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DEMAND DISRUPTION IN CENTRALIZED AND DECENTRALIZED SUPPLY CHAIN WITH COMPETING RETAILERS FACING EXPONENTIAL DEMAND

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ABSTRACT
In this paper we study the price competition in centralized and decentralized supply chain. One supplier and two competing retailers are considered under demand disruption. The market demand is considered to be exponential. The effect of the probability of demand disruption on retail prices and wholesale price of supplier has been discussed. It is found that profits of retailers, suppliers and the total profit of supply chains reduces with the probability of demand disruption. The profit of centralized supply chain is found to be higher as compared to decentralized supply chain.

KEYWORDS: Demand disruption, Supply chain management, Exponential demand

INTRODUCTION
Decision making in a supply chain network can be performed in a centralized or a decentralized way. In a centralized structure, there exsit a central authority responsible for decision making, where as in a centralized structure the individual entities can make their own decisions. In practice no supply chain can be completely centralized or decentralized and both approaches have their advantages and disadvantages. Most commonly the strategic decisions are usually made centrally and operations decisions are decentralized. The effect of centralization in different supply chain problems have been studied in the past using different approaches. Chen and Chen (2005) studied the effect of centralization and decentralization on the multi-item replenishment problem in a two echelon supply chain. They proposed both the centralized and decentralized decisions model and proved the optimal properties of both the models to minimize the cost. Duan and Liao (2013) determined the optimal replenishment policies of capacitated supply chains operating under the centralized and decentralized control using a simulation based optimization framework. They concluded that it is beneficial to adopt centralized control and proposed a mechanism to coordinate the decentralized system so that the each player in the supply chain is benefited. Demand disruption in supply chain is an important issue to be studied. Uncertainty plays an important role in the modern supply chain system. Handling uncertainty in a efficient and effective way is becoming more and more to the success of supply chain management. The disruption in demand is caused by some haphazard events, such as the promotion of sale, the raw material shortage, the new tax or tariff policy, machine breakdown, and so on. The disruption management studies the situation when an operation plan has to be made before the disruption is resolved, and deviation cost will be occurred for revising the operational plan in its execution period with the resolution of the demand disruption, hence all the retailers and suppliers in the entire supply chain will be severely affected by these demand disruption. The demand disruption cannot be determined (Xu et (2003), Yang andYu(2005)). Price competition is one of many ways that a product or service can compete in the market place. In price competition, two products which are substantially similar are judged by prospective consumers on their respective pricing, with the purchase made mostly on the basis of which is cheaper. Other forms of competition are always in play, however ,and will affect the price competition. Xiao et al. (2005) studied the coordination of a supply chain system with one manufacturer and two competing retailers when there are demand disruptions. A price subsidy rate contract is considered to coordinate the investments of the competing retailers with sales promotion opportunities and demand disruptions. . Zhang et al.(2012) studied the coordination of a supply chain with one manufacturer and two retailers under demand disruptions by revenue sharing contracts. A variety of mathematical forms have been developed to charactering demand functions which depends on firm's operational and marketing activities. Such demand functions are being used by researchers in economics and different functional areas of business. Several theoretical demand models have been developed from various perspectives to investigate the impact of price on the consumer demand and to examine firm's optimal pricing decisions for the setting with

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monopolistic or multiple competitive firms. The linear model is extensively used in the literature because it gives rise to explicit results for the optimal solution and it is relatively easy to estimates its parameters in an empirical study. On the other hand, in most practical cases the assumption of linear demand function and requirement of finite upper bound on the price do not correspond to reality. Some researchers have used exponential demand functions in supply chain management problems. Huang et al. (2006) investigated disruption management for supply chain coordination with exponential demand function. Chai Wenlong et al. (2013) explored the effects of demand disruption uncertainty on the supply chain. A linear demand function is considered in this their study. In this study we have studied the demand disruption of a supply chain. The supply chain consists of a single supplier and two retailers. The retailers compete in the market. The particular interest is the occurrence probability of demand disruption on each retailer. The market demand is assumed to be exponential.

METHODOLOGY

We consider the supply chain which consists of one supplier and two competing retailers. The supply chain is centralized or decentralized. In centralized supply chain the supplier 'owns' her two exclusive retailers and in decentralized supply chain the seller sells the product to market through retailers. In the formulation of the problem we follow the following notations:

w_0: the unit wholesale price of the supplier,
a_i: the market scale for retailer i ,
p_i : the retail price for retailer i ,
Q_i: the market demand for retailer i,
φ_i: the probability of demand disruption on retailer i,
π_i: the profit of retailer i,
π_0: the profit of supplier,
Π: the total profit of the supply chain,

An exponential demand function is assumed and retailer i is given as

$$Q_i(p_i, p_j) = a_i e^{(-\beta p_i + d_i p_j)} \quad (1)$$

i,j =1,2 , i is not equal to j

Where d_i is the measure of sensitivity of the i th retailer's sales to the change of the j the retailer's price.

