Revisiting the Bullwhip Effect under Economic Uncertainty

Khalid Al-Akhal
PhD Scholar
University of International Business and Economics (UIBE)
Beijing, China.

Abstract

For the past decade, economic uncertainties were the only certainty. At the breakout of the global financial crisis, sales managers at the air conditioning industry noticed two strange distortions in the supply chain. At the downstream, factories were increasing their levels of inventories of specific raw materials mainly copper pipes and power cables whereas at the upper stream the distribution channels were logically making lower orders of the finished products compared to the actual market demands. This paper aims at analyzing some of the situational factors that lead to these two types of distortions. In doing so, it also proposes that the model of the Bullwhip Effect (BWE) will have an inverse shape under economic uncertainty compared to the conventional shape reported in supply chain traditional literature. Despite the fact that a number of BWE distortions were reported by several scholars, the phenomenon has never been studied under the special situational factors during an economic uncertainty.

Keywords: Supply Chain; Demand Fluctuation; Bullwhip Effect; Financial Crisis; Economic Uncertainty; Industrial Raw materials.

Introduction

Indeed, demand fluctuation is a significant problem for suppliers, planners, demand managers and operations managers. Fluctuations make forecasting and inventory management more difficult and tend to increase inventory levels and decrease service levels (Zotteri 2012). It is a phenomenon that has been one of the major challenges in supply chains and commonly termed as the 'Bullwhip Effect' representing a magnified variation of information about demand at the order side of the supply chain. Historically, Simon (1952) and Forrester (1958) were the first pioneers who investigated the phenomenon through simulation analysis. However, it was not until the seminal work of Lee et al (1997a), the phenomenon became widely known among operations management practitioners as well as scholars. Nonetheless, the conventional measurements were under question in some studies (Nielsen 2013 and Sucky, 2009) whereas few other scholars even denied the very existence of the phenomenon (Cachon et al., 2007; Fransoo and Wouters, 2000).

Ultimately, the Bullwhip Effect has remained a hot topic among a large number of scholars whose works can fell into two main categories: statistical simulations and case studies. This research, however, is a theoretical one, which argues that under economic uncertainty orders distortions in specific industries will take a different shape compared to the conventional model witnessed under normal economic situations. For example, orders of specific raw materials at the downstream will have higher amplifications while orders of finished products at the upper stream will be downsized significantly, resulting in an inverse shape of the Bullwhip Effect compared to its conventional shape.

The following section will provide an extended literature review to the definitions, causes, symptoms and remedies of the phenomenon. The paper will present two theoretical propositions based on previous empirical evidence and other situational factors that were evident from world's reliable statistics. Those were on the effects of the financial crisis on global supply chains, international merchandise trade and commodities prices.

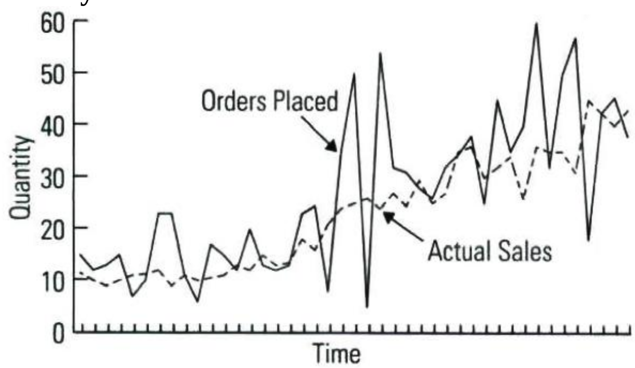
Literature Review:

The terms "Whiplash", "Whipsaw" or "Bullwhip Effect" refer tothe amplification of distortion as it propagates upstream the supply chain caused by orders to the supplier having larger variance than sales to the buyer (Lee et al 1997b). In other words, it is when the amount of periodical orders amplifies as one move upstream in the supply chain towards the distribution of products end (Beergame.org 2015).

