

Literature review of the bullwhip effect in supply chains: causes, impacts, and mitigation strategies

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Abstract:

The objective of this literature review is to reconstruct the conceptual evolution of the Bullwhip effect, identifies operational (forecasting errors, batching, delays) and behavioral causes (decision biases), analyzes logistics impacts (costs increases, production instability, stockouts and deterioration of inter-organizational relationships). The study shows that effective mitigation requires an integrated approach that combines information sharing, decision coordination, and the use of advanced technologies such as AI, blockchain, and collaborative planning systems. The synthesis offers a structured approach to the bullwhip effect and offers avenues for future research on the empirical analysis of reduction strategies and decision-making processes in different industrial contexts.

Keywords : bullwhip effect, supply chain, demand variability, operational and behavioral causes, mitigation strategies.

Jel Classification Codes : D21, L23,M11

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1- Introduction :

Supply chains constitute a major strategic challenge for firms in a context marked by globalization, increasing complexity of production networks, and intensified competition. Organizational competitiveness depends on the efficient management of physical, informational, and financial flows. Nevertheless, despite technological progress and advanced planning tools, many supply chains remain highly vulnerable to demand fluctuations, resulting in significant operational inefficiencies.

One of the most prominent manifestations of these inefficiencies is the bullwhip effect, which refers to the progressive amplification of demand variability as information moves upstream from final consumers to suppliers. This phenomenon was notably illustrated by the case of Pampers diapers at Procter & Gamble, where relatively stable consumer demand generated disproportionately larger fluctuations across distributors, wholesalers, and manufacturers (Lee et al., 1997). Such amplification simultaneously produces excess inventories and stockouts, thereby disrupting supply chain stability.

This vicious cycle has been observed in various sectors, including retail, automotive, and agri-food industries. Its consequences include instability in production planning, higher inventory holding costs, frequent stockouts, and inefficient resource allocation. Moreover, the bullwhip effect weakens interorganizational coordination, erodes trust among partners, and negatively affects firms' financial performance through increased working capital requirements.

Existing research addresses the bullwhip effect from informational, operational, and behavioral perspectives. However, empirical findings remain fragmented and sometimes

contradictory, while proposed solutions vary across organizational and industrial contexts. This dispersion of knowledge highlights the need for a structured synthesis to clarify the conceptual evolution of the phenomenon, its determinants, its consequences, and the mitigation strategies advanced in the literature.

The question of the study: *How can the bullwhip effect in supply chains be explained, what are its operational and behavioral determinants, and to what extent do existing theoretical and practical approaches contribute to mitigating its impact on firm performance?*

The Objectif of this paper is to provide a theoretical investigation of the bullwhip effect through a comprehensive literature review. It aims to trace the conceptual development of the phenomenon, identify its main causes, and examine its implications for logistics performance. Based on this synthesis, the study also highlights the principal strategies proposed in the literature to reduce the bullwhip effect and strengthen coordination among supply chain actors.

The importance of the study: This literature review offers a systematic summary of the bullwhip effect, emphasizing its primary determinants, repercussions, and mitigation techniques to aid both scholarly study and managerial practice.

Methodology: This systematic literature review covers the period 1961-2025, with the keywords "bullwhip effect," "effet coup de fouet," "supply chain variability," "behavioral causes," and "mitigation strategies." Among the initial 85 publications, 52 peer-reviewed articles in English and French were selected based on inclusion criteria (quality, thematic relevance) and exclusion criteria (non-academic documents). The classification is based on four main axes: definitions and conceptual evolution, operational and behavioral causes, organizational impacts, and mitigation strategies, with Zotero for bibliographic management.

1. Evaluation and definition of the concept of bullwhip effect:

The bullwhip effect comes from the seminal work (Forrester, 1961), who in *Industrial Dynamics*, described a phenomena of demand amplification in production and distribution systems. As demand information moves through different stages of the supply chain, this phenomenon, also known as the Forrester effect, explains why product shortages and surpluses are becoming more common (H. Lee et al., 1997). Forrester used simulation models to show that making decisions without being able to see the whole picture, along with delays in implementing changes, leads to bigger swings in stocks and order volumes.

(Clark, 1917) was the first to look at how modest changes in demand can cause big changes in economic systems. This kind of behavior is often not linear in supply chains (Geary et al., 2006). So, the bullwhip effect may be seen as a gradual rise in demand variability along the supply chain, which shows how logistics operations are always changing. It comes from problems with how demand is passed on, which make the fluctuation seen upstream seem more than it really is.