The linearized form of the demand function given in (1) can be written as

$$Q_i(p_i, p_j) = \log(a_i) - \beta p_i + d_i p_j \quad (2)$$

The market scale or the demand for retailer-i will change with an occurrence of demand disruption , the demand function of retailer-i can be written as

$$Q'_i(p_i, p_j) = \log(a'_i) - \beta p_i + d'_i p_j \quad (3)$$

Where a'_i and d'_i are the market scale for retailer-i and the substitutability coefficient under demand disruption respectively. a'_i and d'_i are assumed to be:

$$a'_i = a_i + \Delta a_i \quad (4)$$

$$d'_i = d_i + \Delta d_i \quad (5)$$

Demand disruption in decentralized supply chain

The profit of suppler is given as

$$\Pi_0 = w_0 [\{\log(a_1 + \Delta a_1) - \beta p_1 + (d1 + \Delta d_1) p_2\} \varphi_1 + \{\log(a_1 - \beta p_1 + d_1 p_2\} (1-\varphi_1) + \{\log(a_2 + \Delta a_2) - \beta p_2 + (d_2 + \Delta d_2) p_1\} \varphi_2 + \{\log(a_2 - \beta p_2 + d_2 p_1\}(1-\varphi_2)] \quad (6)$$

The profit of supplier is given as

$$\Pi = (p_1 - w_0) [\{\log(A_1) - \beta p_1 - D_1 p_2\} \varphi_1 + \{\log(a_1) - \beta p_1 + d_1 p_2\}(1-\varphi_1)] + (p_2 - w_0)[\{\log(A_2) - \beta p_2 + D_2 p_1\} \varphi_2 + \{\log(a_2) - \beta p_2 + d_2 p_1\}(1-\varphi_2)] \quad (7)$$

Where A_1, A_2, D_1, and D_2 are given as:

$A_1 = a_1 + \Delta a_1$,
$A_2 = a_2 + \Delta a_2$,

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$D_1 = d_1 + \Delta d_1$
$D_2 = d_2 + \Delta d_2$
Differentiating equation (7) partially w.r.t p1 and p_2 and equating to zero we get simultaneous equations in p_1 and p_2. Solving these equations the optimal values of p_1 and p_2 are obtained which are given bel0w.

$$P_1 = c_1 + w_0\, c_2/\delta \quad (8)$$
$$P_2 = c_3 + w_0\, c_4/\delta \quad (9)$$

Where c1, c_2, c3, c_4 and δ are given as:

$$c_1 = 1/\delta[\,2\beta\{\log(A_1)\,\varphi_1 + \log(a_1)(1-\varphi_1)\} + \{\log(A_2)\varphi_2 + \log(a_2)(1-\varphi_2)\,\}\{D_1\varphi_1 + d_1(1-\varphi_1) + D_2\varphi_2 + d_2\,(1-\varphi_2)\}]\,,$$
$$c_2 = 1/\delta\,[\{D_1\varphi_1 + d_1\,(1-\varphi_1) + D_2\,\varphi_2 + d_2\,(1-\varphi_2)\}\{\beta - D_1\varphi_1 - d_1(1-\varphi_1)\} + 2\beta\{\beta - D_2\varphi_2 - d_2\,(1-\varphi_2)\}],$$
$$c_3 = 1/\delta[\,2\beta\{\log(A_2)\,\varphi_2 + \log(a_2)(1-\varphi_2)\} + \{\log(A_1)\varphi_1 + \log(a_1)(1-\varphi_1)\}\{D_2\varphi_2 + d_2\,(1-\varphi_2) + D_1\varphi_1 + d_1\,(1-\varphi_1)\}]\,,$$
$$c_4 = 1/\delta\,[\{D_2\,\varphi_2 + d_2\,(1-\varphi_2) + D_1\varphi_1 + d_1\,(1-\varphi_1)\}\{\beta - D_2\,\varphi_2 - d_2(1-\varphi_2)\} + 2\beta\,\{\beta - D_1\varphi_1 - d_1\,(1-\varphi_1)\}],$$
$$\delta = 4\,\beta^2 - [D_1\varphi_1 + d_1\,(1-\varphi_1) + D_2\,\varphi_2 + d_2\,(1-\varphi_2)]^2,$$

The optimal price of supplier is obtained as follows.
Substituting the values of p1 and p_2 from equations (8-9) in to equation (7)
We obtain the following equation.

$$\text{Л}_0 = w_0\,[\log(A_1)\,\varphi_1 + \log(a_1)(1-\varphi_1) + \log(A_2)\,\varphi_2 + \log(a_2)(1-\varphi_2) + \{D_2\varphi_2 + d_2\,(1-\varphi_2) - \beta\}\{c_1 + c_2 w_0/\delta\} + \{D_1\varphi_1 + d_1(1-\varphi_1) - \beta\}\{c_3 + c_4\, w_0/\delta\}\,] \quad (10)$$

