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Influence of Forecasting Factors and Methods or Bullwhip Effect and Order Rate Variance Ratio in the Two Stage Supply Chain-A Case Study

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Abstract— **Bullwhip effect and order variability control in the supply chain received the widespread attention of researchers and practitioners. The present study investigate the impact of forecasting factors and methods on bullwhip effect and order rate variance ratio in two stage supply chain. Moving average, simple exponential smoothing and Holt's forecasting methods are applied and the forecast with different factors are estimated. The analysis of results shows that, the bullwhip effect increases by increasing the number of moving period for both stage of the supply chain and the bullwhip effect at manufacturing entity is relatively more than the retailer entity. The bullwhip effect is reduced when increasing the value of the smoothing constants. Moving average method yields minimal bullwhip effect than the other methods. Holt's forecasting method with α=0.3 and β=0.3 gives the minimal bullwhip effect than the 3 period moving average method. Order rate variance ratio also gives similar observation like bullwhip effect in the entire investigation. The present study outlines scope to reduce the bullwhip effect, but not eliminate the bullwhip effect.**

Index Terms— **Forecasting factor, forecast method, bullwhip effect, order variance ratio, consumer goals supply chain.**

I. INTRODUCTION

Supply chain management is an integrated activity designed to attain the maximum delivery performance at competitive cost. The efficiency of the supply chain measured in terms of number of on time delivery and reduction in inventory level. However, these measures can be controlled by monitoring the variability of sales, manufacturing and supply. The effect caused due to the fluctuation of the sales manufacturing and supply is called bullwhip effect [11]. In sufficient or excessive utilization of capacity, exclusive inventory and poor delivery performance, product an availability and revenue loss are considered as the major cause of bullwhip effect [29]. Identification, quantification and eliminating the bullwhip effect is the right way to manage the performance of supply chain.[9]categorized the bullwhip effect in to Forrester effect (Demand and lead time signal processing), Burbidge effect (order batching effect), Houlihan effect (rationing and gaming effect) and promotion effect (price fluctuation).Among the categories the bullwhip due to demand signal processing is associated with lot of complications.[1] proposed an integrated approach of discrete wavelet transform and artificial neural network (DWT-ANN) for forecast processing. It is observed from the analysis of result; the mean square error obtained from the (DWT-ANN) approach is lower than the Autoregressive moving average approach (ARIM) [4]. Bullwhip effect and Net stock amplification estimated by (DWT-ANN) model comparatively loss than ARIMA model. [4] Aimed to measure the bullwhip effect in a two stage supply chain. First order auto regressive model is applied to forecast the demand and base stock inventory policy is followed to replenish the items. Effect of auto regressive co efficient and lead time on bullwhip is studied. Analysis of result shows that the bullwhip effects increase by increasing the auto regressive co-efficient and lead time.[3] investigated the effect of auto regressive co-efficient and order lead time in the high order auto regressive demand processing. They selected two stage supply chain and followed base stock inventory policy in their proposed work. The result of numerical investigation shows that the auto regressive co-efficient and lead times have significant impact on bullwhip effect, when processing with second order auto regressive model. [11]Attempted analyse the impact of exponential smoothing forecast on the bullwhip effect in an electronic supply chain. It is observed from the result, the longer lead time and selecting poor forecasting model parameters introduce the bullwhip effect. [5] Studied the demand fluctuation caused by moving average, and exponentially weighed moving average forecasting method in a two stage supply chain single order auto regressive stochastic model is applied for demand processing. Whereas order up to inventory policy. They suggested the rules to minimize the bullwhip effect for employing these forecast methods. Discussed the impact of forecasting method on bullwhip effect for a simple replenish system. The demand is described by the first order autoregressive process and order up to the policy is followed to replenish the inventory. Analysis of the numerical [12] investigation indicates that the forecasting method offers significant influence on the bullwhip effect. [10] Developed a simulation modeling to investigate the impact of forecast method selection on bullwhip effect and inventory performance. They selected a material requirement planning (MRP) based inventory policy to replenish the items. It is found from the results of numerical investigation the MRP based policy yields better performance in terms of reduction in bullwhip effect and improvement in inventory measure when compared to the traditional order up approach. [7] Conducted a comparative study on bullwhip effect in a single stage supply chain. They applied autocorreleated demand functional model to process the demand data. Correct, moving average and exponentially

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weighed moving average forecast method are employed to amplify the bullwhip effect. The comparative study provides the optimal solution of the bullwhip effect control policy. As a further contribution, the current deals the impact of forecasting factors and methods on bullwhip effect and order rate variance ratio in two stage supply chain.

