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MODELING OF TWO-ECHELON INVENTORY SYSTEM UNDER EXPONENTIAL PRICE DEPENDENT DEMAND

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ABSTRACT

In the present day scenario of globalization, the concept of supply chain management (SCM) has gained significance as one of the 21st century manufacturing paradigms for improving organizational competitiveness. In this context, a two level supply chain model is developed considering a single manufacturer and single retailer. The main objective of this research is to demonstrate the optimality of the decision variables and objective function for respective entities as well as for the entire chain under exponential price dependent demand. The mathematical model is developed in two fold. First, the expression for the total variable cost of the retailer and manufacturer is developed independently and then for the entire supply chain as a function of ordering/set up costs and carrying costs. Numerical example is devised and the computer program is written in MATLAB. The model is solved for optimality of inventory level, number of shipments and the total relevant cost of the individual entities and the entire chain for coordinated and non coordinated supply chain. Also, the sensitivity analysis is carried out. From the research findings, it is evident that with supply chain coordination, the total relevant cost of supply chain decreases.

Keywords: supply chain management, exponential price dependant demand, total relevant cost, competitive strategy.

INTRODUCTION

The initiatives of liberalization, privatization, and globalization paved ways to great number of opportunities coupled with complex challenges. Globalization of market, increased competition, reducing gap between products in terms of quality and performance are compelling the academicians and industry to rethink about how to manage business operations more efficiently and effectively. Supply chain management (SCM) presents significant opportunities for improving margins and reducing cost. Inventory is a major source of cost in a supply chain and has a very large impact on responsiveness. The location and quantity of inventory can move the supply chain from one end of the responsiveness spectrum to the other. Actions are needed to lower the amount of inventory needed without increasing cost or reducing responsiveness. Inventory usually represents from 20 to 60% of the total assets of the manufacturing firms. Inventory management policies are very critical in determining the profit of the firms (Arnold, 1998). Multi echelon inventory management is a major issue in SCM, i.e., an approach that addresses supply chain issues under an integrated perspective (Routroy, and Giannoccaro *et al*.). The trade-off implicit in the inventory driver is between the responsiveness that results from more inventory and efficiency that results from less inventory. Hence, a competitive strategy is desired. Actions taken by one member of the chain can influence the profitability of all others in the chain.

Firms are thinking to compete as a part of supply chain against other supply chains, rather than as a single firm against other individual firms. Supply chain coordination improves, if all stages of the chain take actions that together increase total supply chain profits. Supply chain coordination requires each stage of the supply chain to take into account the impact of its actions on other stages. Lack of coordination leads to a degradation of responsiveness and an increase in the cost of a supply chain. Malone and Crowston (1994) presented "The act of managing dependencies between entities and the joint effort of entities working together towards mutually defined goals" as the most commonly accepted definition of coordination in the literature. Weng (1995) presented a model for analyzing the impact of Joint decision policies on channel coordination in a system consisting of a supplier and group of homogeneous buyers. Furthermore, it is a fact that the holding costs of each echelon are dependent on the price of the material at that echelon and the cumulative costs, which influences the final price of the item to the customer. Hence, the competitiveness of the supply chain depends significantly on the price and there by demand. At the same instant, firms have to concentrate on effective utilization of the working capital, which is the source to be invested for inventories. So, while making strategic managerial decision, the study of supply chain coordination mechanism under price dependant environment becomes worthwhile.

In this paper, two-echelon inventory system is modeled under exponential price dependant demand. The organization of this paper is made into six sections. Literature is reviewed in Section-2. In Section-3, a mathematical model is developed. Numerical investigation is presented in Section-4 along with results and discussions. Section-5 provides conclusions and future scope. References are presented in Section-6.

LITERATURE REVIEW

A brief review of literature pertaining to supply chain coordination is presented in this section. Several studies were proposed joint inventory optimization models and addressed supply chain coordination in terms of lot size inventory, trade credit, quantity discounts, etc. Many shipment policies were proposed in literature for single-vendor single-buyer problem.

In particular, Lee and Rosenblatt (1986) proposed an algorithm to determine a profit maximizing quantity discount pricing schedule for a single product, single-buyer model. Anupindi and Akella (1993) developed three models for optimal ordering policies for a single-buyer with multiple vendors. Joint ordering policies were investigated by Kohli and Park (1994) to reduce transaction costs between a single vendor and a homogeneous group of buyers. Goyal (1976) analyzed an integrated inventory model and proposed a framework to minimize the total relevant cost for a single supplier single customer problem. In the proposed model, the author has assumed that the inventory holding cost is independent of the price of an item. Hill (1999) proposed a more general batching and shipping policy involving the successive shipment size of the first m shipments increases by a fixed factor and remaining shipments would be of equal sized.