The value of w_0 of which optimize л_0 is obtained using the principle of calculus and is given as

$$w = \delta[\{\beta - D2\varphi_2 - d_2(1-\varphi_2)\}c_1 + \{\beta - D_1\varphi_1 - d_1(1-\varphi_1)\}c_3 - \{\varphi_1\log(A_1) + (1-\varphi_1)\log(a_1) + \varphi_2\log(A_2) + (1-\varphi_2)\log(a_1)\}]\,/[D_2\varphi_2 + d_2(1-\varphi_2) + c_2 + D_1\varphi_1 + d_1(1-\varphi_1)\,c_4\,] \quad (11)$$

Where w denotes the critical value of w_0 which optimizes w_0 .The value of w given in equation (11) is substituted in equations (8-9) in place of w_0 to obtain the optimal values of p_1 and p_2. The values of w, p_1 and p_2 thus obtained are substituted in equations (6-7) to obtain the optimal values of prices of retailers and the supply chain. Demand disruption in centralized supply chain In centralized supply chain the supplier determines the retail prices of her retailers so as to maximize the profit of the supply chain. The total profit of the centralized supply chain is defined as

$$\Pi = p_1[\,\{\log(A_1) - \beta p_1 + D_1 p_2\}\varphi_1 + \{\log(a_1) - \beta p_1 + d_1 p_2\}(1-\varphi_1)\,] + P_2\,[\{\log(A_2) - \beta p_2 + D_2 p_1\}\varphi_2 + \{\log(a2) - \beta p_2 + D_2 p_1\}(1-\varphi_2)] \quad (12)$$

The optimal values of p_1 and p_2 which optimizes the centralized supply chain can be obtained by the method described in section 3.1.
The optimal prices for retailers in centralized supply chain thus obtained are given below.

$$P_1 = [\{D_1\varphi_1 + d_1(1-\varphi_1) + D_2\,\varphi_2 + d_2(1-\varphi_2)\}\{\log(A_2)\,\varphi_2 + \log(a_2)(1-\varphi_2)\} + 2\beta\,\{\log(A_1)\,\varphi_1 + \log(a_1)(1-\varphi_1)\}]\,/\delta \quad (13)$$
$$P2 = [\{D_1\varphi_1 + d_1\,(1-\varphi_1) + D_2\,\varphi_2 + d_2(1-\varphi_2)\}\{\log(A_1)\,\varphi_1 + \log(a_1)\,(1-\varphi_1)\} + 2\beta\,\{\log(A_2)\,\varphi 2 + \log(a_2)(1-\varphi_2)\}]\,/\delta \quad (14)$$

With these values of optimal prices of retailers, the profit of centralized supply chain can be obtained.
Numerical example
The price competition of a supply chain with one supplier and two competing retailers under demand disruption is illustrated with the help of the following numerical example;
$a_1 = a_2 = 20$, d1=0.5, d_2 0.4, $\Delta a_1 = \Delta a_2 = -8$.
These parameters are taken from numerical example from Chai et al. (2013).

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Fig.1 (a) shows the decrease in optimal prices of retailers in decentralized supply chain when there is a demand disruption for retailer-1. The probability of demand disruption varies from 0 to 1. The probability of demand disruption for retailer-2 is fixed at 0.1 the figure shows a steep decrease in the optimal price of retailer-1. This reduction in the prices is due to the less demand with the probability of demand disruption for retailer-1. Fig.1 (b) shows the decrease in the optimal prices of retailers and the wholesale price of the supplier. The supplier also reduces the wholesale price to share the demand disruption.