The phenomenon has been a source of inspiration for scholars who tried to investigate it empirically across different industries (Anderson et al., 2000; Blanchard, 1983; Cachon et al., 2007 Mckenney and Clark, 1994; Hammond, 1994; Kelly, 1995). The classical examples were the Beer Game (Sterman, 1989), Barilla Case (Hammond, 1994) and Procter & Gamble (Lee et al 1997a).

Further, the possible causes of the Bullwhip Effect in forward supply chains were discussed extensively in literature: (i.e. Anderson et al 2000; Bourland et al 1996; Cachon and Fisher, 2000; Chen et al 2000; Croson and Donohue, 2006; Lee et al 2000; Croson and Donohue, 2005; Lee et al 1997b; Lee et al 1997a Graves 1999; Steckel et al 2004; Sterman 1989; Wharburton 2004; and Zotteri, 2007). In most cases the researcher focused on one or different but related variables. For example Zotteri (2007) focused on price fluctuation and forward buy driven by sales targets. Others even studied the phenomenon empirically in a closed loop or reverse supply chains (Adenso-Dı´az et al 2011, Da et all 2008; Huang and Liu 2008; Pati et al 2010; Pritchard et al 2013; Zanoni et al 2006; Zhang et al 2011; and Zhou et al 2006).

Figure 2: Higher Variability in Orders from Dealer to Manufacturer Source: Lee et al 1997a



According to Lee et al (1997a) the main causes are: exponential smoothing in demand forecast, order batching, price fluctuation, rationing and shortage gaming. Costantino et al (2015) who focused mainly on forecasting provided empirical evidence that SPC-FS system is superior to the other traditional forecasting methods in terms of bullwhip effect and inventory variance. Adenso-Dı´az et al (2012) concluded that an increase in the percentage of material returned reduces the likelihood of finding a growing bullwhip pattern. In addition, it is more likely for this pattern to appear when the demand variation is low. Furthermore, Zotteri (2012) stressed that price fluctuations and forward buys driven by sales targets play a decisive role. Finally, Anderson and Morrice (2011) extracted a long list of factors affecting this phenomenon from previous literature:

- Erratic human behavior correcting inventory and WIP.
- Safety stock policy and delivery time (lead time).
- Demand forecasting technique and order batching policy.
- Information Sharing.
- Lack of Synchrony and number of links in the chain
- Variable demand/ price policies
- Operation capacity constraints.

The common symptoms of the Bullwhip Effect are excessive inventory, poor product forecasts, insufficient or excess capacities, poor costumer service due to unavailable products or long backlogs, uncertain production planning and high costs for corrections (Lee at al 1997a). According to the famous simulation online platform, Beergame.org (2015) the resulting inefficiencies may include, high (safety) stock levels, poor customer service levels, poor capacity utilization, aggravated problems with demand forecasting, and ultimately high cost and low levels of inter-firm trust. Finally, Pritchard et al (2013) reiterated these symptoms as reduced service levels, large fluctuations in utilization levels, the need for greater safety stock to be held by stocking points, and greater production capacity needed by production points. In contrast to most literature, Mackelpranga and Malhotrab (2015) suggested the Bullwhip Effect despite having an impact on reduced ROA, it has no relationship with the operating margin. In fact the authors argued in their analysis of 383 actual customer base-supplier dyads that the Bullwhip phenomenon is far more complex and nuanced than previously described in extant literature.

From the common supply chain alignment to even using social networks “Guanxi” Baker et al (2014), scholars suggested different remedies to mitigate the Bullwhip Effect. According to Disney et al (2014) Bullwhip avoidance occurs when demand is dominated by low frequency harmonics in some instances. In other instances the Bullwhip avoidance happens when demand is dominated by high frequency harmonics.

