The Role of Forecasting Parameters in Reducing Bullwhip Effect

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Abstract **: The bullwhip effect represents the phenomenon where orders to suppliers tend to have larger variance than sales to buyers (demand distortion) it propagates upstream in supply chain management. This paper investigates the selection of appropriate forecasting parameters in reducing bullwhip effect.Demand forecasting are one of the main causes of bullwhip effect. It is examined at 24 different sceneries in each echelon of three levels supply chain to determine the optimal parameters. Minitab software using Holt-winters forecasting technique has been used for the present work. The results revealed that increase of smoothing parameter levels had significant impact on bullwhip effect.**

Keywords— ***Supply chain management, bullwhip effect, Holt-winter's forecasting .***

I. INTRODUCTION

In recent years industries have been able to significantly improve their inventory management process through the integration of information technology into their forecasting and replenishment systems and by sharing demand related information with group members. The bullwhip effect represents the phenomenon, where orders to suppliers tend to have larger variance than sales to buyers (i.e. demand distortions) propagates upstream in supply chain management.

The bullwhip effect introduced by J. Forrester (1958), sterman(1989) used the beer game, the most popular simulation of a simple production and distribution system to demonstrate bullwhip effect. Metters,lee all(1997) identified fair causes of bullwhip effect,Metters.lee(1997) identified four causes of bullwhip effect: demand forecasting, order batching, price fluctuation and supply shortages. Chee.al (2000), uses different forecasting techniques zhang (2004), investigate the impact of forecasting methods on bullwhip effect, Duc. et. al(2008)uses an arima model to study Demand evolution in supply chain , Boute & Lambench (2009) used spreadsheet simulation to show that adjusting smoothing parameter of inventory policy for optimal bullwhip effect. Similar to their study, in the following section we are going to investigate the role of adjusting the parameters of demand forecasting policy to reduce the bullwhip effect.

Based on Lee et.al (1997) there are four major Causes of the bullwhip effect:

Demand forecast updating: It refers to how an increase or decrease in demand forecast by an organization tends to become amplified in an order to a supplier. The demand forecasting "regency effect "is the human tendency to over adjust a forecast in response to a signal of changing market conditions.

Order batching: Ordering in batches is the main inventory policy in many cases. The policy results in necessity of storing higher stocks to avoid depletion.

Price fluctuation: Price increase or decrease results in unexpected behavior of customers. For example: when the price increase or decrease customer rationally buys more and vice versa. These unforeseen behaviors results bullwhip effect.

Rationing and shortage gamming:

This cause is similar to price fluctuation since when customers start buy more than their needs in order to satisfy their future needs, it results demand exceeding supply.

The paper is organizes as follows: In next section (II) problem statement and methodology. In section (III) explains quantification of bullwhip effect by design of experiments, choosing optimal range from result table is in section (IV), conclusions in section(V).

II. PROBLEM STATEMENTS:

The present work investigate role of forecasting parameters in reducing bullwhip effect and to determine optimal parameters of forecasting model.

A. Methodology

Holts-Winter exponential smoothing is applied to time series models. This method estimates forecast demand by considering three components like level, trend and seasonality. Multiplicative method has been employed because demand fluctuations are more.

B. Notations :-

L_t = level at time 't'

α= weight for the level

T_t = Trend at time 't'

β= weight for the trend

S_t = seasonal component at time t,

γ= weight of seasonal component

P = seasonal period (12months) ,

Y_t = Demand at time 't' ,F_t = Forecast value

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C. Multiplicative type model:

$Lt = \alpha(yt/st\text{-}p) + (1-\alpha)[Lt\text{-}1 + Tt\text{-}1]$ ……1

$Tt = \beta[Lt - Lt\text{-}1] + (1-\beta)Tt\text{-}1$ 2

$St = \gamma(yt/Lt) + (1-\gamma)\ St\text{-}p$ …….3

$Ft = (Lt\text{-}1 + Tt\text{-}1)\ St\text{-}p$ …….4

Using the equation 1,2,3,4 the values are forecasted in Minitab software

III. QUANTIFICATION OF BULLWHIP EFFECT:-

To analyze impact of smoothing parameter on bullwhip effect, design of experiments has been employed..