Further, the coordination problem of “mismatch in timing of order” in single supplier-multiple buyer environment was addressed by Guornani (2001). Also, the author has developed an analytical model and applied joint system cost consideration and quantity discounts in order to minimize the cost. Sizjadi, Ibrahim, and Lochest (2006) presented a new methodology to apply joint economic lot size in case where multiple buyers are demanding one type of item from a single vendor and proposed multiple shipment policy which is more beneficial than a single shipment policy considered by Banerjee (1986). Sarmah, Acharya and Goyal (2006) reviewed literature dealing with buyer-vendor coordination models that have used quantity discount as coordination mechanism under deterministic environment. Authors have presented a gap in research models and suggested to focus on a situation of demand varying with time or price of the product.

Xiuhwili and Qinamwang (2007) reviewed coordination mechanisms of supply chain systems in a framework, i.e., based on supply chain decision structure and nature of demand. Also, he suggested three components for a coordination mechanism for a decentralized supply chain system namely an operational plan to coordinate the decisions and activities of the supply chain members, a structure to share information among the members, and an incentive scheme to allocate the benefits of coordination so as to entice the cooperation of all the members. Sarmah *et al*. (2007) proposed a mechanism for coordination and profit sharing between a manufacturer and a buyer with target profit under credit option. Wang (2008) proposed decision models for order quantity and ordering cycle under decentralized supply chain and centralized supply chain to analyze effects of supply chain coordination for deteriorating goods with stock demand rate. Sinha and Sarmah (2008) designed a coordination mechanism through quantity discount policy under asymmetric information environment that allows the system to perform as closely as that of under complete information. Dutta and Sarmah (2009) carried an analysis of supply chain coordination in a multi-agent market. Chaharsooghi and Heydari (2010) proposed supply chain coordination model for the joint determination of order quantity and reorder point using credit option. Chen *et al*. formulated a two-stage optimization problem in which the supplier decides the amount of the capacity reservation in the first stage, and the retailer determines the order quantity and the retail price after observing the demand information in the second stage. Raza Sarlak and Ali Nookabadi (2011) developed a mathematical model and discussed coordination issues of a distribution system consisting of a manufacturer, supplier, and several retailers.

In addition, for the purpose of determining optimum order quantity, in most restrictive cases, the demand and unit cost of production are assumed constant. In fact, the demand for any product is influenced by the customer’s response to the marketing variables such as the velocity of demand. The selling prices of products will become one of key factors in affecting the system performance of supply chain. Reduced price of an item will increase the demand for that item. In this context, the work related to single stage inventory models with dependent demand includes the work of Ladany and Sternlib (1974), considering the effect of price variations without including advertisement. Urban T.L (1992) has studied the deterministic inventory models considering the marketing decisions. Subramanyam and Kumaraswamy (1981) derived EOQ by taking advertisement, price fluctuations and price elasticity into consideration. Furthermore, Nagaraju *et al*. (2012) proposed two-echelon inventory model with the selling price dependent demand under wholesale price index (WPI) and consumer price index (CPI). Also, they demonstrated that the gross profit of the retailer increases significantly where as that of a manufacturer reduces with a decrease in WPI and increase in CPI. Syam Sundar *et al*. (2012) developed a two level supply chain model under linear price dependent demand for optimal replenishment quantity, inventory ratio and annual total relevant cost, with and without coordination. More recently, Pezeshki *et al*. (2013) investigated the price and capacity-building decisions in a coordinated supply chain assuming linearly decreasing demand with respect to price at the retailer point. Also, the authors have proposed revenue sharing reservation contract with a penalty as a coordination mechanism.

In light of the above literature, in this paper a two-echelon supply chain model is developed under the consideration of exponential price dependant demand and parametric analysis is carried out.

MATHEMATICAL MODEL DEVELOPMENT

Features and assumptions of the model

This section deals with the features and assumptions under which the model is framed and the notations used. For the convenience of model development, the suitable assumptions and notations are summarized as follows:

a) Exponential price dependent demand rate
b) Infinite production rate
c) Instantaneous replenishment
d) Manufacturer's inventory is some multiple times of retailer's inventory
e) Shortages are not allowed
f) Negligible lead times

Notation

For easy reference, the following notations are used throughout this model development.

