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# SUPPLY CHAIN COORDINATION WITH FLEXIBLE PAYMENT POLICY UNDER EFFECT OF GREEN TECHNOLOGY INVESTMENTS

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**Abstract:** At present, augmentation of carbon gases in atmosphere has become a major concern. Regulatory bodies in many countries have focused on reduction of carbon emissions. Several countries follow carbon tax and carbon cap trade policy to control emission of carbon gases. This study has been carried out to obtain joint inventory policies for a supply chain involving a manufacturer and a whole-seller. Moreover, the manufacturer invests in green technology to reduce units of carbon gases. Products are considered deteriorating in nature. Manufacturer delivers product by adopting a lot-for-lot policy to meet the whole-seller's demand. The manufacturer offers the whole-seller flexible payment options including advance payment with discounted product price and delayed payment with increment in product price. Optimal policies for both individuals and the supply chain are discussed with aim to maximize total profit. The model is worked out and results are compared for four cases: (*i*) advance payment with green technology investments (*ii*) advance payment without green technology investments (*iii*) delayed payment with green technology investments (*iv*) delayed payment without green technology investments. A solution procedure has been proposed and explained through a numerical example. Study is concluded with managerial insights.

**Keywords:** Carbon emission, carbon tax, carbon trade, green technology, deterioration, flexible payment.

**MSC:** 90B05.

## 1. INTRODUCTION

Global warming and its disastrous effects have forced mankind to think in the direction of carbon gases reduction. Governing bodies and regulatory agencies in several countries have fixed upper limit on release of carbon units in air for large scale industries and manufacturing units. Several researchers have contributed on reduction of carbon gases in an inventory system. Also some non government organizations have taken initiatives to create awareness about carbon emission and its harmfulness amongst people. Subsequently anxious customers have turned to buy eco-friendly and organic products. Moreover, carbon tax policy has been introduced in many countries to control the pollutant gases. Hence manufacturing units have shown keen interest in production of eco-friendly products. Inventory managers need to design strategy to control pollutants in the production process. Greening investments play a very important role in controlling volume of carbon units released during manufacturing process of product. However form the investor's perspectives, it is expected that these investments also increase the profitability of the business unit.

In present competitive marketing scenario credit policy and discount on advance payment play significant role for dealers having short fall of capital and having liquid asset respectively. If the dealer has opportunity to choose one of the options from (*i*) pay in advance and get benefit of reduced product price (*ii*) pay later after the replenishment at higher product price then there can be a strong deal between the manufacturer and the dealer. Here the dealer gets opportunity to pay in advance and enjoy a discount on the price or to get some span for the payment by opting delayed payment but in the later case the dealer pays a higher product price than the normal price. Thus the dealer can adopt the best strategy that is most appropriate to increase one's profitability and suits best to his/her own financial condition. The dealer can choose to pay in advance and get attractive discount on price if the dealer has sufficient liquid assets. If the dealer is not financially capable than the delayed payment option can be helpful to run the business smoothly.

Present study describes supply chain coordination between a manufacturer and a dealer. The manufacturer produces the product and delivers to the dealer using lot-for-lot policy. Product deteriorates at a constant rate of deterioration. Carbon gases are released by the manufacturing firm at different stages of manufacturing process. The manufacturer invests in green technology to control carbon emission units and adopts carbon cap – trade policy to increase overall profit. The manufacturer offers two choices to the dealer for payment. (*i*) The dealer can pay in advance before the replenishment of the product and can get the product at discounted rate depending on the payment time. (*ii*) The dealer can settle the payment at the time of replenishment or later than that and get the product at a higher price which is decided as per the payment time. On the other hand the dealer receives product and sell it to customers with price sensitive, time dependent - quadratic in nature demand rate. One is charged interest in the case of borrowing money and interest is earned in the case of depositing revenue to bank of financial firm. The study aims to find out optimum cycle time, green technology cost, selling price and payment time for the dealer to maximize the total profit of the supply chain. Individual profits of the manufacturer and the dealer are also studied. Two different cases $(i)$ with green investments and $(ii)$ without green investments are discussed for advance payment as well as delayed payment. The model is authenticated by a numerical example. An investigation has been accomplished to study the effect of compact changes in fixed parameters associated with the model on the decision variables. The rest of the paper is comprised of the following sections.