Duan et al (2014) proposed a model where exponential smoothing is performed to forecast demand of every product to mitigate the Bullwhip Effect in supply chains. The Equation below calculates exponential smoothing (Duan et al. 2014):

$$\min \sum_{i=1}^{n} \sum_{t=1}^{m} (O_{i,t} - \widehat{D}_{i,t})^2$$

Where:

$\widehat{D}_{i,t-1}$ = Demand forecast for Former period for product i. i=1,2,…,n, t=1,2,….m

$O_{i,t}$ = Delivered order quantity of product i, primed on demand forecast for future period t

Jaipuria and Mahapatra (2014) came up with a proper demand forecasting mechanism. In their study, an integrated approach of Discrete wavelet transforms (DWT) analysis and artificial neural network (ANN) denoted as (DWT-ANN) were proposed for better demand forecasting, hence less amplifications should occur in the supply chain. Lee et all (1997a) suggested a set of remedial strategies to counter each cause of the phenomenon, please see the table below. Finally it can be argued that wrong forecasting is by far the most important factor contributing to the Bullwhip effect. Further, such poor forecasting usually attributed to poor data extracted from previous orders (demands). Therefore one can eliminate the Bullwhip Effect if forecasting can use actual future data. Such definite future demands can only be possible with the technique of advance selling (AS) whereas excess inventory can be greatly eliminated with probabilistic selling (PS). These strategies present different ways allowing the seller to deal with information disadvantage (Fay and Xie 2010).

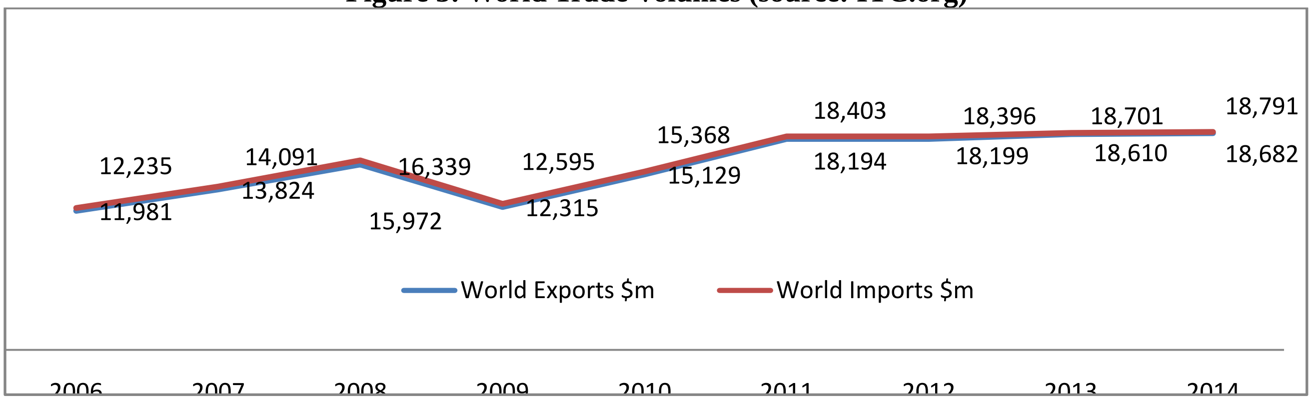
Table 1: Bullwhip Effect Causes and Remedies (Lee et al. 1997a)

Cause	**Remedy**	**Information Sharing**
Exponential smoothing	Avoid multiple demand forecasts	
Order batching	Break order batches	
Price fluctuation	Stabilize prices	
Rationing and shortage gaming	Eliminate Shortage Gaming	

Propositions

For the past decade, economic uncertainties were the only certainty. The world economy experienced a severe, sudden, and synchronized collapse in late 2008. The magnitude of the drop in global trade was the largest since World War II (Fransoo et al 2015). The manufacturing sector observed almost instantaneous demand drops (Dooley et al 2010). In such times of economic crisis and uncertainty, market demand levels on finished products -merchandise trade, will drop dramatically (See figure 3: ITC.org 2015). Simultaneously any procurement manager will seek to improve the financial position of his company. For example, any rapid inventory growth increases a retailer’s risk of bankruptcy (Gaur et al 2014). This “typically” leads to the strategic decision of reducing inventories (Fransoo et al 2015). Accordingly, it is assumed that when the demand variation and price changes are high, the bullwhip effect (exaggerated ordering) for the up-stream will tend to be lower.