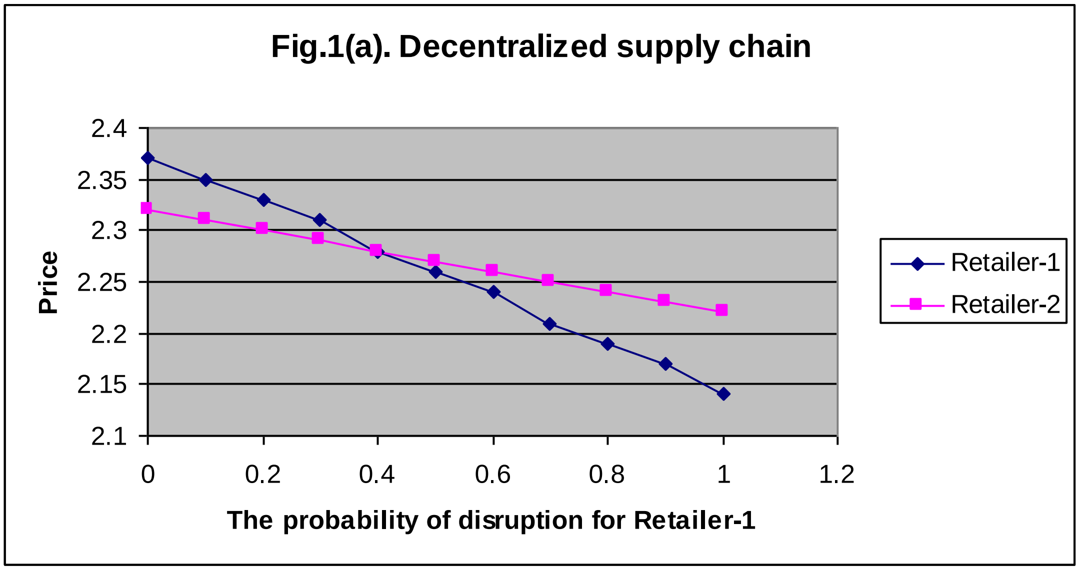

FIG. 1(a).Decentralized Supply Chain

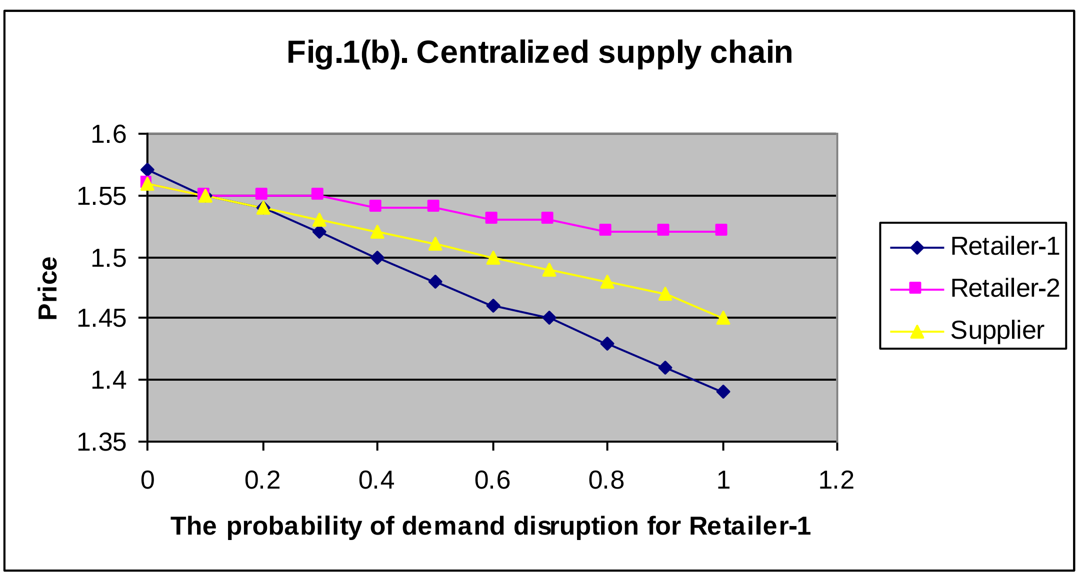

FIG. 1(B) Centralized Supply Chain

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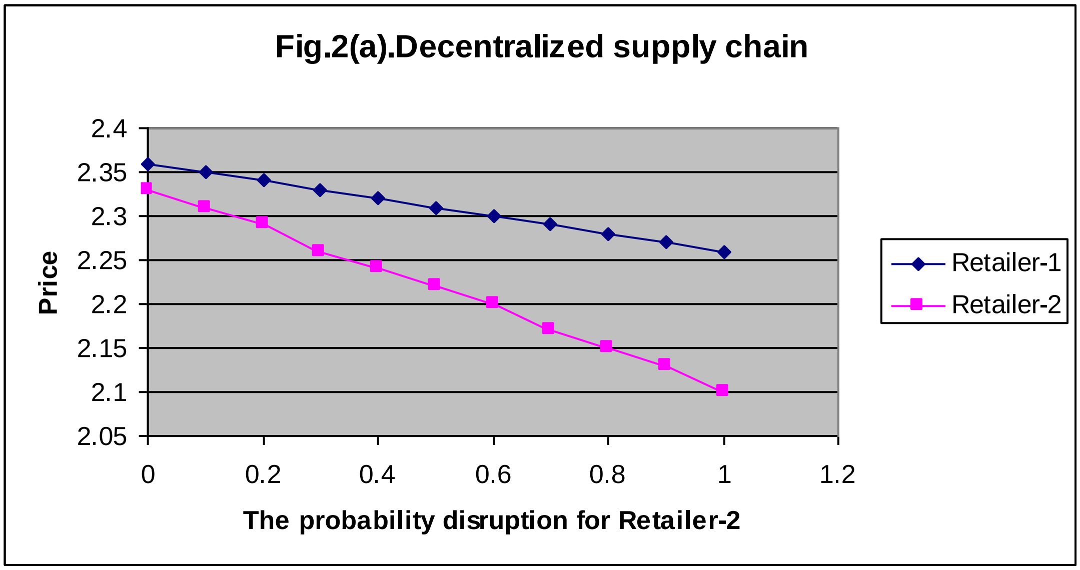