Previous related research works are discussed in section 2. Section 3 contains notations and assumptions used in the development of the mathematical model. Section 4 is structured by the mathematical model and the solution procedure. Section 5 is comprised of an illustrative example and sensitivity analyses with managerial insights. Section 6 concludes the study.

## 2. LITERATURE REVIEW

A number of research work have been carried out keeping the focus on carbon emission and environmental policies. Ghosh and Shah [1] considered linear demand function of retail price and greening level to investigate the impact of green level on the optimal decisions of individual players of supply chain structure. Swami and Shah [2] worked out the green supply chain with combined greening effect of the manufacturer and the retailer and established that the ratio of greening efforts by the manufacturer and the retailer is same as the ratio of their green sensitivities to green costs.

Ghosh and Shah [3] adopted game theoretical approach to investigate optimum policies for a green supply chain under the effect of cost sharing contract for greening efforts. They studied two different cost sharing models to analyze its impact on the total profit of supply chain. Li et al. [4] examined pricing and greening strategies for supply chain members. They used Stackelberg game model and discussed both the centralized and decentralized cases. They showed that the retail price in centralized case is higher than that in decentralized case. They considered e-commerce approach in their study.

Aljazzar et al. [5] investigated effect of delay in payment as a strategy to reduce carbon emission. They developed a model to optimize environmental problems and economic issues of a supply chain. As a result they found that trade credit helps to improve environmental and economical performance of the supply chain. Giri et al. [6] developed a supply chain model with effect of trade credit. The manufacturer offers trade credit to the retailer and provides choice to the retailer to pay before, on or after the replenishment of product with profit sharing conditions. On this basis, they considered six different cases to analyze optimum policies for the supply chain.

Shen et al. [7] gave a production inventory model with consideration of carbon tax policy. In the study they considered deteriorating products and used collaborative preservation technology investments in order to reduce the deterioration rate. Product demand was considered to be constant. They provided several numerical examples to demonstrate solution procedure. Dari and Sani [8] investigated an economic production quantity model for delayed deteriorating products. They considered quadratic type time dependant product demand and linear holding cost that vary with time. They analyze the model by dividing it into three stages and investigated optimum production rate in order to minimize total cost per unit time.

Shah et al. [9] presented a model for a manufacturer-retailer supply chain with retailer's flexible payment time. In the study the retailer is allowed to pay in advance or to pay after the replenishment of product. Retailer also passes the trade credit to customers. They considered the product demand price sensitive and time dependent. They investigated optimum policies to maximize the total profit of each individual as well as the supply chain. Taleizadeh et al. [10] explored an EOQ to obtain optimal policies for an evaporating item. He considered partial back ordering and advance payment in the study and explained the model with a real case study of gasoline. Debnath et al. [11] examined fuzzy economic production quantity model with time dependent quadratic demand and exponential holding cost. They considered the model by allowing shortages with fully backlog of shortages. They also considered obsolescence cost and carbon emission cost. They used generalized derivative approach to solve the model. They also considered trade credit into account and provided numerical examples to validate the model.

Fander et al. [12] gave a model for chemical supply chain. Manufacturer uses technology level to provide high quality products. They considered lead-time contract to maximize the profit of the supply chain. In the study they considered manufacturer's lead time and technology level dependent demand. Shah et al. [13] presented an eco-friendly inventory model for a manufacturer-distributor supply chain. They considered carbon emission dependent demand to develop the inventory model for deteriorating products. They considered effective energy consumption and variable production rate in order to reduce carbon emission. They minimized the total cost of supply chain by taking carbon tax policy into account.

Singh et al. [14] studied the impact of energy consumption and carbon emission in a supply chain. They considered two level trade credit policy and obtain optimum values of decision variables in quasi closed form solution. They also considered flexible manufacturing concept to control carbon emission units. Shah et al. [15] investigated inventory policies for a system of deteriorating products. They analyzed the model by considering price sensitive – stock dependent demand. The model considers carbon emission units and analyzed the effect of greening effects on production of carbon units and total profit of the supply chain.

