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Quantifying Bullwhip Effect and reducing its Impact

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ABSTRACT

This paper quantifies factors which are responsible for the bullwhip effect within the specific theatre, e.g. Middle East. A comprehensive analytical understanding of the phenomenon is derived by considering at least twenty critical factors including Advertising, Sales Promotions, Seasonal Effect, Price Variations, Substitute or competitive products, delays in order processing and raw material shortage. The paper suggests Methods of mitigation of Bullwhip.

Keywords: Bullwhip, supply chain management, substitute products, seasonal effect

JEL Classification: L91, M16

Introduction

A lot of research has been made in monitoring of Supply Chain Management, which includes designing, planning and execution. Many researchers have identified solutions to build value for a spirited base, leveraging worldwide logistics by coordinating supply with demand in a global marketplace.

Bullwhip Effect is the phenomenon, which deals with the variances of amplified demand when it moves upstream. This Effect has gained the interest of many research scholars across the world for the last few decades. Bullwhip Effect represents distortion when orders to the suppliers experience amplification that is typically hard to identify.

Literature Review

According to Lee, Padmanabhan, and Whang, (1997) "the bullwhip effect refers to the phenomenon where orders to suppliers tend to have larger variance than sales to the buyers and distortion propagates upstream in an amplified form". The more shackles in the supply chain the more complicated it becomes. This deformation of demand amplifies the demand farther, which is conceded up the supply chain. It has been acknowledged that some of the motives that the bullwhip effect has become apparent include the following:

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- Advertisings & Promotions
- Sales Staff Incentives
- Over reacting to the backlog orders.
- Trust / Little or no communication between supply chain partners.
- Delay times between order processing, demand, and receipt of products.
- Order batching
- Limitations on order size
- Inaccurate demand forecasts / Seasonal Effects
  Free return policies (Leishman, Robison, Rogers, & Zarbock, 2005).

Global competition in the world market today posses many challenges to achieve a degree of predictability in the supply chain and evade the impact of Bullwhip Effect. This study examined the bullwhip effect and provided some models to lessen it, however less research has been done on quantifying the effect of bullwhip and its measurement still remains an exigent research pathway. It is appealing to concentrate mainly on the first-order autoregressive demand process. In numerous practical circumstances, the demand process is more fundamental with higher order autoregressive models and giving numbers to the bullwhip effect in these circumstances still remain a challenging unsolved problem. While, the existing evidence proves that Bullwhip Effect with some critical factors, such as Raw Material Shortage, Information and Order Delays, Price variations, Competition there seems to be very little empirical measurement that connects Bullwhip Effect with specific causal effects. This paper deals with quantifying such parameters. The rest of the paper includes Design & Analytical Approach (Research Design & Survey Forms), Results, Discussions & Conclusion.

Design Analytical Approach

Research Design

Sources of the research information includes sample of Thirty Five (35) manufacturing and trading companies from Pakistan. Major attempts are being conducted to cover most of the Sector Research spans to Fast Moving Consumer Goods (FMCG), Pharmaceutical, Electronics and Electrical, Textile, Financial Institutions, Telecommunication, Petroleum, Transportation, Appliances and Automobile Sectors. Twenty (20) critical factors are being analyzed to quantify the effect of bullwhip most importantly include Advertising, Promotions, Availability of Literature, Sales Staff incentives, Forward or Advance Booking, Price variations, Seasonal Effect, Information Delays, Trust with the partners, Substitute or Competitive products, Political instability.

Qustionnaire Survey was prepared using "Likert scale" for measuring the strength of each factor that cause bullwhip in a given company for a subject company from Zero (0 – Not Applicable) to Five (5 – Strongly in Agreement).

The data collected was analyzed using the Non-Parametric Tests of χ^2 Chi-Square to test the variance of normally distributed population. The results were then compared with the Table values at varying degree of confidence and to find variances for depicting the effect of bullwhip for each parameter under contemplation.

Results and Discussions

The findings are organized in the (Table-1) that follow here under. The most critical factors observed are Substitution and Seasonal Effect, and they are having values of 28.94 and 28.60 respectively.

Table 1

RANKS	FACTORS	CHI-SQUARE VALUE
1st	Substitute Products / Competition	28.94
2nd	Seasonal Effect	28.60
3rd	Raw Material Shortage	26.54
4th	Promotions	18.66
5th	Information Delays	17.63

In the ranking of Top Five, the other critical factors include Raw Material Shortages, Information Delays and Promotions on Products.

Table 2

Substitute Products / Competition	
Category	**Observed N**
0	1
1	3
2	1
3	5
4	9
5	16

The Table-2 depicts the importance of the subject factor that out of 35 (Thirty Five), 25 (Twenty Five) companies are accepting the effect of Bullwhip is due to Substitute or Competitive products available in the market. Therefore the Percentage of Bullwhip Effect is above 70% for this effect and a Chi-Square value of 28.94.

Table 3

Seasonal Effect

Category	Observed N
0	1
1	2
2	2
3	4
4	11
5	15

Seasonal Effect also directly effects the variances of demand in Middle East Countries. For subject factor, 26 (Twenty Six) companies have rated the Bullwhip effect with respect to this factor. While the Percentage of Bullwhip Effect 74% in this scenario. (As Shown in Table-3).