(H. Lee et al., 1997) codified the present concept of the bullwhip effect, which is when the number of product orders that vary grows as you go up the supply chain. This problem leads to too much money being spent on inventory, lost sales, limited customization of services, and inefficient transportation. The bullwhip effect is the difference between actual demand and predicted demand, which can cause either too much inventory or not enough. Forecasting errors and poor information exchange in supply chains are the main causes of this.

Logistics managers at Procter & Gamble came up with the name "bullwhip" after seeing big differences between actual consumer demand and internal replenishment orders. Companies like Hewlett-Packard, Bristol-Myers Squibb, and Wal-Mart later reported similar patterns (Handfield et al., 2002). The bullwhip

effect is especially common in businesses with markets that are developing quickly and changing all the time, such as telecommunications, electronics, automotive, furniture, agri-food, and textiles (Hugos, 2018).

(Forrester, 1961) and (Simon, 1952) were two of the first researchers to look into this issue in a systematic way. Forrester examined it via simulation and framed it as demand amplification. Later, (J. Sterman D., 1989) studied this behavior at the Massachusetts Institute of Technology using the Beer Distribution Game from the MIT Sloan School of Management. He stressed how important behavioral elements and management learning are in reducing its size. (Blanchard, 1983), (A. Blinder, 1986; A. S. Blinder, 1982), and (Kahn, 1987) made more contributions that helped people grasp the bullwhip effect as a systemic problem that is often not taken seriously or understood correctly in real life.

The next part looks at important classical and modern works that have had a big impact on how we think about and study the bullwhip effect.

Author	Definition	Contribution
(Forrester , 1961)	Phenomenon characterized by a variance in orders transmitted to suppliers that is greater than that of the final customer demand	First conceptualization of the phenomenon thru system dynamics; highlighting the role of delays and local decisions.
(H. Lee et al., 1997)	Small variations in demand propagate like a domino effect along the supply chain, leading to an amplification and distortion of demand information to primary suppliers.	Formalization of the term "bullwhip effect" and identification of the major causes (forecasts, batches, prices, rationing).

(Chen et al., 2000)	Small fluctuations in final demand lead to large variations in orders and inventory levels at suppliers due to forecasting errors, order batching, price fluctuations, and rationing.	Highlighting the operational mechanisms and statistical quantification of the amplification.
(Coelho et al., 2009)	Characteristic of the logistics network resulting in a variation in orders greater than that of sales from the previous link, generating an increasing distortion of upstream demand.	Systemic vision of the bullwhip effect as a structural property of the supply chain network.
(M. Silva, 2010)	Progressive amplification of demand variations caused by failures in forecasting processes, ineffective communication, and inadequate inventory management policies	Integration of informational and managerial dimensions.
(Michna et al., 2015)	Combined result of communication delays, batch ordering policies, forecasting errors, and inventory management, amplifying the variability of orders compared to actual demand.	Integrative approach encompassing informational, behavioral, and operational factors.

(Michna & Nielsen, 2015)	Intensification of order variability upstream, due to forecasting errors, frequent demand updates, and poorly calibrated replenishment practices.	Emphasis placed on decision-making practices and their effects on operational costs.
(El Beheiry et al., 2024)	Variability increases not only thru informational distortion but also thru the structural complexity and topology of modern logistics networks.	Enrichment of the concept thru the integration of network complexity and their architecture.
(Darmawan et al., 2025)	Trend of replenishment orders becoming increasingly variable as they move upstream in the supply chain.	Modern update of the concept and empirical validation in complex industrial environments.

Source: prepared by the authors

These definitions lead to a general understanding of the bullwhip effect as a process of gradual increase in order variability relative to actual demand along the supply chain. They also reveal that this phenomenon is the result of a combination of informational, decisional, and structural factors. The study of the causes of the bullwhip effect then becomes essential to better understand its mechanisms and limit its negative consequences, which is the subject of the next section.

2. The causes and mechanisms of the Bullwhip effect

2-1. The operational causes of the bullwhip effect:

This section presents the main operational causes of the Bullwhip Effect (BWE) highlighted in the literature. Studies reveal that forecasting, ordering, inventory management, lead times, information sharing, replenishment, and pricing policies are essential to the increase in demand variability in supply chains.

2-1-1 Inaccuracy of demand forecasts

Companies' forecasts often rely on received orders rather than the actual market demand. Each link adjusts its decisions based on local historical information, which leads to a gradual increase in forecasting errors throughout the supply chain. It is due to the absence of a direct link between upstream actors and the actual demand of end consumers, which increases uncertainty and order variability according to (H. L. Lee et al., 1997)

(M. E. Silva & Villar, 2011) illustrate this phenomenon by showing that demand is stronger downstream ($N+2$) than upstream ($N-1$), thus confirming the amplifying effect of the bullwhip. The increase in lead time further reinforces this distortion, as it forces companies to maintain larger safety stocks, making forecasts less reliable.

