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Models of Perishable Stock for Stock-Dependent Quadratic Demand in the Presence of Inflation

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Abstract-

For perishable goods, inventory models are created using stock-dependent quadratic demand under inflation. The pace of degradation is thought to be constant. The conventional Reccati differential equation approach is used to determine the model's solution. The impact of inflation on the overall profit of the system is examined for items whose demand is quadratic and dependent on inventory level. We test the model with a theoretical example. Finally, the model's sensitivity is shown and examined.

Keywords: Quadratic demand, inflation, stock dependent, perishable, inventory

Introduction

In inventory system, the following demand types are typically taken into account: stock-dependent, time-dependent, price-dependent, probabilistic, and constant demand. There is a widespread misconception that shoppers will purchase more when they see enormous mounds of merchandise on display in mega markets

(Levin et al. [1]). Additionally, it has been observed by Silver and Peterson [2] that store sales typically follow the goods that is on display. Since then, attempts have been made by scholars to look at inventory models that assume a functional form between the rate of demand and the inventory that is on hand. A deterministic inventory system with a stock-dependent demand rate was developed by Baker and Uber [4], whereas Gupta and Vrat [3] proposed inventory models with variable rates of demand. An Inventory Model for Deteriorating Items and Stock Dependent Consumption Rate was covered by Mandal and Phaujdar [5]. A comment on an inventory level dependent demand rate was published by Datta and Pal [6], Goh [7] created an EOQ model with general demand and a holding cost function, An EOQ model under inflation and temporal discounting that allowed for shortages was presented by Ray and Chaudhuri [8]. Dynamic lot sizing with returns and disposals was the topic of discussion between Beltran and Krass [9]. An inventory model for Weibull degrading items with stock-dependent demand, time-varying holding costs, and variable selling prices was covered by Raman Patel and Reena [10]. An ideal inventory model for time-dependent decaying products with stock-dependent demand rates and shortages was investigated by Rekha Rani et al. [11]. A declining items inventory model with stock-dependent demand under shortages and changeable selling price was created by Raman Patel and Reena [12]. A periodic review inventory model with stock-dependent demand, allowable payment delays, and price discounts for backorders was examined by Pal and Chandra [13]. An inflation-induced stock dependent demand inventory model with a payment delay that is acceptable was examined by Yashveer Singh et al. [14]. An inventory model with inventory-dependent demand for decaying commodities in a single warehouse system was created by Tripathi and Mishra [15]. An EOQ model with a stock-dependent demand rate and variable time was covered by Maisuriya et al. [16]. An inventory model with stock-dependent demand and two storage capacities for non-instantaneously decaying commodities was examined by Singh and Malik [17]. An inventory model for degrading items with a stock-dependent selling rate and partial backlog under inflation was covered by Kuo-Lung Hou et al. [18]. An EOQ model for perishable goods under stock and time-dependent selling rate with shortages was created by Valliathal and Uthayakumar [19]. The EOQ models for perishable goods under stock-dependent selling rate were created by Padmanabhan and Vrat [20]. A fresh study of an EOQ model for deteriorating items with shortages under inflation and time discounting was provided by Valliathal and Uthayakumar [21]. Inventory models for degrading items with fluctuating selling prices under stock-dependent demand were examined by Yen-Wen Wang et al. [22]. The best integrated inventory strategy for stock-dependent demand was reported by Nita Shah et al. [23] when trade credit was connected to order quantity. In a shortage-driven stock-dependent consumption market, Patra and Ratha [24] examined an inventory replenishment approach for deteriorating items under inflation. The underlying premise of these studies was that the demand rate is dependent on stock and can be either linear or exponential.Therefore, it is suggested that when the demand rate is a quadratic function of stock level, the best inventory strategies for deteriorating items be studied. Section 2 of this paper outlines common assumptions and notations used in the development of the mathematical model. The model's formulation and solution are found in Section 3.

This section includes the sensitivity analysis and a numerical example. Some closing thoughts are provided in Section 4.

Assumptions And Notations-

The mathematical model is developed on the following assumptions and notations:

(i) The Demand rate D(t) at time t is assumed to be D(t) = a + bI(t) + c(I(t))², a e" 0, b $\neq$ 0, c $\neq$ 0. Here 'a' is the initial rate of demand, 'b' is the initial rate of change of the demand and 'c' is the acceleration of demand rate.

(ii) Replenishment rate is infinite and lead time is zero.

(iii) p is the selling price per unit.

(iv) The rate of inflation is constant

(v) The unit cost and other inventory related cost are subjected to the same rate of inflation, say k. This implies that the ordering quantity can be determined by minimizing the total system cost over the planning period.