Figure 3: World Trade Volumes (source: ITC.org)



Proposition 1: During times of economic uncertainty, pressures of reducing operational capital will lead upstream procurement managers to place lower orders than the actual demand.

On the other hand, at the downstream, Emery (1987) suggests that if there are strong seasonality in demand for products, firms need to maintain larger inventories as a means of smoothing production cycles. For example in the AC industry not only did the product have seasonal demand, but also the economic uncertainty causes demand variance. Two years after the first hit of the financial crisis, Alessandria et al (2010) provided evidence that there is an important role for inventory holdings in downturns, particularly for trade dynamics. Their research results showed that aggregate inventory dynamics during the financial crisis are also not unusual. The influx of investors into commodity markets witnessed an exponential growth leading to a rise in market prices and volatility (Baffes, 2011; Chan et al., 2011). Accordingly, it is evident as well as rational for procurement managers at the downstream to hold excess inventories in times of economic uncertainty due to industrial pressures.From a financial point of view there are also strong reasons for manufacturers to hold excess inventories of certain raw materials in times of economic uncertainty. For example, Prasanna and Shalini (2015) proved that the global financial crisis had direct effect on the rise of commodity prices in all sectors such as energy, precious metals, industrial metals and agricultural products. Caballero et al. (2008) reported high prices of commodities like oil and gold as one of key forces in driving the financial crisis. Alessandria et al (2010) stated that from August 2008 through April 2009, United States non-petroleum real imports and exports fell about 27 percent. However despite that collapse was massive in trade, it was substantially larger than the 15 percent drop in manufacturing industrial production. Although empirical studies indicate that most supply chains tend to collapse during disruptions caused by major unanticipated disasters and many of them never recover afterwards (Chen et al 2015; Eskew, 2004; Tang, 2006), what actually happened during the financial crisis is that the manufacturing production was substantially less affected and commodities prices were appreciated simply because currencies values were immensely fluctuating and many were depreciating. Both commodities prices deeply sunk at the time the financial crisis hit the world before they recover back later. Accordingly, it can be assumed that:

Proposition 2: During times of economic uncertainty, industrial as well as financial pressures will lead downstream procurement managers to place higher orders than the actual demand.

Discussion

Despite the fact that a number of BWE distortions were reported by several scholars, the phenomenon has never been studied under the special situational factors during an economic uncertainty. For example, not only did Cachon et al (2007) measure the Bullwhip-effect but also investigated why it is different under different conditions. Duan et al (2015) hypothesized that any decrease in the number of owns price for the down-stream firm is associated with an increase in the bullwhip effect. In reverse supply chains, Adenso-Dı´az et al (2012) discovered that an increase in the percentage of material returned reduces the likelihood of finding a growing bullwhip pattern, which is more likely to appear when the demand variation is low. Further, Cachon et al. (2007) reported that industries within the wholesale sector had higher demand amplification levels than either retail or manufacturing industries. Last but not least, Tsuruta (2015) who investigated the relationship between bank loans and trade credit during the financial crisis accidentally discovered a positive relationship between credit availability and inventory.

For example, trade credit serves both financial and transaction motives reducing capital and inventory costs (Ferris, 1981; Bougheas et al 2009; Daripa& Nilsen, 2011; Emery, 1987). Given the extensive empirical evidence and rationale previous propositions, it is expected that data inputs under economic uncertainty will result in an inverse shape of the Bullwhip effect.