D Retailer's selling price dependent demand per unit time (normally one year)
D $= ae^{-bP_R}$ where a is fixed demand, a>0, b>0 and a>>b
P_R Selling price of the retailer (Rs/unit)
A_R Ordering cost at retailer (Rs/order)
A_m Setup cost at manufacturer (Rs/setup)
C_R Unit cost at retailer (Rs/unit)
Cm Unit cost at manufacturer (Rs/unit)
n Shipment frequency from manufacturer to retailer
Q_R Replenishment quantity of retailer
Q_R^* Optimal ordering quantity at retailer
Q_m Manufacturer's production batch size ($Q_m = nQ_R$)
I Interest rate
TVC_R Total variable cost at retailer (Rs/year)
TVC_m Total Variable cost at manufacturer (Rs/year)
TVC_S Total variable cost of supply chain (Rs/year)
TVC_S^* Optimal total variable cost of a supply chain during a year

Model formulation

Consider a two echelon inventory system with single manufacturer supplying a single kind of a product to a single retailer with exponential selling price dependent demand. Under this phenomenon, the following cost factors are considered at each echelon of the inventory system.

Retailer optimal policy

Annual ordering cost of the retailer is expressed as:

$$\frac{ae^{-bP_R}}{Q_R}A_R$$

Annual holding of the retailer is expressed as:

$$\frac{Q_R}{2}C_R I$$

Then, the total variable cost of the retailer is obtained by adding annual ordering cost of the retailer and annual holding cost of the retailer

$$TVC_R\left(Q_R\right) = \frac{ae^{-bP_R}}{Q_R}A_R + \frac{Q_R}{2}C_R I \qquad (1)$$

Proposition-1: The Total Variable cost of the retailer is a convex function of Q_R. Thus, the optimum ordering quantity Q_R* is obtained by taking the first order derivative of total variable cost function, as given by equation (2).

$$Q_R^* = \sqrt{\frac{2ae^{-bP_R}A_R}{C_R I}} \qquad (2)$$

Proof: Taking the first order and second order partial derivatives of equation (1) with respect to Q_R, we have

$$\frac{\partial(TVC_R)}{\partial Q_R} = -\left(\frac{ae^{-bP_R}}{Q_R^2}\right)A_R + \left(\frac{C_R I}{2}\right) = 0$$

$$\frac{\partial^2(TVC_R)}{\partial {Q_R}^2} = \left(\frac{2ae^{-bP_R}}{{Q_R}^3}\right)A_R > 0$$

Since the second order derivative is always greater than zero, TVC_R (Q_R) is convex with respect to Q_R.

Manufacturer optimal policy

The annual setup cost of the manufacturer is expressed as $= \frac{ae^{-bP_R}}{nQ_R}A_m$

(Since the production batch size at the manufacturer is multiple integer of ordering quantity at the retailer)

Annual holding of the manufacturer is expressed as:

$$\frac{(n-1)Q_R}{2}C_m I$$

Then, the total variable cost of the manufacturer is obtained by adding the annual setup cost and annual holding cost.

$$TVC_m\left(n, Q_R\right) = \frac{ae^{-bP_R}}{nQ_R}A_m + \frac{\left(n-1\right)Q_R}{2}C_m I \qquad (3)$$

Proposition-2: For the given value of Q_m, TVC_m (n, Q_R) is convex in n. Then, the optimal value of n, n* always satisfies the following condition.

$$n^*(n^*-1) \geq \left(\frac{2ae^{-bP_R}A_m}{Q_m^2 C_m I}\right) \geq n^*(n^*+1) \qquad (4)$$

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Proof: For given values of Q_m and n, the optimal value of n, n^* always satisfies the following expression given below.

$$TVC_m\left(n^*\right) \le TVC_m\left(n^*-1\right)$$

$$TVC_m\left(n^*\right) \le TVC_m\left(n^*+1\right)$$

Substituting the relevant values in equation (3) for the condition $TVC_m\left(n^*\right) \le TVC_m\left(n^*-1\right)$, and upon simplification and rearranging the terms, the following inequality is obtained as:

$$n^*\left(n^*-1\right) \ge \left(\frac{2ae^{-bP_R}A_m}{Q_m^2 C_m I}\right) \tag{5}$$

Similarly substituting the values in eq. (3) for the condition $TVC_m\left(n^*\right) \le TVC_m\left(n^*+1\right)$ and after simplification and rearranging the terms, the following inequality is obtained as $n^*\left(n^*+1\right) \le \frac{2ae^{-bP_R}A_m}{Q_m^2 C_m I}$ (6)

From equations (5) and (6), the following expression is obtained as:

$$n^*\left(n^*-1\right) \ge \frac{2ae^{-bP_R}A_m}{Q_m^2 C_m I} \ge n^*\left(n^*+1\right)$$

Annual total variable cost of the supply chain is equal to sum of the total variable costs of the retailer and manufacturer.