(vi) A(t) is the ordering cost at time t.

(vii) θ(0 < < 1) is the constant rate of deterioration.

(viii) C(t) denotes unit cost at time t.

(ix) I(t) is the inventory level at time t.

(x) Q(t) is the ordering quantity at time t=0

(xi) 'h' is per unit holding cost excluding interest charges per unit per year.

Formulation And Solution of The Model

The objective of the model is to determine the optimum profit for items having stock dependent quadratic demand and the rate of deterioration is assumed to be a constant with no shortages.

The inventory level depletes as the time passes due to demand and deterioration during (0,t,) and due to demand only during the period (t_1, T).

If 1(t) be the inventory level at time t, the differential equations which describes the inventory level at time t are given by

$$\frac{dI(t)}{dt} + \theta I(t) = -\left(a + bI(t) + c\left(I(t)\right)^2\right) \qquad 0 \le t \le t^1 \qquad (1)$$

$$\frac{dI(t)}{dt} = -(a + bI(t) + c(I(t))^2) \qquad t_1 \le t \le T \qquad (2)$$

together with I(t)=I(0) at time t=0 and I(T)=0. (3)

Now equation (1) can be expressed as

$$\frac{dI(t)}{dt} = -(a + (b+\theta)I(t) + c(I(t))^2) \qquad (4)$$

which is a non-linear first order Reccati equation. The solution of equation (4) is obtained as follows:

Let 'f' is any solution of equation (4) and also we use the following transformation

$$I(t) = f + \frac{1}{V} \tag{5}$$

where v is a function of time 't'.

Then the above equation (5) reduces to linear equation in 'v' as

$$\frac{dv}{dt} - (b + \theta + 2cf)v = c \tag{6}$$

To get an explicit solution of equation (6), we now assume f(t) as

$$\mathrm{f(t) = t} \tag{7}$$

and using the initial conditions, then the solution of equation (6) is given by

$$v = \frac{ctt_1 \frac{c(b+\theta)t_1 t^2}{2} + (b+\theta)t^1 + \frac{c(b+\theta)t_1^3}{2} - 1}{t_1\,(1 - (b+\theta)t - ct^2)} \tag{8}$$

Thus from equations (5), (7) and (8), the solution of equation (4) can be expressed as

$$I(t) = t + \frac{t_1\,(1 - (b+\theta)t - ct^2)}{ctt_1 \frac{c(b+\theta)t_1 t^2}{2} + (b+\theta)t_1 + \frac{c(b+\theta)t_1^3}{2} - 1} for\ 0 \le t \le t_1 \tag{9}$$

In a similar manner, we obtained the solution of equation (2) which is given by

$$I(t) = t + \frac{t_1\,(1 - bt - ct^2)}{ctt_1 - \frac{bct_1 t^2}{2} + bt_1 + \frac{bct_1^3}{2} - 1} for\ t_1 \le t \le T \tag{10}$$

Since I(0) Q at t = T, the Ordering Quantity 'Q' is calculated as

$$Q = \frac{2T}{2(b+0)T + c(b+0)T^3 \ -2} \tag{11}$$

Let C(t) denotes the unit cost at time t.

i.e., C(t)=$C_0 e^{kt}$ where C_0 is the unit cost at time zero.

Let A(t) denotes the Ordering cost at time t.

i.e., A(t) = $A_0 e^{kt}$ where A_0 is the ordering cost at time zero.

Total system cost during the planning period ‘ τ, is the sum of the Material cost, ordering cost and Carrying cost. Assume that τ = m*T, Where ‘m’ is an integer for the number of replenishments to make during the period ‘ τ, and ‘T’ is time between replenishments.

The Ordering cost during the period (0, τ) is

A(0) + A(T)+A(2T) + A(3T) +..........................+ A(m-1)T]

$$= A_0 e^{(0)kT} + A_0 e^{(1)kT} + A_0 e^{(2)kT} A_0 e^{(3)kT} + \cdots .. + A_0 e^{(m-1)kT}]$$

The optimality conditions given by (18) and (19) are satisfied with the choice of the parameter given above. For these values the optimum values of replenishment time (τ), cycle time (τ), ordering quantity (Q) and the total profit P(T, τ) of the system are 0.953, 8.149, 160.994 and 9449.00 respectively when stock dependent quadratic demand rate is considered. These optimum values of the system are tabulated in Table-1 and Table-2 for various values of inflation parameter (k) and deterioration parameter (θ) by keeping the other parameter as a constant. The following are noted from Table-1 and

Table-2:

(i) For a fixed value of 0=0.05 and the inflation rate k increases from 0.04 to 0.044, the cycle time and the ordering quantity remain unchanged but the total profit P(T, τ) and replenishment cycle time are marginally effected.