However, the previous researches have been carried out mainly with carbon emission-related issues. This study includes the concept of carbon-cap-trade policy and flexible payment policy to enlarge scope of trade and to encourage greening investments.

## 3. ABBREVIATIONS AND ASSUMPTIONS

The authors will use the following abbreviations in the development of the proposed model.

### 3.1. Abbreviations

*3.1.1. Parameters associated to the manufacturer*

| | |
|---|---|
| $A_m$ | Set-up cost (in $) |
| $h_m$ | Storage cost per unit/ unit time (in $) |
| $C_m$ | Purchase cost per unit (in $) |
| $u_0$ | Carbon units released during set-up |
| $u_1$ | Carbon emission/unit in production |
| $u_2$ | Carbon emission/unit-time in storage |
| $CU$ | Total carbon units per cycle |
| $CUG$ | Total carbon emission units per cycle under green investments |
| $Cc$ | Carbon cap |
| $Ct$ | Carbon tax per unit |
| $P$ | Production rate |
| $T_1$ | Production time |
| $I_m(t)$ | Inventory level at time $t$ |
| $\xi$ | Greening cost (decision variable) |
| $Iv$ | Opportunity loss in delayed payment |
| $TP_m$ | Total profit per cycle |

*3.1.2. Parameters associated to the dealer*

| | |
|---|---|
| $A_d$ | Set-up cost (in $) |
| $h_d$ | Storage cost per unit/ unit time (in $) |
| $C_d$ | Purchase cost per unit (in $)(normal) |
| $w_1$ | Purchase cost – advance payment case (in $) |
| $w_2$ | Purchase cost – delayed payment case (in $) |
| $R$ | Demand rate |
| $\theta$ | Deterioration rate ($0 < \theta < 1$) |
| $\delta_i$ | Factor associated with the payment time ($i = 1, 2$) |
| $Q$ | Total quantity of product sold per cycle |
| $p$ | Selling price per unit (decision variable) |
| $T$ | Cycle time (decision variable) |
| $M$ | Payment time (decision variable) |
| $I_d(t)$ | Inventory level at time $t$ |
| $Ie$ | Rate at which interest is earned |
| $Ic$ | Rate at which interest is charged |
| $TP_d$ | Total profit per cycle |

*3.1.3. Objective Function*

| | |
|---|---|
| $TP$ | Total profit of the supply chain per unit cycle |

### 3.2. Assumptions

(a) Products deteriorate at a constant rate $\theta$ ($0 < \theta < 1$).

(b) The manufacturer adopts lot-for-lot production policy in order to meet dealer's demand.

(c) Emission of carbon gases is considered during the set-up, production and storage.

(d) The manufacturer uses green investments to control carbon emission. There is a quadratic relationship between the greening cost per unit time (Ghosh and Shah-2015). Thus, total greening investments of the manufacturer per unit cycle $T$ is $\int_0^T \int_0^\xi m \cdot \xi^2 d\xi dt$ . Here $m > 0$ is greening efforts effectiveness factor. Under effect of green investments the carbon emission units reduced to $CUG = CU_1 + (CU - CU_1)e^{-m\xi}$ . For $0 < k < 1, CU_1 = k \cdot CU$ is minimum threshold value of carbon units under green investments.

(e) The manufacturer adopts carbon-cap-trade policy to generate revenue by selling excess carbon units.

(f) The manufacturer offers the dealer flexible payment time scheme to settle the account. Product cost for the dealer is variable and it depends on the payment time. The dealer has two choices for payment. $(i)$ Advance payment: The dealer needs to pay in advance before the replenishment of order and receives product at discounted rate $w_1 = (1 - \delta_1 M)C_d$ depending on the advance payment time $M$. Here, $\delta_1$ is the discounting factor with $0 < \delta_1 < 1$ and $M < \frac{1}{\delta_1}$ . $(ii)$ Delayed payment: By selecting this option the dealer can pay at the time of replenishment or later but by doing so the dealer need to pay higher amount $w_2 = (1 + \delta_2 M)C_d$ for the product depending on delayed payment time $M$. Here, $\delta_2$ is the uplift factor with $0 < \delta_2 < 1$ and $M < \frac{1}{\delta_2}$ .

