



Bullwhip effect for all? Non-sensitive supply chains

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Abstract: bullwhip effect (BWE) is a phenomenon that is highly in focus due to the impact on supply chain performance and financial results. It is necessary to keep focus on the phenomenon, but the cases need to be determined when investigation is relevant. The aim of this paper is the determination of the operational supply chain characteristics that makes the occurrence of the BWE less likely. This shows what are the attributes need to be checked to define if the examined chain or echelon is immune or not for the bullwhip effect. In this article the investigation is based on the triggering factors of the phenomenon. These causes are paired with the operational supply chain characteristics. Based on that we can define the key factors that are showing if the examined chain's operation is relevant or not for the occurrence of bullwhip effect. Beside the importance of tracking and elimination of the bullwhip effect we also need to consider that the phenomenon is not relevant for all product and supply chain type.

Keywords: bullwhip effect; supply chain performance; operational supply chain characteristics; bullwhip effect causes

1 Introduction

The bullwhip effect phenomenon is broadly researched in the scientific literature. The interest is not only significant from the academic perspective but also from the practical point. In the past 40 years several analyses researched the bullwhip effect but there is still no ready to use solution to avoid it. The business importance is mainly connected to the cost related impact that is generated as the consequence. The financial impact is not the only outcome, effective operation is also damaged. Indirectly this also result in further costs and improvement actions need to be initiated. Considering the current economic situation impacted highly by COVID'19 supply chain performance is crucial. Due the that, the efficient operation injured, and companies are still on the way back to normal operational performance.

The importance of the bullwhip effect phenomenon is indisputable in a typical supply chain. It is still worth to consider the question 'What makes a supply chain



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sensitive for bullwhip effect?'. The sensitivity is depending on the setup of the supply chain. The characteristics that are supporting the bullwhip- friendly environment need to be selected. This support to make the decision if the examination is relevant or not.

This article shows a literature review of the bullwhip effect focusing on the causes of the phenomenon. It also introduces the relevant supply chain characteristics. From the bullwhip effect perspective length of the supply chain, time need of the operation and the applied strategy is crucial.

To determine the cases that are not sensitive for the bullwhip effect we need to find connection between the causes of the phenomenon and the operational supply chain characteristics. This enables to define the non-sensitive chains.

2 Literature review

2.1 Bullwhip effect (BWE)

Due to the malfunctions faced in the supply chain when bullwhip effect occurs the analysis of the phenomenon is important. The research of the phenomenon has several approaches and directions. The main understanding of the phenomenon is still the same. The research of the phenomenon has long history. It was known as forrester effect based on the first researcher of the topic (J.W. Forrester, MIT Sloan School of Management). The term itself was defined in a 1997 study by Lee, Padmanabhan and Wang. From practical perspective the first recognition is attributed to Procter and Gamble. The scope of their analysis was the causeless fluctuation of the diaper demand and orders. The customer's needs were not explaining the level of variability. The phenomenon was also present at other sectors and companies. The authors phrased the upcoming definition: "the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e., demand distortion), and the distortion propagates upstream in an amplified form (i.e., variance amplification). (Lee et al., 1997, p546)" Other definition approaches from a different perspective. It defines based on the difference between customer demand and the produced quantities. "The effect by which slow moving consumer demand creates large swings in production for the suppliers at the other end of the supply chain." (Wang & Disney, 2016, p691) Financially the bullwhip effect becomes crucial once the fluctuation of production leads to higher cost than the inventory holding (Wang & Disney, 2016). The occurrence of the phenomenon is also influenced by the market environment. Competition also needs to be considered as a factor. In addition, the structure of the supply chain is also impactful from the BWE perspective (Xuluo, 2021).



The main causes behind have been stated by Lee et al as below (Lee et al., 1997):

- Demand signal processing: focus is on the retailer's level of the supply chain but applicable on the full chain. Supplier has difficulty with tracking appropriately the retailer's signals; the true demand pattern is not getting through the chain. As sub-reasons forecast related items are categorized here:
 - low level of forecast accuracy
 - low level of understanding of the market information
 - applied forecasting strategy
 - stock out handling process
 - missing learning approach
- Rationing game: products with limited supply order can exceed the real needs to secure availability. The starting point of the issue is typically the manufacturer, but all level of the chain is affected. Here we also can define sub-reasons:
 - number of supply chain members
 - missing transparency
 - missing synchronisation and control
 - local vs global approaches
 - fear of shortage (multiplicative impact)
- Order batching: can be caused by periodic review processes and the cost of the orders. Bullwhip effect can be result of different rules and strategies applied in the chain without proper harmonisation. The sub-reasons of order batching are as follows (Potter & Disney, 2006):
 - implemented lot size
 - required ordering timelines
 - lack of harmonisation of replenishment strategies
 - capacity limitations
- Price variation: supply chain resilience needs to be considered during the promotional planning. If the plans are not in line with the flexibility of the chain oscillation can happen. Below price related sub-reasons can be stated:
 - fluctuation of material price
 - fluctuation of finished goods price
 - unplanned and not properly planned promotions