$$TVC_S\left(n, Q_R\right) = TVC_R\left(Q_R\right) + TVC_m\left(n, Q_R\right)$$

Coordinated supply chain

Suppose, when both the parties decide to cooperate and agree to follow the joint optimal policy, the annual total variable cost of the coordinated chain is given as:

$$TVC_S\left(n, Q_R\right) = \frac{D}{Q_R}\left(A_R + \frac{A_m}{n}\right) + \frac{Q_R I}{2}\left(C_R + (n-1)C_m\right) \tag{7}$$

As the demand is a function of exponential price dependent,

$$D = ae^{-bP_R} \tag{8}$$

Upon substitution of the equation (8) in equation (7), the annual total variable cost of the supply chain is expressed as:

$$TVC_S\left(n, Q_R\right) = \frac{ae^{-bP_R}}{Q_R}\left(A_R + \frac{A_m}{n}\right) + \frac{Q_R I}{2}\left(C_R + (n-1)C_m\right) \tag{9}$$

Proposition-3: The total variable cost of the supply chain is a convex function of Q_R. Thus, the optimum Q_R^* is obtained by taking the first order derivative of the total variable cost function, as given by the equation (10)

$$Q_R = \sqrt{\frac{2ae^{-bP_R}\left(A_R + \frac{A_m}{n}\right)}{I\left(C_R + (n-1)C_m\right)}} \tag{10}$$

Proof: Taking the first order and second order partial derivatives of the equation (9) with respect to Q_R, we have

$$\frac{\partial}{\partial Q_R}(TVC_s) = \frac{-ae^{-bP_R}}{Q_R^2}\left(A_R + \frac{A_m}{n}\right) + \frac{I}{2}\left(C_R + (n-1)C_m\right) = 0$$

$$\frac{\partial^2}{\partial Q_R^2}(TVC_s) = \frac{2ae^{-bP_R}}{Q_R^3}\left(A_R + \frac{A_m}{n}\right) > 0$$

Since the second order derivative is greater than zero, TVC_S $(Q_{R)}$ is convex with respect to Q_R. Next, substituting equation (10) into equation (9) and simplifying, the expression for optimal total variable cost of the supply chain is obtained as

$$TVC_S = \sqrt{\left(2ae^{-bP_R}\left(A_R + A_m/n\right)\left(I\left(C_R + (n-1)C_m\right)\right)\right)}$$

Proposition-4: For the given value of Q_R, TVC_S (n,Q_R) is convex in n. Then, the optimal value of n, n* always satisfies the following condition.

$$n^*\left(n^*-1\right) \le \frac{2ae^{-bP_R}A_m}{IQ^2{}_R C_m} \le n^*\left(n^*+1\right)$$

Proof: For given value of Q_R, the optimal value of n, n^* always satisfies the following expression given below:

$$TVC_S\left(n^*\right) \le TVC_S\left(n^*-1\right)$$

$$TVC_S\left(n^*\right) \le TVC_S\left(n^*+1\right)$$

Substituting the relevant values in equation (9) for the condition $TVC_S\left(n^*\right) \le TVC_S\left(n^*-1\right)$ and after simplification and rearranging the terms, the following inequality is obtained as:

$$n^*\left(n-1^*\right) \le \frac{2ae^{-bP_R}A_m}{IQ_R^2 C_m} \tag{11}$$

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Similarly substituting the values in equation (9) for the condition $TVC_S\left(n^*\right) \le TVC_S\left(n^*+1\right)$ and after simplification and rearranging the terms, the following inequality is obtained as $n^*\left(n^*+1\right) \le \frac{2ae^{-bP_R}A_m}{IQ_R^2C_m}$ (12)

Combining equations (11) and (12) the following expression is obtained as:

$$n^*\left(n^*-1\right) \le \frac{2ae^{-bP_R}A_m}{IQ^2{}_RC_m} \le n^*\left(n^*+1\right)$$

Extensions

Further, it is also interested to analyze the variation of the ratio actual to optimal annual total variable cost of supply chain with the variation of the ratio actual to optimal ordering quantity. Hence an attempt is made to derive the expression which is given as follows.

$$\frac{TVC_S}{TVC_S^*} = \frac{\left[\frac{Q_R^*}{Q_R} + \frac{Q_R}{Q_R^*}\right]\sqrt{\frac{I}{2}\left(ae^{-bP_R}\right)\left(A_R+\frac{A_m}{n}\right)\left(C_R+(n-1)C_m\right)}}{\sqrt{2I\left(ae^{-bP_R}\right)\left(A_R+\frac{A_m}{n}\right)\left(C_R+(n-1)C_m\right)}}$$

NUMERICAL INVESTIGATION

For the illustration of the model, consider an item with the following variables and constant values. The model is solved using MATLAB for the data shown below and the results are tabulated in Table-1.