(g) The demand rate faced by the dealer, $R = a \cdot (1 + b \cdot t - c \cdot t^2 - \alpha \cdot p)$ is price sensitive and time dependent – quadratic in nature. Here $a$ is constant demand, $0 < b < 1$ and $0 < c < 1$ are demand parameters due to time dependent quadratic nature of demand function. $\alpha > 0$ is the price elasticity factor.

## 4. MATHEMATICAL MODEL AND SOLUTION PROCEDURE

### 4.1. Mathematical Model

We start with separate model formulations for the manufacturer and the dealer. Then we proceed to evaluate combined total profit of the supply chain.

*4.1.1. Manufacturer's view*

The manufacturer produces product with production rate $P$. Thus the total production time to meet the dealer's requirement is $T_1 = \frac{Q}{P}$ and the inventory level at any time $t$ is given by the differential equation $\frac{d}{dt}I_m(t) = P; 0 \leq t \leq T_1$. Solving this differential equation using the initial condition $I_m(0) = 0$, we obtain $I_m(t) = P \cdot t$

Total storage cost $HC_m = h_m \int_0^{T_1} I_m(t)\, dt = \frac{h_m P {T_1}^2}{2}$ (1)

Carbon emission during set-up, production and storage are $u_0$, $u_1 \cdot P \cdot T_1$ and $\frac{u_2 \cdot P \cdot {T_1}^2}{2}$ respectively. Hence total carbon units are

$$CU = u_0 + u_1 \cdot P \cdot T_1 + \frac{u_2 \cdot P \cdot {T_1}^2}{2} \quad (2)$$

This quantity can be reduced using green investments. Hence the carbon units under the effect of greening investments are:

$$CUG = CU_1 + (CU - CU_1)e^{-m\xi} \quad (3)$$

Revenue generated by selling excess carbon units is:

$$RC_t = Ct(Cc - CUG) \quad (4)$$

According to the dealer's payment time, we have following cases for calculating the manufacturer's total profit.

$Case - I$ Advance payment:

If the dealer chooses to make advance payment then the manufacturer offers the product at discounted price $w_1$.The manufacturer keeps the amount in bank or financial firm to earn interest. By this the manufacturer tries to recover the loss in profit because of offering lower selling price. Interest earned by the manufacturer is $IEm_1 = Ie \cdot w_1 \cdot Q \cdot M$and the sales revenue is $SR_{m1} = (w_1 - C_m)Q$. Hence total profit of the manufacturer for case-I is as shown below.

$$TP_{m1} = \frac{1}{T}(SR_{m1} + RC_t + IE_{m1} - A_m - HC_m - GI - CTC) \quad (5)$$

$Case - II$ Delayed payment:

If the dealer chooses to pay later then dealer need to pay higher product price $w_2$. Here the manufacturer earns more from the dealer but due to delay in payment the manufacturer may have rolling money which is not obtained in the reality. Hence the manufacturer faces opportunity loss $OL_m = Iv \cdot w_2 \cdot Q \cdot M$ and the sales revenue is $SR_{m2} = (w_2 - C_m)Q$. So the total profit of the manufacturer for case-II is as shown below.

$$TP_{m2} = \frac{1}{T}(SR_{m2} + RC_t + OL_m - A_m - HC_m - GI - CTC) \quad (6)$$

*4.1.2. Dealer's view*

Dealer's inventory level decreases due to product demand and the deterioration. So the inventory level at any time $t$ is given by the differential equation $\frac{d}{dt}I_d(t) = -R - \theta I_d(t)$. By solving this differential equation using the boundary condition $I_d(T) = 0$ we get the inventory level of the dealer at time $t$ as shown below.