These categories have been completed later with others, the most significant is lead time. Due to the long geographical distances keeping lead time as 0 became impossible in the typical cases. This lead time related information also need to be considered during the forecasting and replenishment process (Geary et al. 2006). Information sharing is also present in several approaches as reason of the bullwhip



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effect. This is hardly connected with the globalized supply chain concept. Even though, the impacts are realised on echelon level. The process is still driven by supply chain echelons and partner connections between them (Bhattacharya and Bandyopadhyay, 2010).

The consequences of the bullwhip effect can differ highly. It can lead to overstock some cases, but in other cases it can result in stock out situation. Both mentioned outcomes mean financial impact beside the decreased efficiency. This impact can be result of a lost sales opportunities as indirect cost or it can increase the warehousing cost directly. This financial impact can go through multiplicative impact in the chain. By the time manufacturing location is impacted the potential loss can grow significantly. This influence is not limited to the financial area. Distortion of the information is also significant; it endangers the efficient operation (Szegedi, 2012). The mentioned elements increase the uncertainty of the planning that can influence the accuracy as well. The expenses also appear due to production and transportation capacity utilisation (Warburton & Disney, 2007).

The co-operation is more challenging as today's supply chains are more likely considered as networks than chains. The idealised supply chain is characterised by transparent information flow, coordinated processes, and harmonised, common strategy. If these circumstances are present the bullwhip effect is less likely to happen. Nonetheless, from the realistic point in real-life surrounding these characteristics are limitedly available, and it is almost impossible to have all of them at the same time. Information sharing can support increased accuracy in the forecasting process. The problem is not solved by granting the high level of accuracy, but the level of oscillation can be limited. Lead time is also a key element to be checked. To have better control bottleneck points and processes need to be defined. As a result, uncertainty can decrease, and manageability of the processes can increase. Limitation of the impacts of the order batching related difficulties (batch size, timeline) is also increasing the level of control. Finally, harmonisation need to be more in focus in regards processes. If complete harmonisation is not possible compatible methods should be used (Towill et al, 2007).

2.2 Supply chain characteristics

The supply chain has several characteristics. It can be defined using multiple perspectives. It can consider for example the location or the industry. From a different view point it can consider the length of the supply chain (and the number of echelons) and the applied strategies. From the bullwhip effect perspective, it is crucial to work with the time and strategy perspective.

Supply chains became through the years complex and complicated networks with heterogenous cooperation models and operational characteristics. Connections are located all around the globe in different regions and industries. The complex networks generated are competing under these complex circumstances (Sun et al,



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2020). This setup is caused by the fierce competition of the market. Need of outsourcing of processes and adaptation of strategies. The consequence of this complex network and continuous adaptation to the market is greater risk of supply chain disruption (Chang, Lin, 2019).

This complexity has impact on the lead time. Supply networks are typically multiple echelons supply chains. Those are facing longer delivery time and greater uncertainty due to the complex outsourced processes. Longer lead time also impact the inventory level in the chain. It leads to increased stock level to cover the potential forecast error. Beside lead time, from vertical or horizontal cooperation, it more likely leads to disruptions (Chang, Lin, 2019).

Increased level of lead time also makes harder to respond on the disruption. Due to the distance in the chain real-time announcement of the disruption event cannot reach the supplier on time. This is due to the time needed by the supplier to physically fulfil the changed demand. At the end, due to the delayed reaction of the supplier the impact on customer can hardly be eliminated. In contrast shorter supply chains are shorter in replenishment time and more flexible in demand change. Early awareness of an event can be handled in a more agile way (Chang, Lin, 2019).

Lead time reduction play important role in reducing the probability of the bullwhip effect. It also reduces operational costs. The impact is the highest on the manufacturing and remanufacturing level (Lin et al., 2021).

Beside lead time and length of the supply chain applied strategy is also important. Supply chains typically operate with push or pull strategies. Mostly these strategies are not present on their own but on a mixed way. Still there is a lead concept applied in the supply chains. Main difference is on the serving of the customer. Push strategy uses the inventory to satisfy the customer demand. In contrast pull strategy uses the production to satisfy the demand. Push strategy is characterised by high-capacity utilisation but leads to higher inventory. Pull strategy required more flexibility in demand processes and manufacturing and may lead to long delivery lead time (Liu et al., 2020).

3 Methods and results

This article aims to show a possible way to decide if bullwhip effect is relevant or not. The sensitivity regarding the phenomenon can depend on the supply chain characteristics. These elements are determining the basic operational features of the supply chains. They also impact the essentials of the way of working.