Table 4

Raw Material Shortage

Category	Observed N
0	4
1	4
2	2
3	5
4	3
5	17

At the level of inbound logistics, raw material is a main ingredient of a finished product. Any variance in source of raw material can lead to variance in production of finished products. And hence, therefore, Table-4 shows that this factor has a weight age of 57%.

Table 5

Promotions

Category	Observed N
0	3
1	2
2	1
3	7
4	13
5	9

Sales promotions can lead to variance in quantity demanded and supplied, which cause initiate bullwhip effect with the manufacturer. In countries like Pakistan Sales promotion and its effect has being ranked 4th. Which depicts that 22 companies or 62% are agree with the fact that Sales promotions can lead to bullwhip effect. (As shown in Table-5).

Table 6

Information Delays

Category	Observed N
0	3
1	7
2	2
3	1
4	12
5	10

Sharing Information within the Supply network is an important factor for smooth operations. As regards, the results of research is concerned, 22 companies are agree with the fact that Information delays cause bullwhip effect in Supply Chains. This factor has a chi value of 17.63.

Analytical Approach

Proportionality of Bullwhip Effect with each factor can be expressed as under

$$ß \propto Fd \quad \text{and} \quad ß_n \propto F(d)_n$$

$$ß \propto 1 / Fi \quad \text{and} \quad ß_n \propto 1 / F(i)_n$$

Where,

$$F(d)_n = C_n \cdot I_{(s)\,d} \;\&$$

$$F(i)_n = C_n \cdot I_{(s)\,i}$$

And,

$$I_{(s)\,d} = \left| \int_{n=1}^{n=y} \chi^2 \, d(y) \right| \qquad \&$$

$$I_{(s)\,i} = \frac{1}{\left| \int_{n=1}^{n=y} \chi^2 \, d(y) \right|}$$

$I_{(s)}$ d = sensitivity index introduced for scaling purpose. It is a positive number obtained by integrating accumulation of chi-square values for all the directly proportional factors at 'y' degree of freedom.

So,

$$\beta_{(n)d} = F_{(n)d} \cdot P_{(n)d} \quad \&$$

$$\beta_{(n)i} = P_{(n)i} \cdot F_{(i)n}$$

If $\beta_{(n)r} = \beta_n$ for all such factors whose null hypothesis is rejected.
&
$\beta_{(n)a} = \beta_n$ for all such factors whose null hypothesis is accepted.

Then, we can show that Aggregate Bullwhip Effect (β_A) is influenced By the following relationship;

So that,

$$\beta_A = \beta_{(n)r} - \beta_{(n)a}$$

$$\beta_{(n)r} = \Sigma F_{(d)n(r)} \times P_{(n)d} + P_{(i)n(r)} / F_{(i)n(r)}$$

$$\beta_{(n)a} = F_{(d)n(a)} \times P_{(n)d} + P_{(i)n(a)} / F_{(i)n(a)}$$

Where;
Bn = bullwhip Effect for nth factor
Fd = factors that directly influence the bullwhip effect
Fi = factors that inversely influence the bullwhip effect
Cn = % value of chi-square for each nth factor

Value of P(n) is derived as under
C_n = Chi-square % value for nth factor
$\chi^2 = \Sigma C_n$ = Total of Chi Squared values for n factors at y = 5 degree of freedom.
$S_{(\chi)}$ = Area in the right tail under the chi-squared curve value of χ^2 for y = 5

$$\text{So, that } 0.005 \leq \chi \leq 0.995$$

$$\bar{S} = \sum_1^n S(\chi)_n \, / \, n$$

Where, $\bar{S}$ is the Aggregate value of $S_{(\chi)}$ indexed over complete bandwidth of available Significance level for chi-square spectrum of n factors under consideration.

$$D_s = \sum_1^n D_{(n)}$$

So,

$$D_n = \sum_1^n C_{(n)} \, . D_{\bar{s}} \, \bar{S}$$

Cumulative indexed difference for n factors under considerations

For all directly proportional factors

$$P_{(n)d} = \int_1^n S_{(x)n\,d} / \bar{S}$$

And for all inversely proportional factors

$$P_{(n)i} = \int_1^n S_{(x)n\,i} / \bar{S}$$

Reduction of Bullwhip Effect

To reduce

$$\beta_{(n)r} \leq \beta_{(n)}a = V_a \;\&$$
$$\beta_{(n)a} \leq \beta_{(n)}r = V_r$$

$$V_n = \sqrt{\left(\int V_{(a)n}\, V_{(r)n}\right)^2 / n}$$

Conclusion

The study builds upon previous literature on the bullwhip effect. As far as Middle East Countries are concerned, Sporadic Sales promotions, Seasonal Effect, Competitive products, Raw Material Shortages are the most critical factors that cause Bullwhip Effect in most industries. The research validates the assumptions that it is possible to mitigate the negative effect of Bullwhip. It is shown that Bullwhip Effect can be directly or indirectly proportional to some critical factors as majority of the organizations accept bull whip effect presence. The most parametric relationship of industry wide critical factors is substitute products/competition and seasonal effect. They basically amplify or cause distortion in the supply chain process.

Future research can be done in evaluating the critical factors according to the organization's manufacturing specialty in order to restrict this effect as farther as possible.

References

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