$$I_d(t) = a\Big(\frac{(1+bT-cT^2-\alpha p)e^{\theta(T-t)}}{\theta} - \frac{(b-2cT)e^{\theta(T-t)}}{\theta^2} - \frac{2ce^{\theta(T-t)}}{\theta^3} - \frac{1+bT-cT^2-\alpha p}{\theta} + \frac{b-2ct}{\theta^2} + \frac{2c}{\theta^3}\Big) \quad (7)$$

Now we use the initial condition $I_d(0) = Q$ to obtain the ordering quantity of the dealer. Thus,

$$Q = a\Big(\frac{(1+bT-cT^2-\alpha p)e^{\theta T}}{\theta} - \frac{(b-2cT)e^{\theta T}}{\theta^2} - \frac{2ce^{\theta T}}{\theta^3} - \frac{1+bT-cT^2-\alpha p}{\theta} + \frac{b-2ct}{\theta^2} + \frac{2c}{\theta^3}\Big) \quad (8)$$

Total storage cost $HC_d = h_d \int_0^T I_d(t)dt$ (9)

$Case - I$ Advance payment:

To complete the payment in advance the dealer borrows money from the market and charged interest till the time $T + M$. Therefore, interest paid by the dealer is $IC_1 = w_1 \cdot Ic(T + M)Q$ . On the other side the revenue generated through sales is kept in bank which earns interest $IE_1 = p \cdot Ie \int_0^T R \cdot t\,dt$ . Total revenue generated through product sales is $SR_{d1} = (p - w_1) \int_0^T R \cdot t\,dt$. Hence total profit of the dealer is as shown below.

$$TP_{d1} = \frac{1}{T}(SR_{d1} - A_d - HC_d + IE_1 - IC_1) \quad (10)$$

$Case - II$ Delayed payment:

In the case of delayed payment the dealer gets an opportunity to pay later but by opting for delayed payment dealer pays higher amount for the product. Revenue generated is $SR_{d2} = (p - w_2) \int_0^T R \cdot t\,dt$ . Interest earned by the dealer is $IE_2 = p \cdot Ie \int_0^T R \cdot t\,dt$ . Moreover, during the interval $(M, T)$ the dealer is charged interest $IC_2 = w_2 \cdot Ic(T - M)Q$ . Hence, the total profit for the dealer for this case is as shown below.

$$TP_{d2} = \frac{1}{T}(SR_{d2} - A_d - HC_d + IE_2 - IC_2) \quad (11)$$

*4.1.3. Integration to supply chain*

So far we have discussed separate calculations for total profit of supply chain players. Now we proceed to integrate them for obtaining total profit of the supply chain. Total profit of supply chain is shown below in equation (12).

$$TP = \begin{cases} TP_1 = TP_{m1} + TP_{d1} \text{ ; For advance payment} \\ TP_2 = TP_{m2} + TP_{d2} \text{ ; For delayed payment} \end{cases} \quad (12)$$

## 4.2. Solution Procedure

Our aim is to maximize total profit of the supply chain. We need optimum value of decision variables: cycle time, payment time, selling price and greening cost. According to the payment option selected by the dealer, we work out partial derivatives of the respective profit function with respect to decision variables and follow the procedure mentioned below.

***Step 1:*** Allocate values of the parameters other than decision variables in equation (12).

***Step 2:*** Differentiate equation (12) partially with respect to decision variables $M$, $T$, $p$ and $\xi$ to obtain first-order partial derivatives $\frac{\partial TPi}{\partial M}, \frac{\partial TPi}{\partial T}, \frac{\partial TPi}{\partial p}$ and $\frac{\partial TPi}{\partial \xi}$ respectively for the appropriate $i$.

***Step 3:*** Set these first-order partial derivatives equal to zero. i.e.

$$\frac{\partial TPi}{\partial M} = 0, \frac{\partial TPi}{\partial T} = 0, \frac{\partial TPi}{\partial p} = 0, \frac{\partial TP}{\partial \xi} = 0 \tag{13}$$

and solve equations (13) to find values of $(M, T, p, \xi)$. Use these values in equation (12) to find the total profit.