To decide on sensitivity, bullwhip effect reasons need to be checked. The analysed information is showing the circumstances that are the characteristics of a bullwhip sensitive chain. To see the non-sensitive cases, the opposites need to be specified.



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For the deeper investigation the bullwhip effect reason groups are not detailed enough. It needs to be divided further into sub-reasons. As a result, it becomes more tangible, and realistic. The defined sub reasons are opposed with the supply chain characteristics. The opposition is based on the potential malfunctions generated by the given characteristics.

Beside the supply chain it turned out that the product itself also need to be considered. As the product type leads to typical supply chain models. Based on the potential consequences of the BWE and the probability of the occurrence we can create a matrix that shows how deep analysis of the phenomenon is needed.

3.1 Bullwhip effect reasons and non-sensitive cases

As it has been defined bullwhip effect is deeply analysed phenomenon. It has the interest of the academic and the industrial aera too. This is partly due to the typical characteristics of today's supply chains and supply network. In most of the cases the supply chains are containing numerous echelons, the scope of the chains is not limited by geographical borders. There are also intertwining of chains, common and conflicting interests need to be handled in huge networks. For the bullwhip effect the mentioned characteristics are ideal to make the phenomenon happen. Complex, unpredictable operation leads to low level of transparency and control.

Despite the complex, globalised supply chains and network there are still different approaches. In these extents bullwhip effect may not occur, or it does not lead to any significant problem. in table 1. the characteristics of the supply chain that is immune to the phenomenon is collected based on the main reasons of the bullwhip effect.

The unpredictability of the market can be handled better in pull strategy supply chains. The direct information flow leads to less fluctuation in customer demand. In these cases, there is less focus on forecasting. Monitoring of market trends and customer needs are also important here. Nonetheless, the potential loss generated by forecasting mistakes is smaller.

The length of the supply chain is also impactful factor. Long supply chains are more complex, there are multiple echelons involved and mostly multiple countries. This leads to difficulty in achieving the transparency and high level of overall control. It is more difficult to avoid local approaches that are not in line with the chain level goals. In contrast, short supply chains are more controllable.

Table 1.: BWE reasons and non-sensitive cases

BWE reason group	BWE reasons	Non-sensitive cases
Demand processing signal	inaccurate forecast	Pull supply chain
	forecasting strategy	
	handling of stock out	
	misunderstanding of market information	
	lack of learning	
Rationing game	number of echelons	Short supply chain: • number of echelons
	lack of transparency	
	lack of control and synchronisation	
	local approach	
	fear of shortage	
Order batching	lot size of the order	Short supply chain: • geographical distance
	replenishment policy	
	capacity limitations	
	ordering timelines	
Price variation	fluctuation of material prices	Product type, local sources
	fluctuation of finished goods prices	
	changes in other related costs	
	planned and not planned promotions	

Source: Author's creation based on Lee et al. 1997; Potter & Disney, 2006; Geary et al, 2006

Shortness can mean the number of echelons or the geographical distance. In both cases the complexity is reduced, and cooperation has less difficulty. It also decreases the fear of shortage as transparency and control makes the degree of predictability higher. In these cases, it is much easier to avoid the reasons mentioned under the rationing game. Smaller geographical distance can support also in the harmonisation of processes. Policies, measures used, timelines and other mechanisms applied on echelon level can be harmonised much easier. Considering the reasons under order batching group shorter supply chains can make the occurrence of the reasons listed less likely.

The price perspective shows smaller direct dependency on supply chain operation. It is more difficult to avoid them with the tools applied. Still the shorter size of the chain and geographical distance can have positive influence on the operation. From

promotional perspective planning with limited number of echelons is much easier and predictable. In addition, usage of local material sources can also support. Price changes can still happen, but availability is more plannable, so the related costs are less problematic. This way shorter chain's higher flexibility can support the price factor also. The type of the product can also impact the degree of sensitivity. Special, made to order products are less sensitive for the phenomenon.

3.2 The sensitivity – product perspective

As it has been described in chapter 3.1. the supply chain setup is influencing the probability of the bullwhip effect. Beside that the product itself is also an important factor. There are groups of products that are typically not generating the bullwhip effect. These are for example limited edition items with given number of produced quantities. We can list here also make to order crafts items that are unique. Below figure shows a matrix of probability of the bullwhip effect and expected level of negative consequences.

Once the bullwhip effect occurs it has not only performance decrease consequence, but also direct or indirect cost comes with it. In the matrix the consequence axis can be understood as cost. This is included in the matrix with three level of intensity (low, medium, high). The other axis shows the probability of the occurrence. This is based on the characteristics of the chain producing the product and the specific features of the product.

Low probability typically goes with pull strategy and/or short supply chains with high possibility of control and transparency. High probability goes with push strategy make to stock products (mass production items).