FIG. 2(a) Decentralized Supply Chain

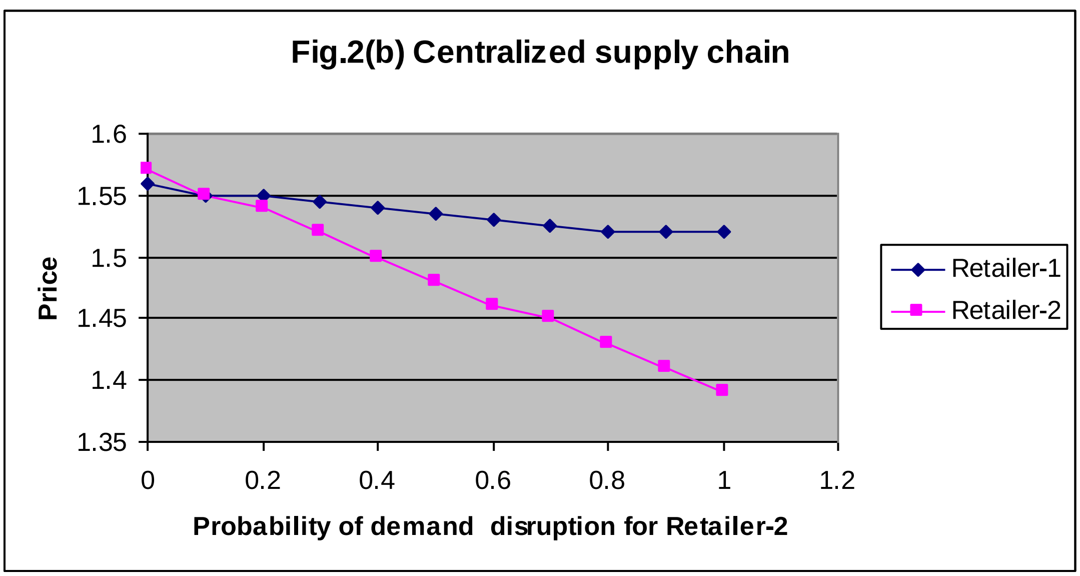

FIG. 2(b) Centralized Supply Chain

The effect of demand disruption for retailer-2for decentralized supply chain is shown in Fig.2 (a). The probability of demand disruption for retailer-2 varies from 0 to 1. The probability of demand disruption for retailer-1 is assumed to be 0.1 there is a substantial decrease in the price of retailer-2. The reason for decrease is same as explained earlier. The figure also shows a decrease in the optimal price of retailer-1. The similar trend of decrease in prices is observed for centralized supply chain as shown in Fig.2 (b).

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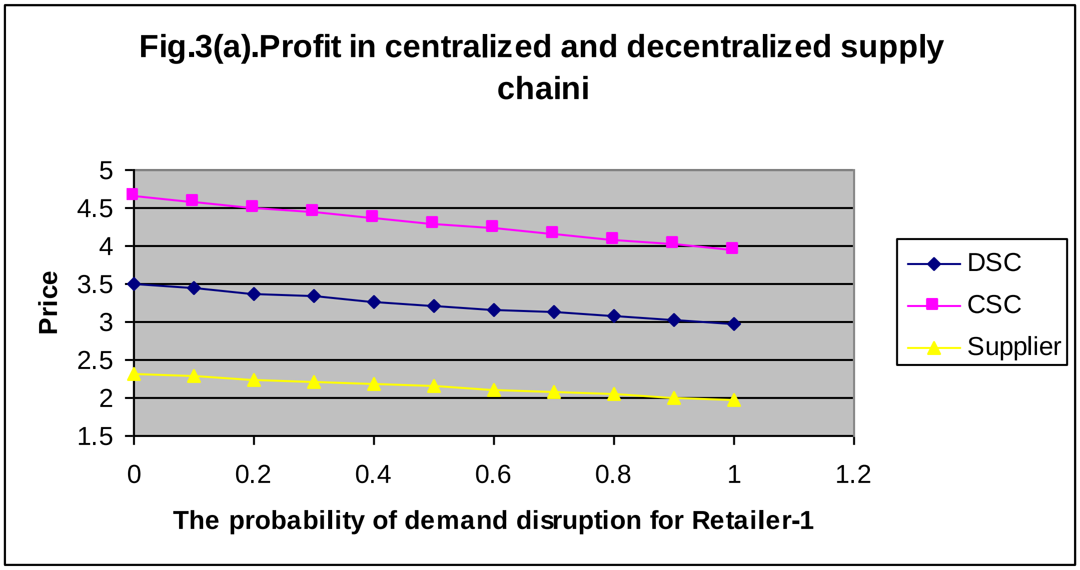