Table 1: Levels of smoothing parameters

Independent Factors	Levels					
	1	2	3	4	5	6
Smoothing parameters α	0.05	0.1	0.15	0.2	0.25	0.30
β	0.05	0.1	0.15	0.2	0.25	0.30
γ	0.05	0.1	0.15	0.2	0.25	0.30

Bullwhip effect is defined as ratio of output order rate to input consuming demand

$$\text{Bullwhip Ratio} = \frac{variance\,(order\ quantity)}{variance\ (actual\ demand)}$$

The order Quantity can be expressed as below:-

$\text{Order Quantity } (Ot) = Dt + Z\,(\sigma t)$ …….6

Where

$$\sigma t = \sqrt{\in \frac{(Dt-D)2}{n-1}} \quad …….7$$

By substituting equation 7 in equation 6 results:

$$\text{Order Quantity}(Ot) = Dt + Z\left[\sqrt{\in \frac{(Dt-D)2}{n-1}}\right] \quad ……..8$$

Where , Dt = forecasted demand , Z = constant chosen to meet desired level (1.658) , σt = standard deviation of forecasted demand , n = seasonal length.

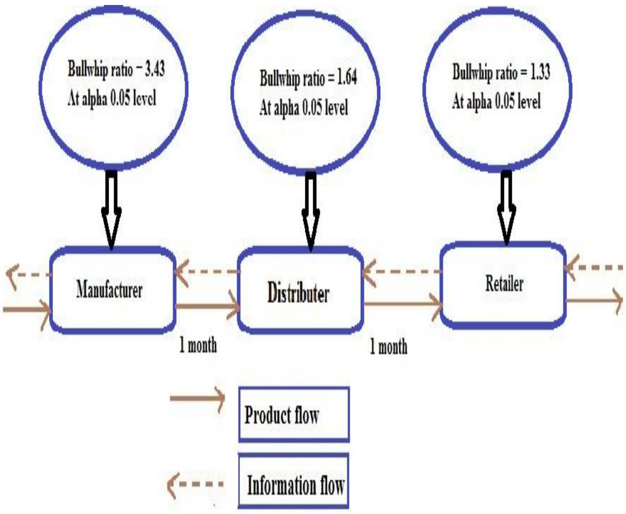


Figure 1:Bullwhip ratio at different stages of supply chain.

Table 2: Retailer Demand:

MONTH	DEMAND	MONTH	DEMAND
1	50	13	123
2	115	14	138
3	122	15	179
4	274	16	273
5	100	17	150
6	319	18	243
7	58	19	265
8	387	20	250
9	304	21	170
10	162	22	165
11	130	23	129
12	91	24	85

Example:

1st month demand = 50 units

Forecasted value = 112.028 [at $\alpha,\beta = 0.05$, $\gamma = 0.30$]

$$\text{Order Quantity} = Dt + Z\left[\sqrt{\in \frac{(Dt-D)2}{n-1}}\right]$$

= 112.028 + [1.658*(sqrt(112.028-214.747)^2)/(12-1)]

= 163.37 / month

Order quantity for 1st month is 163.37

Using “(7)” calculate variance of actual demand and order quantity

Variance of order quantity = 10760.6

$$\text{Then Bullwhip ratio} = \frac{variance(order\ quantity)}{variance\ (actual\ demand)}$$

= 10760.6/8062.9

= 1.33

Bullwhip ratio at alpha 0.05 level in retailer unit is 1.33

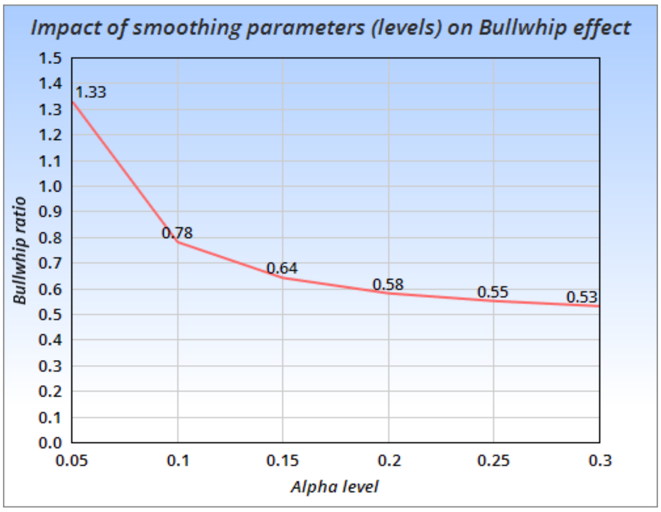
Tab 3:Interpretation of results:-

At each and every independent factors of experimental design bullwhip ratio is tabulated below:

