhip effect. They explained that sharing customer demand information across the chain may substantially reduce the bullwhip effect but may not necessarily eliminate it. Machuca and Barajas (2004) investigated the effect of electronic data interchange on alleviating bullwhip effect and SC inventory costs.

3. Methods of reduction in bullwhip effects

There is no doubt that bullwhip affects the entitle supply chain very badly. However, the bullwhip effects can be reduced through different methods such as applying a good forecasting method, information sharing, human resource management, etc. Lee et al. (1997) gave some suggestions for improving the bullwhip effects. Table 1 is adopted from their survey with some more contributions.

Table 1
A framework for supply chain coordination initiatives

Causes of Bullwhip effect	Information sharing	Channel alignment	Operational efficiency
Demand forecast method and procedures	• Use metaverse • Use point of sale (POS) data • Electronic data exchange • Internet and Intranet • Computer aided ordering • Enterprise resource planning	• Vendor managed inventory (VMI) • Information sharing • Direct communication with consumers	• Lead time reduction • Echelon based inventory control
Order batching	• Electronic data exchange • Internet ordering	• More collaboration on logistics systems • Demand consolidation	• Fix cost reduction in ordering system • Computer assisted ordering
Price variations		• Continuous forecast	• Every day low price system

4. Conclusion

This survey has shown that forecasting methods play an essential role for bullwhip effect reduction. During the past few years, there have been tremendous developments in data processing techniques. Now it is possible to study the clients' behavior through point of sales systems, credit card purchase systems, debit cards, etc. These techniques help us determine where clients are located, how often they order and how to make the pay for their purchases. During the past two decades, there have also been tremendous developments in enterprise resource planning, which would help manage the entire supply chain. There are still many unexpected events in the world which would not be expected through forecasting methods. The Covid-19 was one of the biggest issues which influenced the world economy. The Russian-Ukraine war was another trouble-making event which influenced the supply chain. Management of big enterprises are also recommended to follow political changes in the world to have a better understanding on what could happen in the world. In the past, there were some fictions which predicted Covid-19 years before and maybe some undesirable events could be predicted in other fiction stories. Therefore, the managers of the new millennium are suggested to have a better understanding on what would happen in the world.

References

Barlas, Y., & Gunduz, B. (2011). Demand forecasting and sharing strategies to reduce fluctuations and the bullwhip effect in supply chains. *Journal of the Operational Research Society*, *62*(3), 458-473.

Bhattacharya, R., & Bandyopadhyay, S. (2011). A review of the causes of bullwhip effect in a supply chain. *The International Journal of Advanced Manufacturing Technology*, *54*(9), 1245-1261.

Chen, F., Drezner, Z., Ryan, J. K., & Simchi-Levi, D. (2000). Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information. *Management science*, *46*(3), 436-443.

de Kok, T., Janssen, F., Van Doremalen, J., Van Wachem, E., Clerkx, M., & Peeters, W. (2005). Philips electronics synchronizes its supply chain to end the bullwhip effect. *Interfaces*, *35*(1), 37-48.

Dejonckheere, J., Disney, S. M., Lambrecht, M. R., & Towill, D. R. (2004). The impact of information enrichment on the bullwhip effect in supply chains: A control engineering perspective. *European journal of operational research*, *153*(3), 727-750.

Disney, S. M. (2008). Supply chain aperiodicity, bullwhip and stability analysis with Jury's inners. *IMA Journal of Management Mathematics*, *19*(2), 101-116.

Disney, S. M., & Lambrecht, M. R. (2008). On replenishment rules, forecasting, and the bullwhip effect in supply chains. *Foundations and Trends® in Technology, Information and Operations Management*, *2*(1), 1-80.

Dominguez, R., Cannella, S., & Framinan, J. M. (2015). The impact of the supply chain structure on bullwhip effect. *Applied Mathematical Modelling*, *39*(23-24), 7309-7325.

Duc, T. T. H., Luong, H. T., & Kim, Y. D. (2008). A measure of bullwhip effect in supply chains with a mixed autoregressive-moving average demand process. *European Journal of Operational Research*, *187*(1), 243-256.

Forrester, J. W. (1961). *Industrial Dynamics*. MIT Press.

Fransoo, J. C., & Wouters, M. J. (2000). Measuring the bullwhip effect in the supply chain. *Supply Chain Management: An International Journal*, *5*(2), 78-89.

Giard, V., & Sali, M. (2013). The bullwhip effect in supply chains: a study of contingent and incomplete literature. *International Journal of Production Research*, *51*(13), 3880-3893.

Hoberg, K., & Thonemann, U. W. (2014). Modeling and analyzing information delays in supply chains using transfer functions. *International Journal of Production Economics*, *156*, 132-145.

Hofmann, E. (2017). Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect. *International Journal of Production Research*, *55*(17), 5108-5126.

Jaipuria, S., & Mahapatra, S. S. (2014). An improved demand forecasting method to reduce bullwhip effect in supply chains. *Expert Systems with Applications*, *41*(5), 2395-2408.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). The bullwhip effect in supply chains. *Sloan management review*, *38*, 93-102.

Luong, H. T. (2007). Measure of bullwhip effect in supply chains with autoregressive demand process. *European Journal of Operational Research*, *180*(3), 1086-1097.

Luong, H. T., & Phien, N. H. (2007). Measure of bullwhip effect in supply chains: The case of high order autoregressive demand process. *European Journal of Operational Research*, *183*(1), 197-209.

Machuca, J. A., & Barajas, R. P. (2004). The impact of electronic data interchange on reducing bullwhip effect and supply chain inventory costs. *Transportation Research Part E: Logistics and Transportation Review*, *40*(3), 209-228.

Metters, R. (1997). Quantifying the bullwhip effect in supply chains. *Journal of operations management*, *15*(2), 89-100.

Ouyang, Y. (2007). The effect of information sharing on supply chain stability and the bullwhip effect. *European Journal of Operational Research*, *182*(3), 1107-1121.

Ouyang, Y., & Li, X. (2010). The bullwhip effect in supply chain networks. *European Journal of Operational Research*, *201*(3), 799-810.

Paik, S. K., & Bagchi, P. K. (2007). Understanding the causes of the bullwhip effect in a supply chain. *International Journal of Retail & Distribution Management*, *35*(4), 308-324.

Sucky, E. (2009). The bullwhip effect in supply chains—An overestimated problem?. *International Journal of Production Economics*, *118*(1), 311-322.

Udenio, M., Vatamidou, E., Fransoo, J. C., & Dellaert, N. (2017). Behavioral causes of the bullwhip effect: An analysis using linear control theory. *Iise Transactions*, *49*(10), 980-1000.

Yang, Y., Lin, J., Liu, G., & Zhou, L. (2021). The behavioural causes of bullwhip effect in supply chains: A systematic literature review. *International Journal of Production Economics*, *236*, 108120.