FIG. 3(a) Profit In Centralized And Decentralized Supply Chain

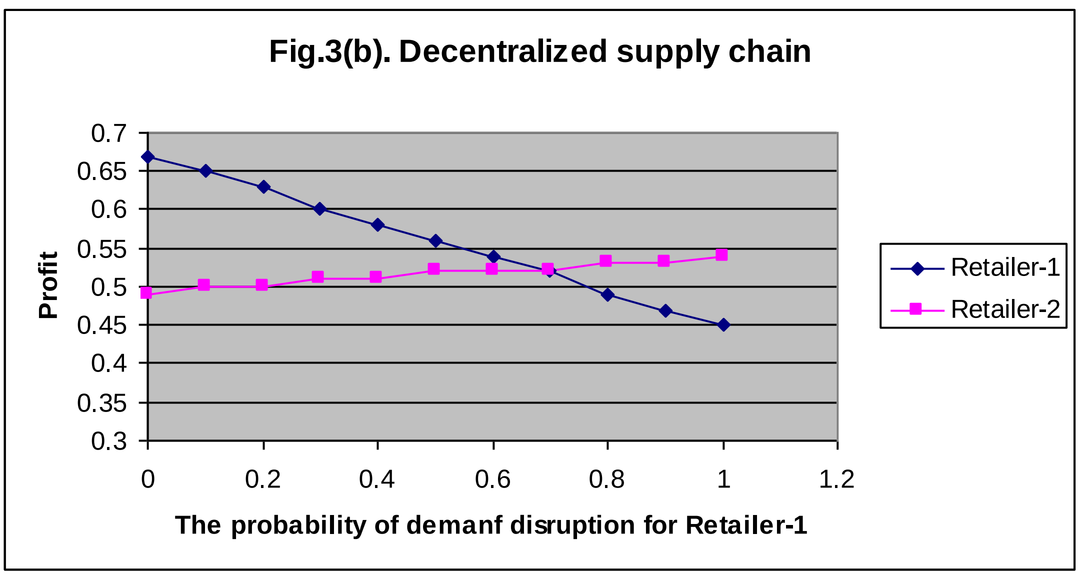

FIG. 3(B) *Decentralized Supply Chain*

The Profits of centralized and decentralized supply chains and of wholesale price of supplier in case of demand disruption for rtailer-1 are shown in Fig.3 (a). The probability of the demand disruption varies from 0 to 1. The probability of demand disruption for retailer-2 is fixed at 0.1. The profit in centralized supply chain is higher in compared to decentralized supply chain. The profits decrease with the demand disruption. Fig.3 (b) shows the profits of retailers in decentralized supply chain in case of demand disruption for retailer-1. It is found that the profit of

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retailer-1 decreases with an increase of probability of demand disruption for retailer-1 while there is an increase in the profit of retailer-2.