The forecasting method has a significant impact on the emergence and intensity of the bullwhip effect, as it creates a distortion of demand information that propagates upstream in the supply chain. The literature identifies four types of forecasting methods (Bhattacharya & Bandyopadhyay, 2011): time series models, machine learning models, multi-agent models, and models derived from control engineering.

However, , (Chaharsooghi et al., 2009) demonstrate that the use of more accurate forecasting methods does not necessarily lead to a reduction in the bullwhip effect.

2-1-2 Batch ordering

Companies frequently place orders in large quantities to reduce administrative and transportation costs or to benefit from commercial discounts. This practice leads to artificial variations in demand perceived by suppliers, who interpret these fluctuations as real market changes and excessively adjust their production.

(Holland & Sodhi, 2004) show that the level of the bullwhip effect is proportional to the square of the batch size. (Potter & Disney, 2006) distinguish between temporal batching and quantitative batching and recommend reducing batch sizes to limit variability. (Yan et al., 2009) confirm that increasing the size of shipments enhances the batching effect and, consequently, the bullwhip effect.

From a macroeconomic perspective, Guimarães (2010) (cited in (Lima et al., 2025) highlights significant differences in inventory management practices between countries, showing that aggressive accumulation and resale strategies can exacerbate imbalances in supply chains.

2-1-3 Commercial promotions and price fluctuations

Promotional offers, seasonal promotions, and discount policies encourage customers to buy in large quantities (forward buying). Demand artificially drops when prices return to normal, creating an illusion of a market downturn and disrupting production planning. Promotional cycles create variations that do not reflect actual consumption. (Ozelkan & Çakanyıldırım, 2009) showed that price variability increases order variability, leading to a phenomenon called Reverse Bullwhip.

2-1-4 Stock policy and lead time

Stock policies based on fixed levels can lead to overstocking or understocking, as they ignore actual demand variations. (Hoberg et al., 2007) demonstrate that policies based exclusively on available stock are unstable, while echelon stock policies allow for better management of variability.

Moreover, the lengthening of lead time pushes companies to overorder to avoid stockouts. (Wang et al., 2008) show that the bullwhip effect increases with the delivery time. The variability of orders increases with the variability of lead time.

4-1-5 Lack of transparency and information sharing

The lack of communication between the actors is one of the major causes of the bullwhip effect. When partners do not have access to actual demand data, each link makes decisions based solely on its own perception, which amplifies distortions.

Johnson et Stevens (2016)(cited in (Lima et al., 2025) indicate that inaccurate information about demand triggers the bullwhip effect. Information sharing is recognized as an effective strategy for reducing this phenomenon (Bhattacharya & Bandyopadhyay, 2011).). However, this practice remains limited by the lack of trust between organizations (Daneshvar Kakhki & Gargeya, 2019).

2-1-6 Rationing and shortage gaming

In a shortage situation, buyers are likely to overorder to secure their stocks, which is called shortage gaming. Suppliers respond with rationing policies, which further increases order variability and raises the total costs of the supply chain (Paik & Bagchi, 2007)

These six operational causes are responsible for a large part of the increase in demand in the supply chain. However, recent

literature shows that the bullwhip effect is not only related to technical processes but also to human and decision-making factors. That is why we will address the behavioral causes of the bullwhip effect.

2-2 The Behavioral Causes of the Bullwhip Effect

Traditionally, research on the bullwhip effect has primarily focused on operational causes. However, these approaches often overlook the impact of human behaviors, which can deviate from perfect rationality due to cognitive, emotional, or social constraints.

From this perspective, this section analyzes how much and in what ways behavioral factors influence the bullwhip effect.

According to (Yang et al., 2021), behavioral causes can be grouped into 7 main categories, with several sub-causes:

2-2-1 Social interaction

Social interactions play a crucial role in the bullwhip effect. **Communication and coordination** between the levels of the supply chain are essential to stabilize decisions: decentralized actors, deprived of direct communication, rely on incomplete local data, leading to excessive order adjustments (Kovacevic et al., 2013; Wu & Katok, 2006). **Information sharing**, particularly sales data (POS) and inventory, reduces uncertainty about actual demand (Croson & Donohue, 2003; Steckel et al., 2004), but remains insufficient in the face of feedback delays and interpretation difficulties (Jin, 2015; Machuca & Barajas, 2004; Sarkar & Kumar, 2015). Finally, **trust** conditions the effectiveness of these mechanisms: a low level of trust fosters opportunistic behaviors such as excessive stocking and information retention (Cao et al., 2014; Croson & Donohue, 2003; W.-H. Hung et al., 2014), while cooperation fails when actors mutually doubt each other's decisions (Cantor & Macdonald, 2009; Haines et al., 2017).