II. PRODUCER FOR CASE DESCRIPTION

The manufacturing firm considered for this study is popular for toffee manufacturing in south India. Presently the firm is struggling with excess inventory or stock problem due to order variability. As an initial step, the demand data for the highest moving product is selected. A retailer who is dealing highest quantity order also chooses for the present investigation. Supply chain is proposed with a manufacturer and a retailer. The order flow, product flow in the proposed supply chain is shown in the figure 1. Demand at manufacturer and retailer are collected for the period of August 2014 to December 2015 and the actual order from the customer for the period of January 2015 to December 2015 also collected and presented in the Table.1. Based on the old demand data from the retailer and manufacturer (January 2014 to December 2014), the forecast for the period from January 2015 to December 2015 are estimated by using moving average, simple exponential smoothing and Holt's forecasting method. Bullwhip effect and order rate variance ratio are evaluated from the forecast estimation and actual order from the customer for the period of January 2015 to December 2015.

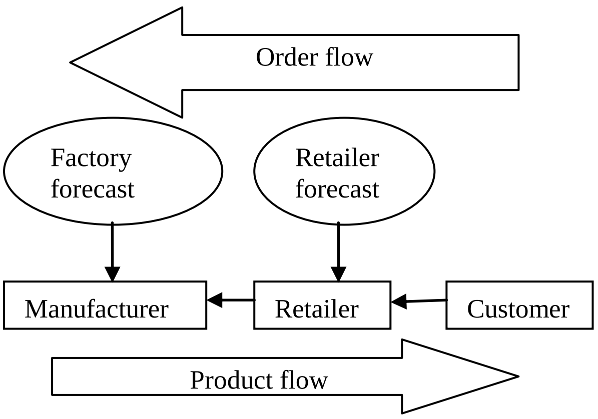

Figure 1. Two stage supply chain

III. EXPERIMENTAL INVESTIGATION

Past demand data from the retailer and manufacturer for the period of August 2013 to December 2014 (Shown in Table.1.) is used to estimate the demand forecast for the period of January 2015 to December 2015. Moving average, simple exponential smoothing and Holt's forecasting methods are applied to estimate the forecast. Moving average forecast is estimated with 3 periods, 4 periods and 5 periods

Table. 1: Retailer demand, manufacturer demand and customer order

Year	Month	Retailer Demand	Manufacturer demand	Year	Month	Customer order
2014	Aug	975	1005	Xxxx	xxxx	xxxx
	Sep	1085	950	Xxxx	xxxx	xxxx
	Oct	920	870	Xxxx	xxxx	xxxx
	Nov	1025	1020	Xxxx	xxxx	xxxx
	Dec	920	940	Xxxx	xxxx	xxxx
2015	Jan	855	1080	2015	Jan	970
	Feb	925	930		Feb	890
	Mar	1125	850		Mar	1100
	Apr	1080	1020		Apr	930
	May	1200	1230		May	1170
	June	1010	1050		June	960
	July	890	1010		July	940
	Aug	930	870		Aug	850
	Sep	1160	945		Sep	1120
	Oct	890	875		Oct	920
	Nov	975	1035		Nov	1020
	Dec	880	1130		Dec	940

moving averages. Exponential smoothing forecast also estimated with different smoothing constants (α=0.1,α=0.2 and α=0.3). Further, the Holt's forecast method used with different smoothing constants for level (α) and smoothing constants for trend (β) ie. (α=0.1;β =0.1, α=0.2;β =0.2and α=0.3;β =0.3). All the forecast values related to retailer and manufacturer are displayed in the Table 2 and Table 3 respectively. Bullwhip effect and order rate variance ratio are evaluated from the forecast estimation for the period from January 2015 to December 2015 and actual order from the customer for the period of January 2015 to December 2015. The relation for the Bullwhip effect and order rate variance ratio for the retailer and manufacturer are given in the equation 1 to 4.