A_R = 100 per order	A_m = 500 per setup
C_R = Rs. 220 per unit	C_m = Rs. 100 per unit
a = 5000	b = 0.009
P_R = Rs. 250 per unit	I = 0.14 Rs/Re/Unit

Table-1. Optimal values of decision variables and objective function.

Description	Without Coordination	With Coordination
Q_R (in units)	58.5	90.74
n	3	2
Q_m (in units)	175.5	181.48
TVC_R (in Rs.)	1801.75	1978.18
TVC_m (in Rs.)	2320.41	2087.12
TVC_S (in Rs.)	4122.16	4065.3

Table-1 shows the optimal values of retailer ordering quantity, shipment frequency, manufacturer's batch size, total variable cost of the respective entities and total supply chain for non coordinated and coordinated supply chain. From this Table, it is evident that retailer replenishment quantity, manufacturer's batch size and total variable cost of the retailer are more for coordinated supply chain where as shipment frequency, total variable cost of the manufacturer and the entire supply chain are less.

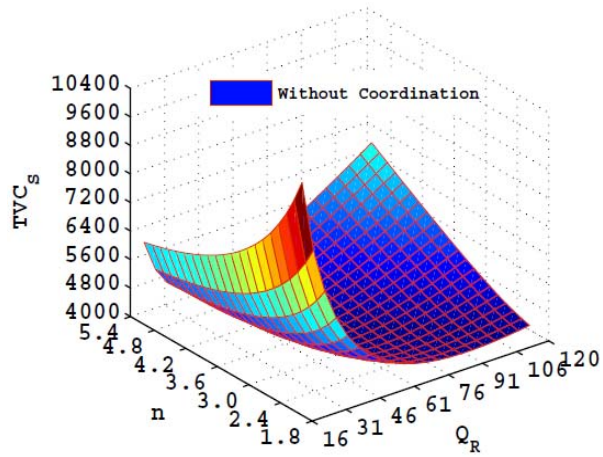

Figure-1. Total variable cost of the non-coordinated chain w.r.t retailer ordering quantity and shipment frequency.

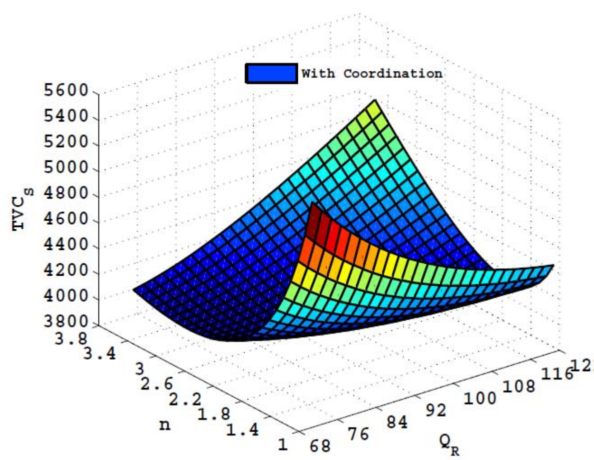

Figure-2. Total variable cost of the coordinated chain w.r.t retailer ordering quantity and shipment frequency.

Figure-1 and Figure-2 show the analysis of variation of the total relevant cost of the supply chain with respect to ordering quantity and shipment frequency for both the cases of coordination. From these figures, it is observed that the variation in total relevant cost of the supply chain assumes convexity in its shape.

Further, it is interesting to analyze the variation of inventory levels at respective entities, shipment frequency and total variable cost of the supply chain with respect to model parameters.

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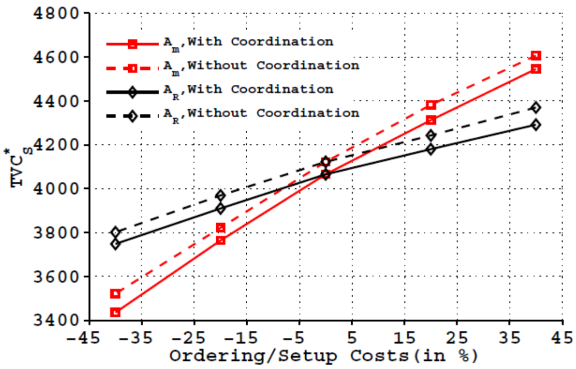

Figure-3. Optimal total variable cost of the supply chain w.r.t ordering/setup costs (in Percentage).

Table-2 and Figure-3 show the analysis of variation of optimal total variable cost of supply chain with respect to variation of ordering cost of retailer and set up cost of manufacturer, with and without coordination. It is observed that as the ordering cost increases the optimal total variable cost of the supply chain increases. It is due to the fact that as the ordering cost of retailer increases, retailer prefers to procure more quantity of items through less number of shipments and the rate of increase in carrying cost is more than the rate of decrease in ordering cost, which in turn increases the total variable cost of the supply chain.