Month	Actual Demand	Order Quantity					
		α= 0.05	α= 0.10	α= 0.15	α= 0.20	α= 0.25	α= 0.30
1	50	163.37	136.75	117.70	106.70	100	101.21
2	85	187.99	157.48	135.73	173.21	117.93	107.07
3	122	201.83	168.11	144.17	130.19	127.23	123.17
4	274	399.97	341.63	299.09	275.25	264.29	261.69
5	100	183.80	150.48	127.09	114.07	109.05	108.79
6	319	399.92	327.28	276.63	248.62	237.94	237.64
7	58	204.09	164.18	136.39	121.11	115.29	115.02
8	387	454.73	356.24	288.84	252.36	239.71	241.25
9	304	305.90	233.19	182.97	156.47	147.85	149.69
10	162	202.55	159.81	130.02	114.00	108.50	109.22
11	130	182.34	143.46	116.28	101.63	96.59	97.24
12	91	158.06	124.56	101.06	88.34	83.90	84.37
13	123	161.33	104.94	66.88	47.72	42.51	45.07
14	138	185.64	120.89	77.25	63.41	59.34	59.82
15	179	199.30	128.82	87.96	70.44	65.09	66.61
16	273	394.96	264.1	176.44	132.47	120.11	125.60
17	150	181.50	114.61	69.67	47.33	41.47	44.91
18	243	394.90	249.33	151.92	103.66	91.09	98.66
19	265	201.52	124.33	72.73	47.18	40.56	44.56
20	250	449	267.36	145.20	84.99	70.06	80.64
21	170	300.05	172.86	85.91	48.65	40.60	46.09
22	165	200	119.91	65.76	38.92	32.22	36.96
23	129	180.65	107.48	58.27	33.84	27.75	32.07
24	85	150.07	93.37	50.78	29.62	24.33	28.02
Bullwhip ratio		1.33	0.78	0.62	0.58	0.55	0.53

Table 3.1:Interpretation of results

From the table (3.1) it is observed that smoothing parameter influence forecast values as a result variance occurs in order quantity which leads to cause of bullwhip effect. The conditions of bullwhip effect are, if bullwhip ratio> 1) it causes to inventory. Demand amplification not occurs i.e. optimal at (Bullwhip ratio =1). There is no bullwhip effect means significantly smoothened when bullwhip ratio < 1). It is observed from above result table Bullwhip ratio is optimal at (0.05-0.10)levels.



From the graph it is observed smoothing parameters influence the bullwhip ratio. The bullwhip ratio decreases as (α,β) increases, as gamma(γ) value decreases bullwhip ratio increases.

IV. SMOOTHING PARAMETERS RANGE FOR OPTIMAL BULLWHIP EFFECT.

Bullwhip ratio is minimum at this range			
Supply chain stages	Smoothing constants		
	Alpha(α)	Beta(β)	Gamma(γ)
Manufacturer	0.15-0.20	0.20-0.25	Less than 0.05
Distributer	0.10-0.15	0.10- 0.15	Less than 0.05
Retailer	0.05-0.10	0.05-0.10	Less than 0.05

V. CONCLUSIONS:

Improper selection of smoothing parameters (α, β, γ) had significant impact on bullwhip effect and forecast values are employed by Holt-winters technique. The impact of gamma (γ) parameter on the bullwhip effect was relatively minor(less than 0.005) than α, β. The results reveals that lower values(less than 0.25) of alpha (α) and beta (β) parameters reduces bullwhip ratio than compared with higher values. Therefore it is concluded that appropriate selection of smoothening parameters had significantly reduces bullwhip effect.

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