$$BUE_{(Retailer)} = \frac{Variance\ of\ the\ order}{variance\ of\ the\ retailer\ forecast} --------(1)$$

$$BUE_{(Manufacturer)} = \frac{Variance\ of\ the\ order}{variance\ of\ the\ Manufacturer\ forecast} --------(2)$$

$$ORVR_{(Retailer)} = \frac{Variance\ of\ the\ order / \left(Average\ of\ the\ order\right)^2}{Variance\ of\ the\ \text{Retailer forecast} / \left(Average\ of\ the\ \text{Retailerforecast}\right)^2} ---------(3)$$

$$BUE_{(Manufacturer)} = \frac{Variance\ of\ the\ order / \left(Average\ of\ the\ order\right)^2}{Variance\ of\ the\ \text{Manufacturer forecast} / \left(Average\ of\ the\ \text{manufacturer forecast}\right)^2} ---------(4)$$

Period	3MA	4MA	5MA	ES (α=0.1)	ES (α=0.2)	ES (α=0.3)	Holt 's (α=0.1, β=0.1)	Holt 's (α=0.2, β=0.2)	Holt 's (α=0.3, β=0.3)
Jan-15	943.3	945	957	935	945	925	904.2	912.85	895.3
Feb-15	1013.3	977.5	972	933	943	925	905.96	913.47	900.9
Mar-15	983.3	992.5	968	971.4	961.2	985	956.8	936.08	985
Apr-15	953.3	950	964	993.1	973.1	1013.5	992.7	952.97	1038
May-15	933.3	970	964	1034.5	995.8	1069.5	1054	982.4	1114.8
Jun-15	1033.3	1007.5	1022	1029.6	997.2	1051.7	1063.2	990.67	1080.5
Jul-15	1100	1037.5	1016	1001.7	986.5	1003.2	1039.3	984.6	1028.25
Aug-15	1096.6	1077.5	1032	987.4	980.9	981.2	1023.9	983.04	994.42
Sep-15	976.6	1040	1036	1021.9	998.8	1034.8	1039.1	1006.47	1032.7
Oct-05	941.6	968.75	1021	995.6	987.9	991.4	1002	998.5	966
Nov-15	896.6	925	950	991.5	986.6	986.5	987.8	999.7	945.5
Dec-15	951.6	931.25	947	969.2	975.9	954.6	953.5	990.96	895.9

Table .2: Demand forecast for the retailer

Period	3MA	4MA	5MA	ES (α=0.1)	ES (α=0.2)	ES (α=0.3)	Holt 's (α=0.1, β=0.1)	Holt 's (α=0.2, β=0.2)	Holt 's (α=0.3, β=0.3)
Jan-15	955	987.5	985	935	945	925	904.2	912.85	895.3
Feb-15	933.3333	930	961	933	943	925	905.96	913.47	900.9
Mar-15	900	931.25	929	971.4	961.2	985	956.8	936.08	985
Apr-15	968.3333	956.25	970	993.1	973.1	1013.5	992.7	952.97	1038
May-15	1043.333	996.25	981	1034.5	995.8	1069.5	1054	982.4	1114.8
Jun-15	1135	1082.5	1037	1029.6	997.2	1051.7	1063.2	990.67	1080.5
Jul-15	1096.667	1103.75	1068	1001.7	986.5	1003.2	1039.3	984.6	1028.25
Aug-15	1033.333	1045	1061	987.4	980.9	981.2	1023.94	983.04	994.42
Sep-15	943.3333	1007.5	1022	1021.9	998.8	1034.8	1039.05	1006.5	1032.7
Oct-05	993.3333	997.5	1038	995.6	987.9	991.4	1002.04	998.5	966
Nov-15	993.3333	967.5	976	991.5	986.6	986.5	987.8	999.7	945.5
Dec-15	1008.333	988.75	969	969.2	975.9	954.6	953.5	990.96	895.9

Table .3: Demand forecast for the manufacturer

IV. RESULT AND DISCUSSION

The impact of the moving period on the bullwhip effect is shown in figure 2. Bullwhip effect increases by increasing the number of moving period for both stage of the supply chain. It is due to the fact that the longer duration in moving period or lead time induces the variability in the demand. The Figure 2, the bullwhip effect at manufacturing entity is relatively more than the retailer entity. Figure 3 depicts the influence of the moving period on the order rate variance ratio. Increase in moving period, the increase the bullwhip effect. It may be noticed from the figure 3, the order rate variance ratio is more at the retailer end when compared to the factory. Figure 4 indicates that, the impact of the smoothing constant on bullwhip effect. It is also observed.

From the figure 4, the bullwhip effect is reduced when increasing the value of the smoothing constant. Bullwhip effect at the retailer entity less than manufacturer entity when α=0.1 and α=0.2, whereas at α=0.3 the manufacturer entity have more bullwhip effect than retailer

It is observed from the figure 5, the order rate variance ratio also indicate the similar observation made by the bullwhip effect.