2-2-2 information feedback

In the context of informational feedback, the selective **perception** of decision-makers—who prioritize information that conforms to their mental models—generates a partial view of the system, obscuring key signals and causing inappropriate adjustments to orders (Haines et al., 2017). **Ambiguity** exacerbates this phenomenon by creating confusion between decisions and outcomes: actors are unaware of the impact of their orders on future stocks and the overall dynamics (J. Sterman, 2000; J. D. Sterman, 1994), favoring choices based on incomplete information that amplifies demand variability. Although **training and learning** improve the understanding of causalities and reduce this variability (Ancarani et al., 2013; Haines et al., 2017), they remain slow and imperfect, explaining the persistence of the bullwhip effect despite accumulated experience.

2-2-3 Bounded rationality and the simplified mental models

Bounded rationality and the simplified mental models of decision-makers amplify the bullwhip effect. These **heuristics** lead them to underestimate supply lead times and focus on local variations ((Narayanan & Moritz, 2015; Su, 2008). **Judgement biases**, particularly anchoring-adjustment and underweighting of the supply line, exacerbate distortions: managers overlook feedback loops, reacting excessively to fluctuations (Croson & Donohue, 2003, 2006; Rong et al., 2008) .

2-2-4 Decision strategy

The decision-making strategies adopted by the actors directly influence the amplification of orders. Certain decision-making routines, such as counterintuitive or non-cooperative behaviors, generate excessive variability in flows (Delhoum & Scholz-Reiter, 2009). Moreover, risk aversion leads decision-makers to over-order to avoid stockouts, thereby promoting excessive hoarding behaviors (Cannella et al., 2019; Di Mauro et al., 2020; K.-T. Hung & Ryu, 2008).

2-2-5 Decisions & behaviors

Final decisions are manifested thru irrational behaviors such as panic ordering and hoarding behavior, as seen in the Beer Game experiments. These behaviors are often operational in nature and driven by fear of shortage (Nienhaus et al., 2006; J. D. Sterman & Dogan, 2015). Moreover, stress and professional pressure can cause errors in stock recording, which further increases order variability (Bruccoleri et al., 2014).

2-2-6 Individual traits

Personal characteristics influence how decisions are handled and managed. (Bloomfield & Kulp, 2013; Byrne et al., 2015) note that certain psychological characteristics—such as impulsivity, need for cognition, or locus of control—influence strategic sourcing choices. Furthermore, (Khan et al., 2019) show an inverse correlation between individuals' awareness and the extent of the bullwhip effect: the more aware decision-makers adopt more stable and predictable behaviors.

Moreover, age and professional experience are not always synonymous with better decision-making performance (Turner et al., 2020).

2-2-7 Emotions

Decision-making is based on emotions such as fear, anxiety, and frustration. They lead to panic behaviors and overstocking when stockouts are anticipated (Croson & Donohue, 2006; Pamulety & Pillai, 2016). These emotions increase perceived demand and contribute to the persistence of the bullwhip effect (Nienhaus et al., 2006; J. D. Sterman & Dogan, 2015).

The literature shows that the bullwhip effect is largely influenced by behavioral factors, which explains the persistence of demand amplification even when operational conditions are improved.

3- The impact of the bullwhip effect

The bullwhip effect (BWE) is manifested by the amplification of demand as it progresses thru the supply chain, leading to distortions in the orders received and disrupting production and distribution operations (Chen et al., 1999). They are directly linked to the performance and competitiveness of companies. Among the consequences of this phenomenon:

3-1 Increase in costs

The increased variation in demand leads to excessive or insufficient inventory, resulting in additional costs for storage, transportation, and logistics flow management (Lima et al., 2025). Companies often need temporary contracts or emergency transport to cope with unexpected demand spikes. These variations make it difficult to optimize costs while maintaining a good level of service.

3-2 Difficulty in Production Planning

Demand fluctuations make production planning difficult, leading to operational inefficiencies and a loss of productivity. Companies must work overtime, hire temporary staff, and use many machines, which increases costs. Conversely, during periods of low demand, resources are underutilized, reducing productivity and increasing the fixed cost per unit produced (Chen et al., 1999).