Similarly, as the set up cost of the manufacturer increases the optimal total variable cost of the supply chain increases. It is due to the fact that as the set up cost increases the manufacturer prefers to produce more quantity of items through less number of set ups and the rate of increase in carrying cost is more than the rate of decrease in setup cost which in turn increases the total variable cost of the supply chain. It is also observed that for a particular value of ordering cost and set up cost, the optimal value of total cost of supply chain is less with supply chain coordination rather than without coordination. It is attributed to the fact that with supply chain coordination, the rate of decrease in ordering cost is more than the rate of increase in carrying cost which in turn decreases the total variable cost of the supply chain.

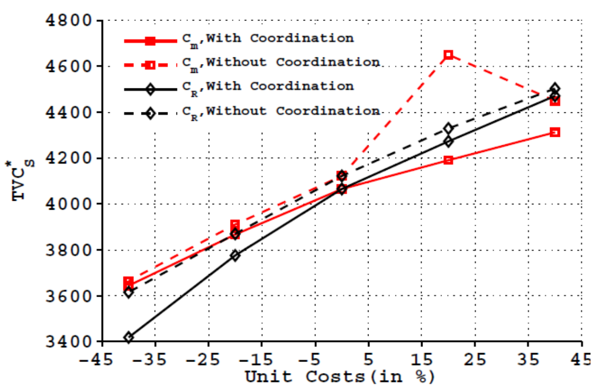

Figure-4. Optimal total variable cost of the supply chain w.r.t Unit costs (in Percentage).

Table-2 and Figure-4; show the analysis of variation of optimal total variable cost of supply chain with unit cost of retailer and manufacturer, with and without coordination. It is observed that as the unit cost of retailer increases the optimal total variable cost of the supply chain increases. It is due to the fact that as the unit cost of retailer increases, retailer prefers to procure less quantity of items through more number of shipments and the rate of increase in ordering cost is more than the rate of decrease in carrying cost, which in turn increases the total variable cost of the supply chain.

Similarly, as the unit cost of the manufacturer increases the optimal total variable cost of the supply chain increases. It is due to the fact that as the set up cost increases the manufacturer prefers to produce less quantity of items through more number of set ups and the rate of increase in set up cost is more than the rate of decrease in carrying cost which in turn increases the total variable cost of the supply chain. It is also observed that for a particular value of unit cost of retailer and manufacturer, the optimal value of total cost of supply chain is less with supply chain coordination rather than without coordination.

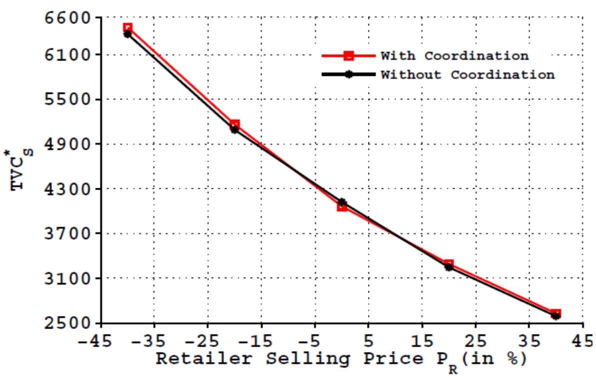

Figure-5. Optimal total variable cost of the supply chain w.r.t retailer selling price (in Percentage).

Table-2 and Figure-5 show the analysis of variation of optimal total variable cost of supply chain with respect to variation of retailer's selling price with and without coordination. It is observed that as the retailer's selling price increases the optimal total variable cost of the supply chain decreases. It is attributed to the fact that as the unit cost of retailer increases, demand at retailer decreases which in turn decreases the total variable cost of the retailer and manufacturer subsequently the total variable cost of the supply chain decreases. It is also observed that for a particular value of retailer's selling price there is no appreciable variation in the optimal value of total variable cost of the supply chain with and without coordination.

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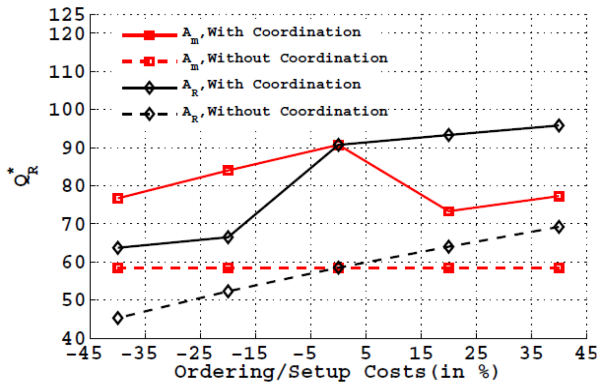

Figure-6. Retailer ordering quantity w.r.t ordering/setup costs (in %).