Figure 4: Conventional Bullwhip Effect

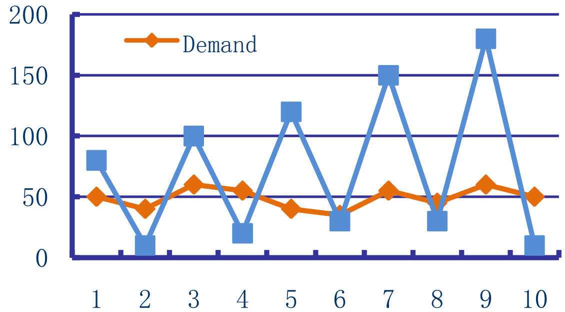
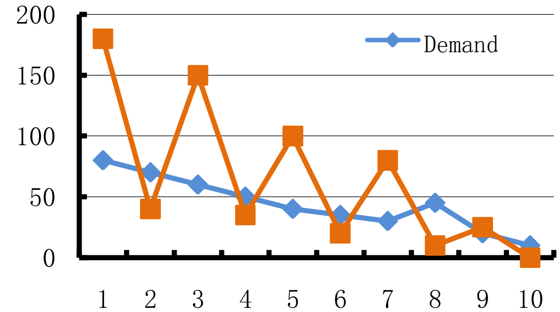


Figure 5: Inverse Bullwhip Effect



Conclusion

The Bullwhip effect is a widely known phenomenon among operations management practitioners as well as scholars, who mainly study the factors affecting the phenomenon. At the begging scholars were interested in measuring the effects and their subsequent amplifications. Nonetheless, some scholars denied the very existence of the phenomenon whereas others noted that the Bullwhip Effect will have different shapes under different conditions. Building on previous literature and situational facts during the 2008 financial crisis, this study proposes an inverse shape of the Bullwhip Effect under economic uncertainty.The main argument is that during an economic uncertainty, procurement managers at the upper stream will seek to reduce inventories as a way to improve the financial position of the company. On the other hand, at the downstream, procurement managers will need to maintain larger inventories of certain raw materials to smooth production cycles and due to the inherent insecurity in the fluctuating value of currencies compared to the safe and potentially rising value of certain commodities. This will ultimately lead to an unavoidable inverse shape to the Bullwhip effect compared to the conventional shape. It is recommended that future research will try to further fill this gap by conducting similar studies in different industries and under different factors of economic uncertainties like natural disasters, terrorism or other systematic factors.

References

Adenso-Dı´az et al (2012) An Analysis of the Main Factors Affecting Bullwhip in Reverse Suppy Chains. Int. J. Production Economics 135 pp917-928.

Alessandria et al (2010) The Great Trade Collapse of 2008-09: An Inventory Adjustment?. IMF Economic Review, Vol. 58, No. 2 (2010), pp. 254-294

Anderson, E., Fine, C., Parker, G. (2000) Upstream volatility in the supply chain: the machine tool industry as a case study. Production and Operations Management 9, 239–261.

Baffes, J., 2011. The long-term implications of the 2007–08 commodity-price boom. Dev. Pract. 21 (4–5), 517–525.

Baker et al (2014) Bullwhip effect reduction and improved business performance through guanxi: An empirical study. Int. J. Production Economics 158, pp. 217-230.

Baldwin, R., 2009. The Great Trade Collapse, Causes, Consequences and Prospects. Centre for Economic Policy Research, London.

Berling and Rosling (2005) The Effects of Financial Risks on Inventory Policy. Management Science, Vol. 51, No. 12, pp. 1804-1815

Bougheas et al (2009). Corporate trade credit and inventories:New evidence of a trade-off from accounts payable and receivable. Journal of Banking & Finance, 33 (2), 300–307.

Bourland, K., Powell, S., Pyke, D., 1996. Exploiting timely demand information to reduce inventories. European Journal of Operational Research 92, 239–253.

Caballero, R.J., Farhi, E., Gourinchas, P.-O., 2008.Financial crash, commodity prices and global imbalances.Technical Report.National Bureau of Economic Research.