Figure 6 shows the effect of smoothing constants (α and β) in the Holt's forecast method on bullwhip effect. The increase in smoothing constants (α and β) reduce the bullwhip effect. The figure 6 also disclose that, the bullwhip effect at manufacturing entity is more than the retailer stage when α=0.1 and β=0.1. For, other values of smoothing constants, the Bullwhip effect at retailer end is more when compared to the manufacturer end. In figure 7, the order rate variance ratio also reflects the same observation.

Impact of forecasting method on bullwhip effect is illustrated in the figure 8. The moving average method yields minimal bullwhip effect than the other methods. Higher bullwhip effect is recorded, when using the exponential smoothing forecast method with the smoothing constant of α=0.1. Holt's forecasting method with α=0.3 and β=0.3. Gives the minimal bullwhip effect than the 3 period moving average method. Figure 9, also express similar indication like bullwhip effect.

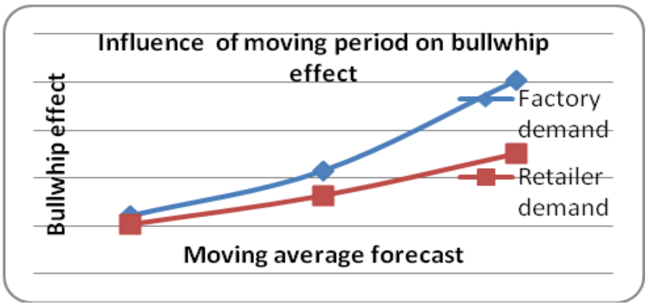

Figure 2. Influence of moving period on bullwhip effect

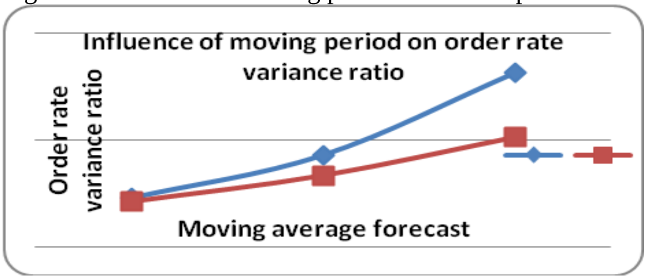

Figure 3. Influence of moving period on order rate variance ratio

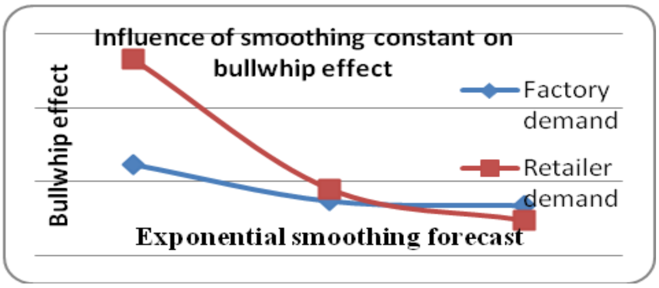

Figure 4. Influence of smoothing constant on bullwhip effect

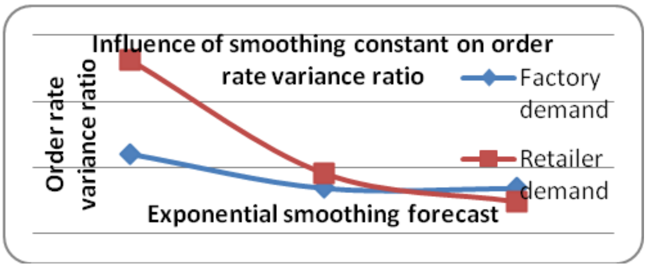

Figure 5. Influence of smoothing constant on order rate variance ratio

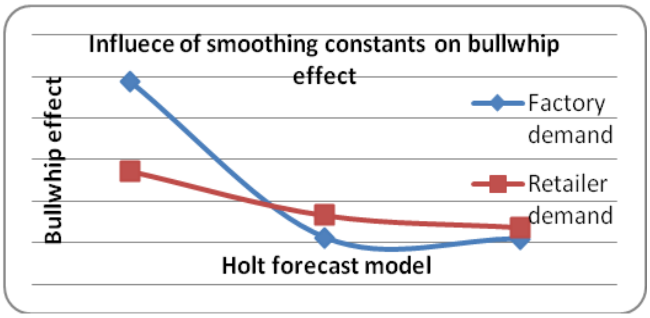

Figure 6. Influence of smoothing constants (α and β) on bullwhip effect

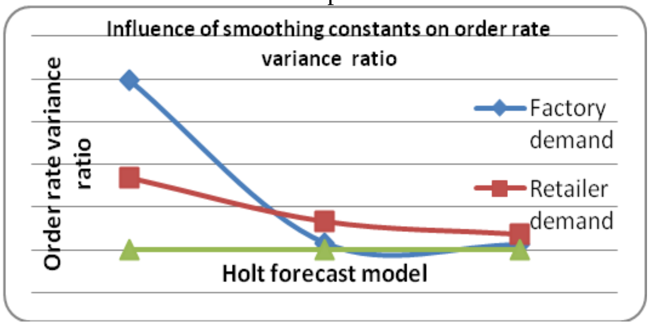

Figure 7. Influence of smoothing constants (α and β) on order rate variance ratio

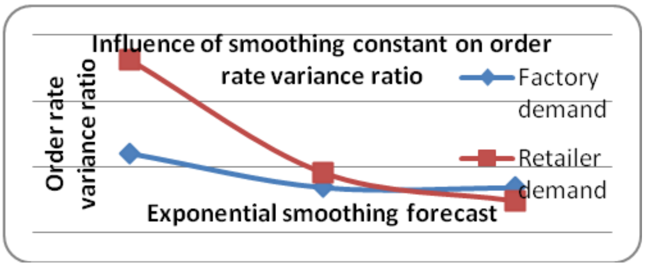

Figure 5. Influence of smoothing constant on order rate variance ratio