Table-2 and Figure-6 show the analysis of variation of optimal ordering quantity of retailer with respect to variation of ordering cost of retailer and set up cost of manufacturer with and without coordination. It is observed that as the ordering cost increases the optimal ordering quantity increases. It is due to the fact that as the ordering cost of retailer increases, retailer prefers to procure more quantity of items through less number of shipments, therefore the ordering quantity increases.

Similarly, as the set up cost of the manufacturer, increases the optimal ordering quantity increases. It is due to the fact that as the set up cost increases the manufacturer prefers to produce more quantity of items through less number of set ups and then supplied to the retailer in more than one shipment. It is also observed that for a particular value of ordering cost and set up cost, the optimal value ordering quantity is more with supply chain coordination rather than without coordination.

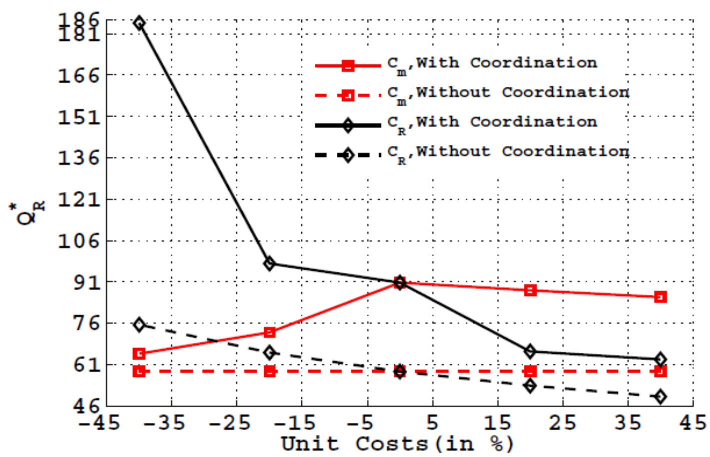

Figure-7. Retailer ordering quantity w.r.t unit costs (in %).

Table-2 and Figure-7; show the analysis of variation of optimal ordering quantity of retailer with respect to variation of unit cost of retailer and manufacturer with and without coordination. It is observed that as the unit cost at retailer increases the optimal ordering quantity decreases. It is due to the fact that as the unit cost of retailer increases, retailer prefers to procure less quantity of items through more number of shipments, therefore the ordering quantity decreases.

Similarly, as the unit cost of the manufacturer increases the optimal ordering quantity increases. It is due to the fact that carrying cost at the manufacturer increases. Consequently, manufacturer prefers to fulfill the retailer's demand through less number of shipments. Hence the ordering quantity at retailer increases. It is also observed that for a particular value of unit cost, the optimal value ordering quantity is more with supply chain coordination rather than without coordination.

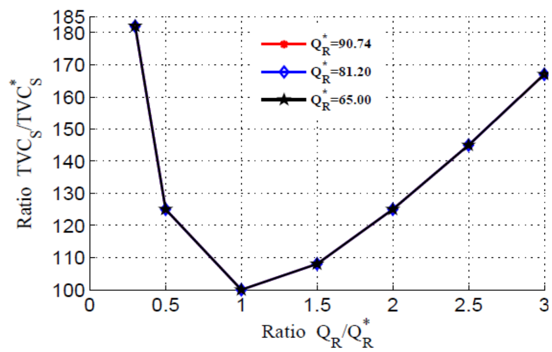

Figure-8. Variation of TVC_S/TVC_S^* w.r.t Q_R/Q_R^*.

Figure-8 shows the analysis of variation of TVC_S / TVC_S^* ratio with respect to change in the ratio of Q_R/Q_R^*. It is observed that when the ordering quantity at the retailer is deviated from the optimal ordering quantity by a factor of two, the total variable cost of the supply chain increases by 25%.

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Table-2. Sensitivity analysis.