***Step 4:*** Check the concavity of profit function.

## 5. NUMERICAL EXAMPLE AND SENSITIVITY ANALYS

### 5.1. Numerical Example

**Example 1.** *Consider* $A_m$=*\$ 500,* $A_d$=*\$ 300,a=100, b=0.2, c=0.3,* $\alpha$=*0.002, P=600,* $\theta$=*0.1, k=0.5, m=0.5,* $\delta_1$=*0.5,* $\delta_2$=*2,* $h_m$=*\$ 1.5,* $h_d$=*\$ 1.8,* $C_m$=*\$ 150,* $C_d$=*\$ 250, Ie=0.15, Ic=0.28, Iv = 0.03, Ct= \$2, Cc=100,* $u_0$=*10,* $u_1$=*3,* $u_2$=*3.*

Using the solution procedure mentioned above, the feasible values of decision variables are obtained as shown in Table-1 .

Table 1: Optimal values of decision variables and total profit in different cases

| *case* | $M$ | $T$ | $p$ | $\xi$ | $TP_m$ | $TP_d$ | $TP$ |
|---|---|---|---|---|---|---|---|
| Advance payment | 0.288 | 0.66 | 353.16 | 13.65 | 1706.4 | 2694.7 | 4401.1 |
| Delayed payment | 0.078 | 0.59 | 351.31 | 13.70 | 3832.8 | 587.4 | 4420.2 |

We check the concavity of total profit function for the supply chain with respect to payment time of dealer, selling price, cycle time and greening cost using 3D diagrams. Concavity of the total profit function for advance payment case and delayed payment case are represented through 3D graphs in Figure 1 and Figure 2 respectively.

Next we analyse the cases with no investment in greening technology. We obtain the values of decision variables, total profit of manufacturer, total profit of dealer, total profit of supply chain and compare them with those results obtained for the cases with green technology investments. The comparison of results is shown in Table-2.

Results in Table-2 show that, in absence of greening technology investments carbon emission increases significantly. It causes a notable decrease in the profit of the manufacturer as well as profit of the supply chain. Thus the green technology investments not only help to reduce emission of carbon units but also increase overall profit of the supply chain. Hence it is worth to invest in green technology.