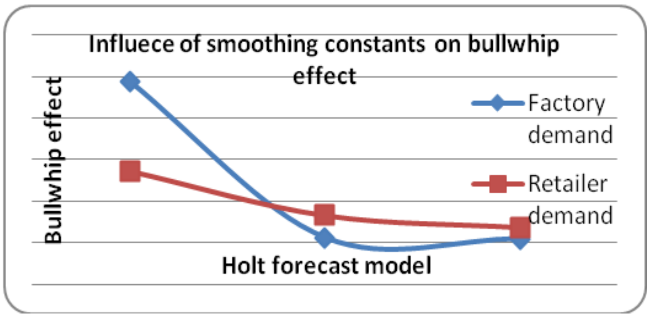

Figure 6. Influence of smoothing constants (α and β) on bullwhip effect

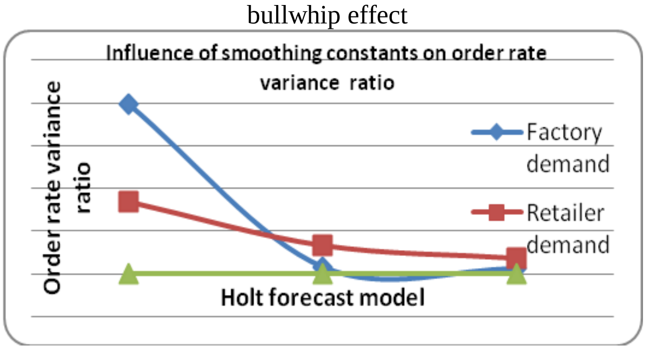

Figure 7. Influence of smoothing constants (α and β) on order rate variance ratio

V. CONCLUSION

From the experimental investigation the following conclusions are drawn. Moving average, simple exponential smoothing and Holt's forecasting methods are applied and the forecast with different factors are estimated. Bullwhip effect increases by increasing the number of moving period for both stage of the supply chain and the bullwhip effect at manufacturing entity is relatively more than the retailer entity. The bullwhip effect is reduced when increasing the value of the smoothing constant. Increase in smoothing constants (α and β) reduce the bullwhip effect while using

Holt's method. The moving average method yields minimal bullwhip effect than the other methods. Higher bullwhip effect is recorded, when using the exponential smoothing forecast method with the smoothing constant of $\alpha=0.1$. Holt's forecasting method with $\alpha=0.3$ and $\beta=0.3$ gives the minimal bullwhip effect than the 3 period moving average method. Order rate variance ratio also gives similar observation like bullwhip effect in the entire investigation. The present study outlines scope to reduce the bullwhip effect, but not eliminate the bullwhip effect. This preliminary study directs the future work like the evaluation of net stock amplification and inventory performance. Investigation effect of bullwhip effect, when extending the stage of supply chain could be an interesting area of further research.

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