Some additional specification factors can also be considered here. For example, food industry would mean smaller consequence relative to other industries on cost level. Nevertheless, if overstock is generated due to the shorter shelf life decrease the chance to figure out any solution.

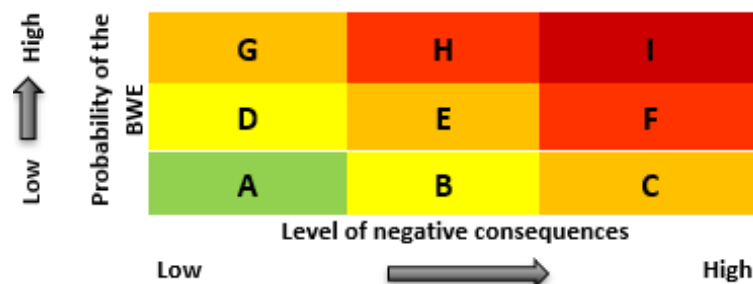


Figure 1: Probability & consequences matrix

Source: Author's creation



As example craftsman to user business can fit in to cell 'A' as the consequences and the probability is low. Contrary, cell 'I' is with high probability and high level of consequences. Global supply chains can be used here as example with push strategy sales and expensive product. Such as some of the electronic devices. Beside seasonality changing technology and trends are also increasing the unpredictability. The length of the chain has high influence on the bullwhip effect and the geographical extent due to the uncertainty generated by the complex and complicated network.

In between the extremes we can consider all the different supply chain setups. For cell 'B' pull strategy car manufacturing can be mentioned as example. Probability is low but potential consequences are still needed to be considered. For cell 'H' high probability of occurrence and medium consequence external product packed with normally sold items as gift can be an example. Planning of these items are always a risk as it is not known how the market will accept it. Forecasting can go wrong and can result in oscillation.

Establishment of any rule that can punctually define the grouping of the enterprises is hard. Several factors need to be checked at the same time as length of the chain, profile of the company, producing and sales strategies. In addition, exceptions can be determined based on unique characteristics. This matrix is just helping to understand level of influence bullwhip effect can make. Based on this a proper level of source can be allocated to tackle the issue on company level.

4 Discussion

Table 1 has collected the cases supply chain can appear non-sensitive or less sensitive in regards the bullwhip effect. Length of the supply chain is impacting the phenomenon. With increased number of echelons joining a network it becomes less controllable and transparent. The shortening of the geographical distance also supports the manageability. Products are accessible easier, and changes can be pushed through faster. The shortest, from maker to customer chains are limited from both mentioned perspectives. Due to the short chain, bullwhip effect has no room to develop and increase the degree of the oscillation.

Pull supply chains are representing a different way of working. The understanding, and cooperation with the market differs from the push approach. Customer's importance is not smaller these cases, but the role in the business process is different. Due to this even if trends need to be monitored importance of the day-to-day forecasting is smaller.

BWE is important but it needs to be in focus only in the relevant cases. This article shows three different perspective that can support the immunity. For clarification it



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would be worth to check further potential characteristics or management models that has direct or indirect impact on the phenomenon. Chains that are less vulnerable from bullwhip effect perspective need less effort on the analysis of it. This support to keep the focus in the proper place. In the same time chains that are impacted by the phenomenon with high potential should put higher priority on the key performance indicators that support the deeper analysis. These cases should consider the chosen trade off. From cost perspective, it may be worth to keep the complexity on high level, but it would mean decrease in flexibility. As both side is important from competition perspective it need to check which gives more benefits.

Conclusion

Occurrence of the bullwhip effect is highly influenced by the characteristics of the supply chain. Increased complexity of the chain also means higher probability of the bullwhip effect. Reason can be the applied supply chain strategy, length of the chain, or high variety of products. Lead time is important factor in the complexity. Long lead times increase the chance of supply chain disruption. Considering the push and pull strategies none of them rules out the possibility of the occurrence of the bullwhip effect. Nonetheless, the pull environment is less favourable for the phenomenon.

As today's most typical supply chains are long, push strategy chains with consumer products the chance for the change is more for the newly built supply chains. Choosing the flexibility against cost supports the increase in customer satisfaction and complete customer service.

The end user is getting more and more into the focus. High level of customisation of the products is demanded by the market. To fulfil the changed requirement flexibility is needed. That can be highly supported by regionalisation approaches. Due to the mentioned changed direction of customer requirements short chains can become widely used on long term. This would also help the fight against the harmful impact of the bullwhip effect.

This article aims to show the possible non-sensitive supply chain setup. The goal is to support the operation to have the focus where it should be placed. If the phenomenon is impacting the operation, it needs to be analysed. On the other hand, if the probability is lower different measures can be in focus. The level of impact is also important. Even with high probability if the impact is low measures may requires review.



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