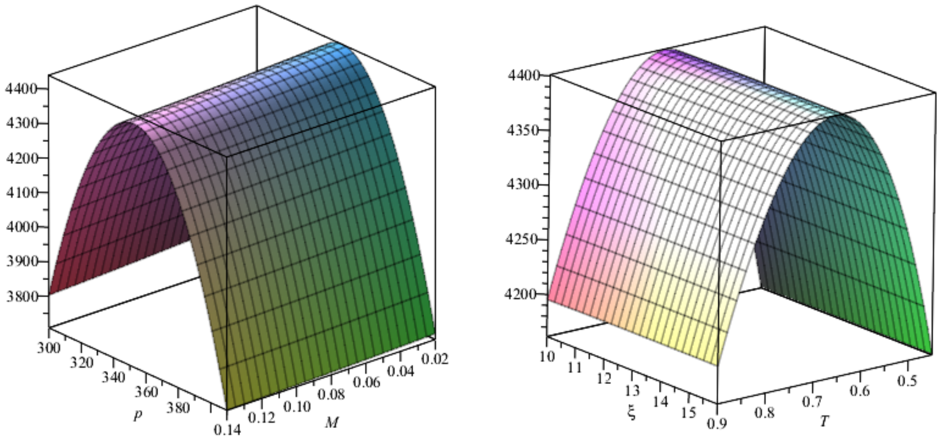


Figure 1. Concavity in advance payment case

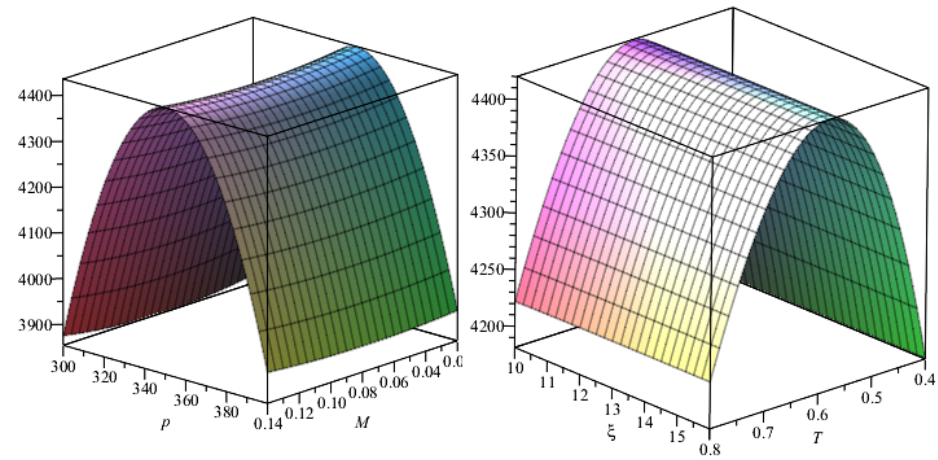


Figure 2. Concavity in delayed payment case

Table 2: Comparison of results: With green technology Versus Without green technology

| Case | Green Tech. | Carbon units | $M$ (year) | $T$ (year) | $p$ (in \$) | $\xi$ (in \$) | $TP$ (in \$) |
|---|---|---|---|---|---|---|---|
| Advance payment | ✓ | 38.02 | 0.288 | 0.66 | 353.16 | 13.65 | 4401.10 |
| | × | 75.35 | 0.280 | 0.67 | 356.22 | – | 4175.36 |
| Delayed payment | ✓ | 34.62 | 0.078 | 0.59 | 351.31 | 13.70 | 4420.17 |
| | × | 68.69 | 0.082 | 0.59 | 354.47 | – | 4188.20 |

### 5.2. Sensitivity Analysis

Now we study the effect of minor changes in some inventory parameters on decision variables and total profit function. Demand parameters and costs associated to the system are key parameters that affect the individual profits of supply chain players and the total profit of supply chain too. We change one of these parameters by small margin and study the effect of this change on profit functions.

Figure 3 represents the change in total profit function due to change in demand parameters. Total profit increases with increase in the constant demand parameter $a$, as shown in Figure $3(a)$. Figure $3(b)$ shows that the individual profits and combined profit decrease due to increase in the price elasticity factor $\alpha$. The change in total profit with respect to change in purchase cost of the manufacturer and purchase cost of the dealer are shown in figure 4 as $4(a)$ and $4(b)$ respectively. From the figure $4(a)$ it can be noted that increase in purchase cost of the manufacturer affect very low to profit of the dealer. However major decrease in profit of the manufacturer and supply chain can be observed. Figure $4(b)$ corresponds to the change in purchase cost of the dealer. Obviously total profits of dealer and that of supply chain decrease. On the other side, profit of the manufacturer increases because purchase cost of the dealer is selling price for the manufacturer.

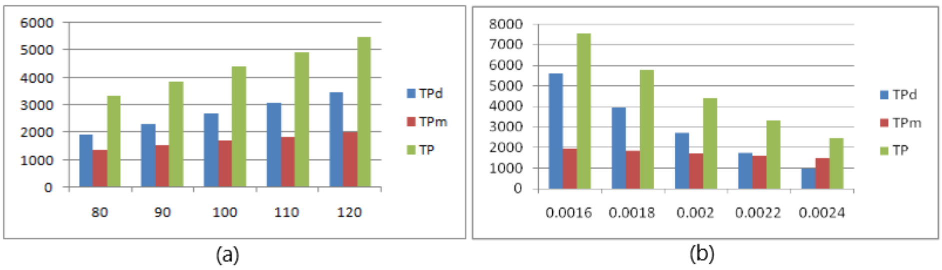


Figure 3. Sensitivity of total profit function with respect to change in demand parameters