3-3 Loss of revenue and customer trust

Delivery delays or stockouts lead to customer dissatisfaction and a loss of revenue, as customers may switch stores. The inability to respond quickly to demand undermines customer loyalty and the

company's reputation, which weakens its market share and competitiveness (Chen et al., 1999).

3-4 Impact on supplier relationships

The variability of orders makes it difficult to plan with suppliers, which compromises the reliability of deliveries and the quality of products. Demand fluctuations can cause delays, excessive or insufficient stock levels, leading to costs and weakened business relationships. To limit these effects, it is essential to promote collaboration, realistic demand forecasts, and flexible contracts (Lima et al., 2025)

3-5 Financial Consequences and Competitiveness

The bullwhip effect leads to significant financial losses, a loss of competitiveness, and an inability to respond quickly to demand variations. It also affects consumer confidence and the ability of companies to better optimize their resources (Lima et al., 2025)

4- Mitigation de l'effet coup de fouet

La mitigation de l'effet coup de fouet est une problématique étroitement dépend de ses causes, car pour réduire son impact, il est nécessaire de bien identifier et comprendre ces causes. La littérature distingue généralement deux axes principaux : les approches théoriques et les pratiques industrielles.

4-1 Mitigation of the bullwhip effect according to the literature

Academic literature proposes several approaches to minimize the bullwhip effect, emphasizing the coordination of supply chain actors and the reduction of uncertainties in information transmission. These approaches can be classified into several types:

Approach/Method	Description	References
Agent-based coordination	Use of multi-agent systems to enhance coordination between levels. Intermediate agents (brokers, controllers, facilitators) provide information to software agents, who coordinate decisions between parts of the chain to minimize order distortions.	(Zarandi et al., 2008)
Retailer–supply chain coordination	Implementation of coordination systems between partners (agents collecting and using data for order adjustment).	(Disney et al., 2008)
Control theory	Application of robust control methods to limit the propagation of demand variations, stabilize production, and reduce order variability.	(Disney et al., 2008) (Guo & Huang, 2007)
Negotiation schemes	Implementation of negotiation mechanisms among supply chain partners to improve coordination and mitigate the bullwhip effect.	(Ouyang & Daganzo, 2005)
Genetic Algorithm	Use of Genetic Algorithms to optimize replenishment policies and reduce order amplification across supply chain echelons.	(O’donnell et al., 2006)

Source: prepared by the authors

4-2 Mitigation of the bullwhip effect in industry

Companies face the bullwhip effect by implementing actions and strategies to reduce order variability and strengthen coordination among stakeholders; they can adopt several methods:

Approach/Method	Description	References
Lead time reduction, echelon-based inventory control	Reduction of lead times and use of echelon inventory to optimize total inventory across upstream and downstream sites	(H. Lee et al., 1997)
Full truckload optimization with mixed products	Ordering full truckloads of multiple products instead of single-product batches to preserve order and transport efficiency	(H. Lee et al., 1997)
Allocation based on past sales, stricter cancellation policies, data sharing contracts	Allocation policies discourage exaggeration of orders; sharing sales, capacity and inventory data reduces gaming behavior	(H. Lee et al., 1997)
Supply chain contracts, VMI, consignment stock	Contracts and coordination mechanisms aim to reduce distorted information and order variability	(Larson, 2001)
AI and Circular Supply Chain	Integration of artificial intelligence and circular economy principles to optimize return flows and recycling forecasts	(Fernández-Arribas et al., 2024)

AI Demand Sensing and CPFR/IBP	Real-time demand sensors AI, Collaborative Planning Forecasting Replenishment, and Integrated Business Planning	(ISM, 2025)
Blockchain and Neural Networks	Blockchain for end-to-end traceability and neural networks for distributed forecasting	(Salwa & Zulfikri, 2024)
Real-time sharing of POS data and AI	Point of Sale data shared instantly along with AI algorithms for supplier coordination	(Lima et al., 2025)

Source: prepared by the authors

5- Conclusion

This study has brought together the main contributions from the literature on the bullwhip effect in supply chains, highlighting its conceptual evolution, causes, consequences, and prevention methods. The results show that this phenomenon results from a combination of operational, informational, and behavioral factors, which highlights its systematic nature.

The bullwhip effect leads to increased costs, unstable flows, and poor overall performance of supply chains. Recent studies highlight the need for information sharing, interorganizational coordination, and the integration of cutting-edge technological solutions to reduce variability and improve the visibility of true demand.

This review emphasizes the need for an integrated approach to understand and sustainably mitigate the bullwhip effect, and proposes future research directions on empirical analysis in emerging contexts such as Algeria.

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