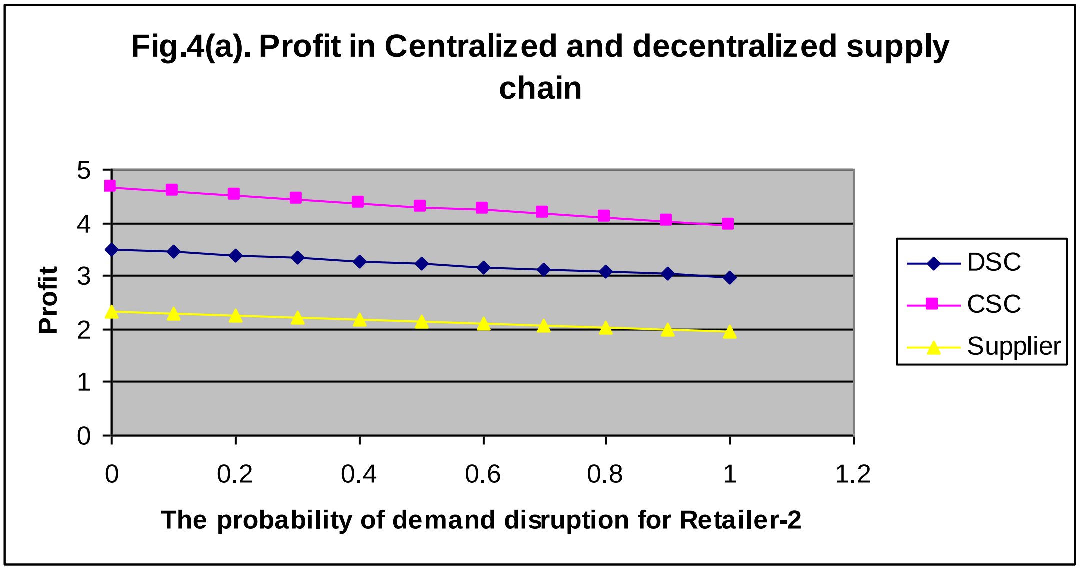

FIG. 4(a) Profit In Centralized And Decentralized Supply Chain

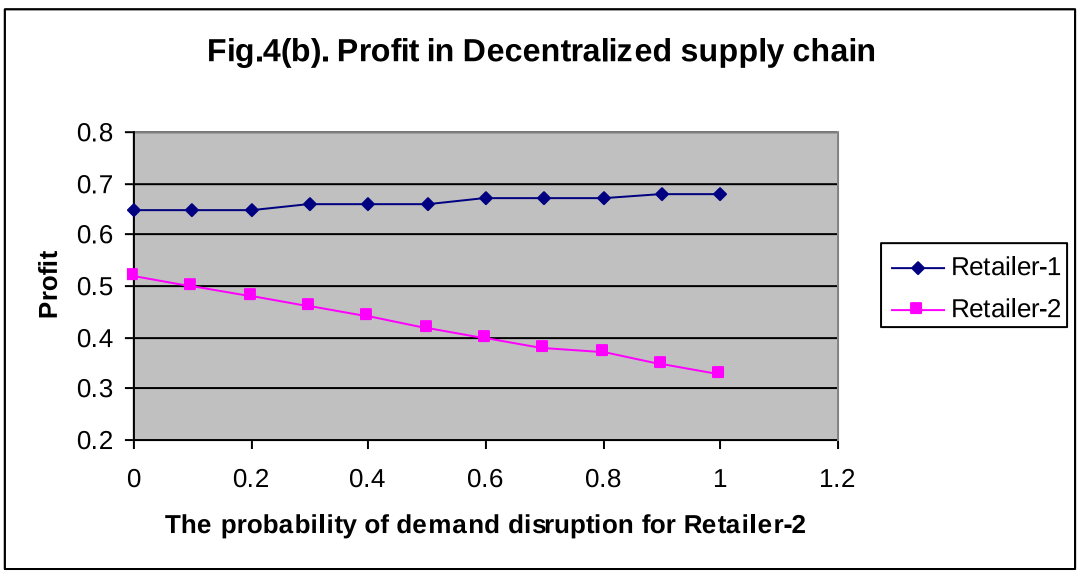

FIG. 4(b) Profit In Decentralized Supply Chain

Fig.4 (a) shows the profits in case of the demand disruption for retailer-2 in centralized supply chain. The probability of demand disruption for retailer-2 varies from 0 to 1. The probability of demand disruption for retailer-1 is fixed at 0.1. The figure shows that the profits of centralize and decentralized supply chains decreases with an

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increase in the probability of demand disruption. The profit of supplier also decreases with demand disruption. The profits of retailers in decentralized supply chain is shown in
Fig.4 (b). In this case the profit of retailer-2 decreases and an increase in the profit of retailer-1 is depicted.

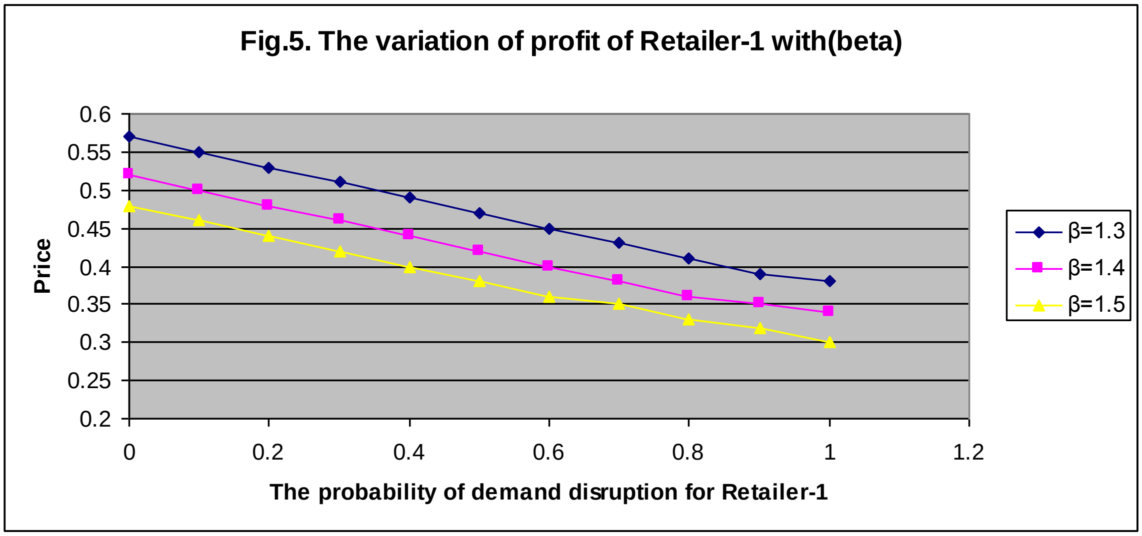

FIG. 5 The Variation Of Profit Of Retailer-1 WITH (Beta)

Fig.5 presents the variation of profit of retaile-1 with β for probability of demand disruption for retailer-1. The probability of demand disruption varies from 0 to 1. In this case also the probability of demand disruption for retailer-2 is fixed at .1. The figure illustrates that the profit decreases for higher values of β. The decrease in profit as the probability of demand disruption increases from 0 to 1 was calculated. It is found to be 33.3%, 34.6%, and 37.0% for β equal to 1.3, 1.4 and 1.5 respectively. Fig.6 shows the same analysis for retailer-2. In this case also it is found that the decrease in profit is large as the parameter β increases.