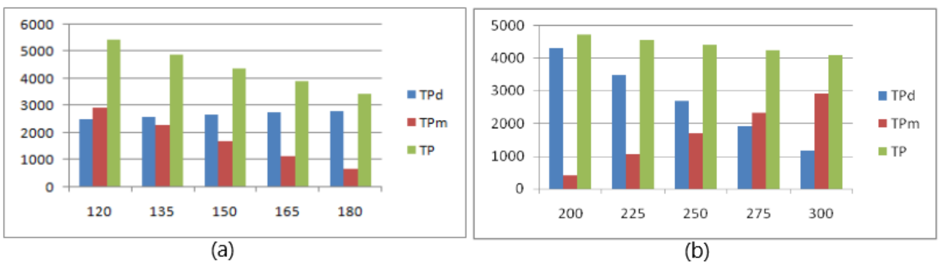


Figure 4. Sensitivity of total profit function with respect to change in purchase cost

Next we analyse the effect of change in demand parameters on carbon units emitted in both the advance payment and delayed payment cases.

Change in carbon emission units with respect to change in various demand parameters is demonstrated in figure 5 and figure 6 . Carbon emission is generally associated to the product demand. From figures it can be seen that carbon emission in advance payment case is higher than that in delayed payment case. Further, figure 5 reflects that increase in the demand parameters $a$ and $b$ causes increase in carbon units too. On the other side increase in demand parameters $c$ and $\alpha$ results into a decrease in the product demand and hence we can observe a decrease in carbon units as shown in figure 6.

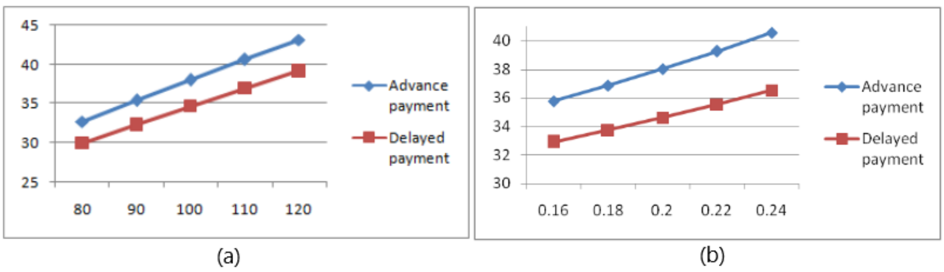


Figure 5. Carbon emission units with respect to change in demand parameters $a$ and $b$

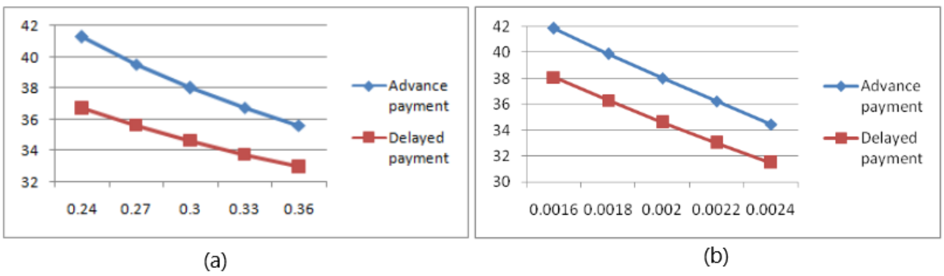


Figure 6. Carbon emission units with respect to change in demand parameters $c$ and $\alpha$

## 6. CONCLUSION

The present study is carried out for a supply chain involving a manufacturer and a dealer. The model is studied for products with constant rate of deterioration. Emission of carbon gases at different stages of product sale has been considered. Manufacturer adopts green investment policy to control and reduce carbon gases.

Manufacturer also acquires the carbon-cap-trade policy to increase the revenue. In order to have strong business bonding, the manufacturer offers the dealer a flexible payment scheme. According to financial status, the dealer can choose to pay in advance or to pay later to the distributor. Product cost for the dealer is variable and it depends on the payment time of the dealer to settle account with the manufacturer. The dealer faces price sensitive - time dependent quadratic demand. Objective of the study is to maximize total profit of the supply chain with given conditions. The problem is formulated to a mathematical model. Solution procedure is provided to get optimum solution and explained by a numerical example. The interesting results from the study show that carbon emission is less in delayed payment case compared to the advance payment case. Moreover green investments are fruitful for the manufacturer as they are useful not only to reduce carbon emission units but also to increase total profit.

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