Parameter	in (%)	Without Coordination						With Coordination						% decrease in TVC_S
		Q_R	N	Q_m	TVC_R	TVC_m	TVC_S	Q_R	N	Q_m	TVC_R	TVC_m	TVC_S	
A_m	+40	58.5	4	234.0	1801.7	2804.9	4606.6	77.3	3	231.87	1872.11	2673.0	4545.1	1.34
	+20	58.5	4	234.0	1801.7	2579.7	4381.4	73.3	3	219.9	1847.8	2464.1	4311.8	1.59
	-20	58.5	3	175.5	1801.7	2020.1	3821.8	84.0	2	168.0	1921.0	1842.7	3763.7	1.52
	-40	58.5	3	175.5	1801.7	1719.8	3521.5	76.7	2	153.4	1868.3	1567.5	3435.8	2.43
A_R	+40	69.2	3	207.6	2131.8	2238.0	4369.8	95.8	2	191.6	2245.5	2045.8	4291.3	1.80
	+20	64	3	192.0	1973.7	2268.4	4242.1	93.3	2	186.6	2114.6	2065.2	4179.8	1.47
	-20	52.3	4	209.2	1611.5	2357.8	3969.3	66.5	3	199.5	1658.0	2251.8	3909.9	1.50
	-40	45.3	4	181.2	1395.6	2405.5	3801.1	63.7	3	191.1	1477.4	2270.7	3748.0	1.40
C_R	+40	49.4	4	197.6	2131.9	2370.9	4502.8	62.9	3	188.70	2194.0	2277.0	4470.9	0.71
	+20	53.4	4	213.6	1973.7	2355.0	4328.7	65.8	3	197.4	2016.9	225.0	4272.9	1.29
	-20	65.4	3	196.2	1611.5	2258.6	3869.6	97.7	2	195.4	1743.1	2032.4	3775.5	2.43
	-40	75.5	3	226.5	1395.5	2220.0	3615.5	184.9	1	184.9	1993.5	1425.1	3418.6	5.45
C_m	+40	58.5	3	175.5	1801.7	2648.0	4449.7	85.5	2	171.0	1933.0	2378.8	4311.9	3.10
	+20	58.5	3	175.5	1801.7	2848.2	4649.9	88.0	2	176.0	1954.1	2236.4	4190.4	9.88
	-20	58.5	4	234.0	1801.7	2108.8	3910.5	72.7	3	218.1	1844.5	2022.5	3866.9	1.11
	-40	58.5	4	234.0	1801.7	1863.1	3664.8	65.0	4	260.0	1811.7	1832.4	3644.2	0.56
P_R	+40	37.3	3	111.9	1148.8	1479.6	2628.4	57.9	2	115.8	1261.7	1330.4	2592.1	1.38
	+20	46.7	3	140.1	1438.7	1853.0	3291.7	72.4	2	144.8	1579.1	1667.1	3246.2	1.38
	-20	73.3	3	219.7	2256.4	2906.0	5162.3	113.6	2	227.2	2477.0	2614.0	5091.0	1.38
	-40	91.7	3	275.1	2825.7	3639.7	6465.4	142.3	2	284.6	3102.3	3273.3	6375.6	1.39
A	+40	69.2	3	207.6	2131.8	2745.8	4877.6	107.4	2	214.8	2340.9	2469.2	4180.1	14.3
	+20	64.1	3	192.2	1973.7	2541.9	4515.6	99.40	2	198.8	2167.0	2286.3	4453.3	1.38
	-20	52.3	3	156.9	1611.5	2075.7	3687.2	81.2	2	162.4	1769.7	1866.4	3636.1	1.39
	-40	45.3	3	135.9	1395.6	1797.5	3193.1	70.3	2	140.6	1532.4	1616.6	3148.9	1.38
B	+40	37.3	3	111.9	1148.8	1479.5	2628.3	57.9	2	115.8	1261.7	1330.4	2592.5	1.36
	+20	46.7	3	140.1	1438.7	1853.0	3291.7	72.5	2	145.0	1580.0	1666.2	3246.2	1.38
	-20	73.2	3	219.6	2256.3	2906.6	5162.9	113.6	2	227.0	2476.9	2614.1	5091.0	1.39
	-40	91.7	3	275.1	2825.7	3639.6	6465.3	142.3	2	284.6	3102.3	3273.3	6375.6	1.39

CONCLUSIONS

The proposed study mainly dealt with the development of a quantitative model for two echelon inventory system for optimal total variable cost of the supply chain and retailer's ordering quantity under the influence of exponential price dependent demand. The model presents a comparative study of decision variables and objective function for non-coordinated and coordinated supply chain. In addition, the parametric analysis is done to see the behavioral pattern of decision variables and objective function with respect to variation in model parameters. From the model analysis, it is evident that the total relevant cost of the supply chain with coordination is less rather than without coordination and the optimal ordering quantity is more with supply chain coordination rather than without coordination.

From the sensitivity analysis it is observed that total relevant cost of the supply chain increases with increase in ordering cost, set up cost and unit cost at retailer and manufacturer. The ordering quantity at retailer increases with increase in ordering cost and set up cost and decreases with increase in unit cost at retailer and manufacturer. Similarly, as the retailer selling price increases, the total variable cost of the supply chain decreases. It is also concluded that the total variable cost of the supply chain is more if the ordering quantity is deviated from the optimal ordering quantity.

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