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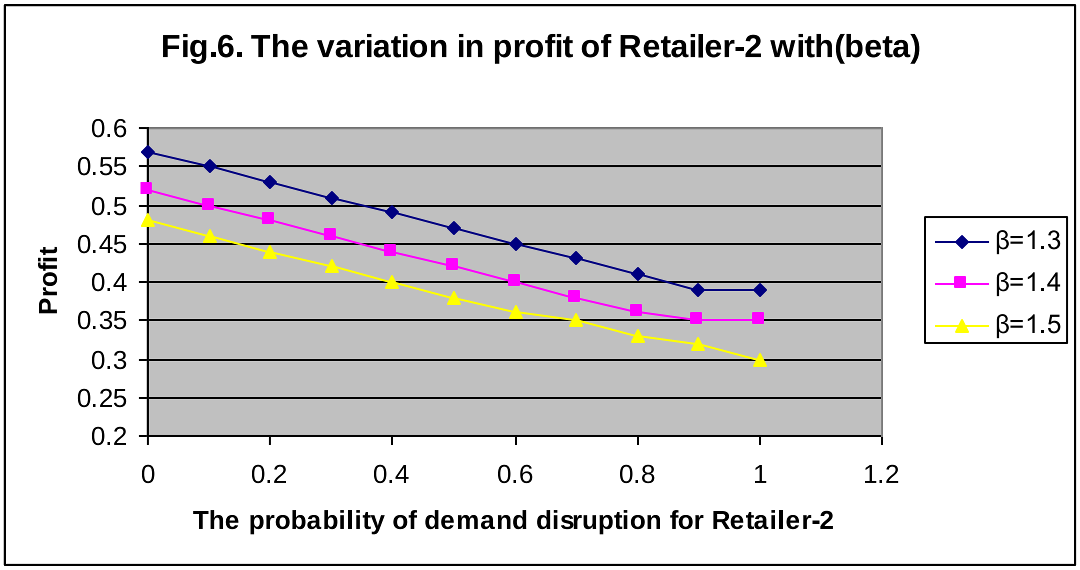

FIG.6 ***THE VARIATION IN PROFIT OF RETAILER-2 WITH(BETA)***

CONCLUSION

The price competition in centralized and decentralized supply chain has been discussed in this study. The model is developed with one supplier and two competing retailers under occasional demand disruption. The market demand is assumed to be exponential. We have found that the price of retailer for which the demand disruption occurs decreases rapidly as the probability of the demand disruption increases. It is found that the profit of retailers, suppliers and total supply chain decreases with the demand disruption. The profit of centralized supply chain is higher as compared to decentralized supply chain.

REFERENCES

[1] Chen, F.Y. Ray, S. and Song, Y.Y., 2006. Optimal pricing and inventory control of revenue management system with dynamic pricing facing linear demand. Optimal Control Application and Methods, 27,323-347.

[2] Chai Wenlong, Sun Huijun, Weiwang, Jianjun Wu, 2013. Price competition model in decentralized and centralized supply chains with demand disruption. Journal of Industrial Engineering and Maqnagement, 6(1), 16-24.

[3] Chen, J.M.and Chen, T.H., 2005.The multi-item replenishment problem in a two echelon supply chain: the effect of centralization versus decentralization. Computers and Operations Research, 32,3191-3207.

[4] Duan, Q. and Warren,Liao.,T.,2013. Optimization of replenishment policies for decentralized and centralized supply capacitated supply chains under various demands. International Journal of Production Economics, 142,194-204.

[5] Fibich, G., Garvious, A. and Lowengrat, O., 2003. Explicit solutions of optimization models and differential games with non smooth reference price effect. Operations Research, 51(5), 721-734.

[6] Huang, C., Yu, G., Wang, S. and Wang,X.,2006. Disruption management for supply chain coordination with exponential demand function. Acta Mathematica Scintia, 26,655-666.

[7] Petruzzi, N.C. and Dada, M., 1999. Pricing and the newsvendor problem: A review with extensions. Operations Research, 47(2), 183-194.

[8] Song, Y.Y., Ray, S. and Li, S.L., 2008. Structural properties of buyback contracts for price setting newsvendors. Manufacturing and Service Operations Management, 10(11), 1-18.

International Journal of Engineering Researches and Management Studies

[9] Qi, X., Bard, J.F. , and Yu, G., 2004. Supply chain coordination with demand disruption. International Journal of Management Science, 32,301-312.
[10] Song, Y.Y., Ray, S. and Li, S.L., 2008. Structural properties of buyback contracts for price setting newsvendors. Manufacturing and Service Operations Management, 10(11), 1-18.
[11] Xia0, T., Yu, G., Sheng, Z., and Xia, Y., 2005. Coordination of a supply chain with one manufacturer and two retailers under demand promotion and disruption management decision. Annals of operation Research, 135,87-109.
[12] Xu,M.,Qi,X.,Yu,G.,Zhang,H .and Gao,C. 2003. The demand disruption management for a supply chain system with nonlinear demand functions. Journal of System Science and System Engineering, 12, 82-97.
[13] Yang, J., Qi, X. and Yu, G., 2005. Disruption management in production planning. Naval Research Logistics, 52,420-445.
[14] Zhang, W., G., Fu, I., Li, H. and Xu, W., 2012. Coordination of supply chain with a revenue sharing contract under demand disruption when retailers compete. International Journal of Production Economics, 138, 68-75.