Chan, K.F., Treepongkaruna, S., Brooks, R., Gray, S., 2011. Asset market linkages: evidence from financial, commodity and real estate assets. J. Bank. Finance. 35 (6), 1415–1426.

Chen et al (2015) Robust supply chain strategies for recovering from unanticipated disasters. Transportation Research Part E 77, 198–214

Daripa, A., & Nilsen, J. (2011).Ensuring sales: A theory of inter-firm credit. American Economic Journal: Microeconomics, 3 (1), 245–279.

Dooley, K.,Yan,T., Mohan,S., Gopalakrishnan, M., (2010) Inventory management and the bullwhip effect during the 2007–2009 recession: evidence from the manufacturing sector. J.Supply Chain Manag. 46, 12–18.

Beergame.org (2015) Bullwhip Effect. [Online] available at: <http://beergame.org/the-game/bullwhip-effect>[Accessed on 2015-05-27]

Cachon, G.P., Fisher, M., 2000. Supply Chain inventory Management and the value of shared information. Management Science 46, 1032–1048.

Cachon, G.P., Randall, T., Schmidt, G.M. (2007) In search of the bullwhip effect. Manufacturing & Service Operations Management 9 (4), 457–479.

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 time and information. Management Science 46 (3), 436–443.

Costantino et al (2015) SPC forecasting system to mitigate the bullwhip effect and inventory variance in supply chains. Expert Systems with Applications 42, 1773–1787

Da, Q.,Sun,H.,Zhou,H.,2008. Simulation of re-manufacturing in reverse supply chain based on system dynamics. In: 5th International Conference Service Systems and Service Management—Exploring Service Dynamics with Science and Innovative Technology,ICSSSM'08,art.no.4598447.

Disney et al (2014) Avoiding the bullwhip effect using Damped Trend forecasting and the Order-Up-To replenishment policy. Int. J.ProductionEconomics149, 3–16.

Dooley et al (2010) Inventory management and the bullwhip effect during the 2007–2009 recession: evidence from the manufacturing sector. J. Supply Chain Management. 46, 12–18.

Duan et al (2015) Bullwhip effect under substitute products.Journal of Operations Management.

Duan et al (2014) An Optimization Model for Mitigating Bullwhip-Effect in a Two-Echelon Supply Chain. Procedia - Social and Behavioral Sciences 138, 289 – 297

Eskew, M., 2004.Mitigating Supply Chain Risk. CEO, April 25–26.

Emery, G. W. (1987).An optimal financial response to variable demand. Journal of Financial and Quantitative Analysis, 22(2), 209–225.

Ferris, J. S. (1981). A transactions theory of trade credit use. Quarterly Journal of Economics, 96 (2), 243–270.

Fay and Xie (2010) The Economics of Buyer Uncertainty: Advance Selling vs. Probabilistic Selling. Marketing Science Vol. 29, No. 6, November–December pp. 1040–1057

Fransoo et al (2015) Destocking, the bullwhip effect, and the credit crisis: Empirical modeling of supply chain dynamics Int. J.Production Economics160, 34–46

Fransoo and Wouters (2000) Measuring the bullwhip effect in the supply chain. Supply Chain Management: An International Journal 5 (2), 78–89.

Forrester, J., 1958. Industrial dynamics: a major breakthrough for decision makers. Harvard Business Review 36, 37–66.

International Trade Center (2015) International Trade in Goods: Exports and Imports Statistics 2001-2014. [Online] available at: <http://www.trademap.org/tradestat/Country_SelProduct_TS.aspx> [Accessed on 2015-06-22]

Jaipuria and Mahapatra (2014) An improved demand forecasting method to reduce bullwhip effect in supply chains. Expert Systems with Applications 41, 2395–2408

Gaur et al (2014) Retail Inventory: Managing the Canary in the Coal Mine. CALIFORNIA MANAGEMENT REVIEW VOL. 56, NO. 2 WINTER, 55-76.