(ii) For some particular value of k=0.04 and 0 increases from 0.046 to 0.054, the cycle time, replenishment cycle time and the total profit P(T, τ) are effected moderately while the ordering quantity is effected significantly.

V. Sensitive Analysis

To study the sensitivity of optimal values of cycle time, ordering quantity and total profit of the system, the above values of parameters are again considered and the values are given in Table-3. The following observations are made from these two tables:

(i) The profit function P(T, τ) is highly sensitive to the changes in the parameter 'p' and also for all the parameters taken together. The profit

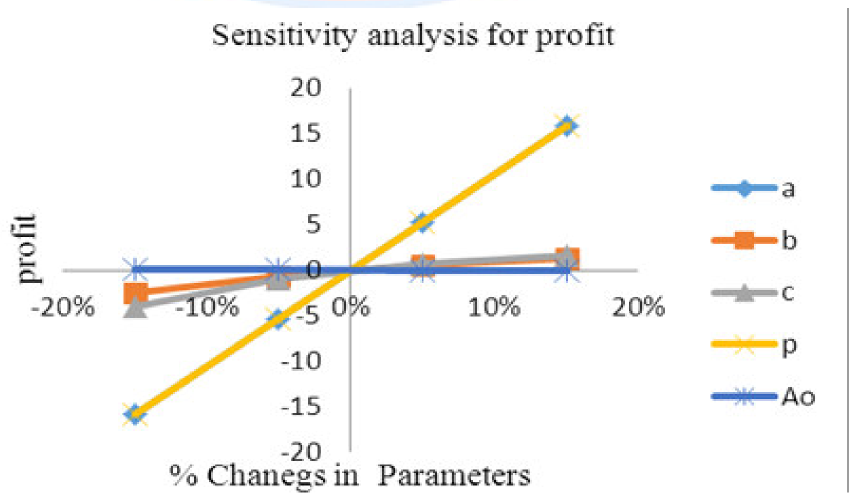

Fig-1: Variations of total profit w.r.t the values of some important parameters

VI. Conclusions

Here stock dependent quadratic demand rate with constant deterioration is considered in developing the inventory models. The solution of the models is obtained using the standard Reccati differential equation method. The system profit is calculated with a numerical example. It is observed that the effect of inflation rate is insignificant in the calculation of the system's total profit for stock dependent demand models. The sensitivity is performed and discussed.

S.No	□	*K*	*T*	□	*P(T,□)*	*Q*
1	0.05	0.040	8.149	0.953	9449	160.994
2		0.041	8.149	0.956	9446	160.994
3		0.042	8.149	0.96	9444	160.994
4		0.043	8.149	0.964	9441	160.994
5		0.044	8.149	0.967	9439	160.994

Table-2:

S.No	*k*	□	*T*	□	*P(T,□)*	*Q*
1		0.046	8.464	0.814	6927	965.784
2		0.048	8.304	0.881	9088	275.982

Table- 3:

Parameters	% change	Change in T (%)	Change in τ(%)	Change in $P(T,\tau)$ (%)	Change in Q (%)
a	15%	0.0000	0.0000	15.8853	0.0000
	5%	0.0000	0.0000	5.2916	0.0000
	-5%	0.0000	0.0000	-5.2916	0.0000
	-15%	0.0000	0.0000	-15.8747	0.0000
b	15%	-1.3989	0.5247	1.2700	-23.8090
	5%	-0.4663	0.1049	0.4974	-9.4339
	-5%	0.4786	-0.1049	-0.6244	11.6271
	-15%	1.4235	0.0000	-2.4341	45.4520
c	15%	-0.9081	29.0661	1.6298	-29.8732
	5%	-0.3068	9.3389	0.6667	-12.4340
	-5%	0.3068	-9.0241	-0.8996	16.5491
	-15%	0.9204	-26.0231	-3.9898	74.2121
θ	15%	-6.7370	36.6212	3.3019	-60.9749
	5%	-2.3070	10.4932	1.8415	-34.2460
	-5%	2.3929	-9.3389	-5.8207	108.6867
	-15%	163.8115	-	-	-

	15%	152.3623	-	-0.1587	0.0000
k	5%	0.0000	0.7345	-0.0529	0.0000
	-5%	0.0000	-0.7345	0.0423	0.0000
	-15%	-	-	0.1482	0.0000
	15%	6.4916	-20.6716	-0.1058	0.0000

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