Kitco.Com (2015) Gold Historical Prices Charts. [Online] availavle at: <http://www.kitco.com/scripts/hist_charts/yearly_graphs.plx> [Accessed on 2015-06-26]

Lee, H., Padmanabhan, V., and Whang, S. (1997a) The Bullwhip Effect in Supply Chains. *Sloan Management Review Spring, pp 93-102.*

Lee, H., Padmanabhan, V., and Whang, S. (1997b) Information Distortion in a Supply Chain: The Bullwhip Effect.*Management Science* Vol. 43, No. 4, pp. 546-558.

Graves, S., 1999.A single item inventory model for a nonstationary demand process. Manufacturing and Service Operations Management 1, 50–61.

Hammond (1994) The Barilla Case. *Harvard Business School Publishing, Boston, Massachusetts*, Case No. 9-694-046.

Huang, L., Liu, Y., 2008. Supply chain dynamics under the sustainable develop- ment. In: 2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008, art. no. 4679408.

Mackelpranga and Malhotrab (2015) The impact of bullwhip on supply chains: Performance pathways control mechanisms and managerial levers. Journal of Operations Management 36, 15–32

Nielsen (2013) Small sample uncertainty aspects in relation to bullwhip effect measurement. Int. J. Production Economics 146, 543–549.

Pati, R.K., Vrat, P., Kumar, P., 2010. Quantifying bullwhip effect in a closed loop supply chain. OPSEARCH 47 (4), 231–253.

Pritchard et al (2013) Returns and the bullwhip effect. Transportation Research Part E 49, 159–175

Prasanna and Shalini (2015) Impact of the financial crisis on Indian commodity markets: Structural breaks and volatility dynamics. Energy Economics [online]

Sterman (1989) Modeling Managerial Behavior: Misperception of Feedback in a dynamic Decision Making Experiment. Management Science 35, pp 321-339.

Sodhi, M. S., & Tang, C. S. (2011).The incremental bullwhip effect of operational deviations in an arborescent supply chain with requirement planning. European Journal of Operational Research, 215, 374–382.

Simon, H. A. (1952). On the application of servomechanism theory in the study of production control.Econometrica, 20, 247-268.

Sucky, E.,2009.The bullwhip effect in supply chains—an overestimated problem? International Journal of Production Economics 118, 311–322.

Tang, C.S., 2006. Robust strategies for mitigating supply chain disruptions. Int. J. Log.: Res. Appl. 9 (1), 33–45.

Tsuruta (2015) Bank loan availability and trade credit for small businesses during the financial crisis. The Quarterly Review of Economics and Finance 55, 40–52

Vincent Metals (2015) Historical Pricing of Copper 2007-2014. [Online] available at: <http://www.vincentmetals.com/Copper_History.html> [Accessed on 2015-06-23]

Wharburton, R.D.H., 2004. An analytical investigation on the Bullwhip-effect. Production and Operations Management 13 (2), 150–160.

Zanoni, S., Ferretti, I., Tang, O., 2006. Cost performance and bullwhip effect in a hybrid manufacturing and remanufacturing system with different control policies. International Journal of Production Research 44 (18–19), 3847–3862.

Zhang, X., Wu, Q., Tian, Z., 2011. Bullwhip effect reduction in closed-loop supply chains using H-infinity control. In: 2011 International Conference on Manage- ment Science and Industrial Engineering, MSIE 2011, art. no. 5707494, pp. 659–663.

Zhou, L., Disney, S.M., 2006. Bullwhip and inventory variance in a closed loop supply chain. OR Spectrum 28 (1), 127–149.

Zotteri (2012) An Empirical Investigation on Causes and Effects of the Bullwhip-effect: Evidence from the personal Care Sector. Int. J. Production Economics pp 489-498.

United Nations Conference on Trade and Development UNCTAD/ United Nations New York and Geneva (2014) World Investment Report Overview Investing in the SDGs: An Action plan Switzerland. United Nations Publications.