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# EPQ MODEL TO PRICE-SENSITIVE STOCK DEPENDENT DEMAND WITH CARBON EMISSION UNDER GREEN AND PRESERVATION TECHNOLOGY INVESTMENT

***Abstract.*** *Now-a-days, preserving products and environmental balance are alarming yet greater concerns in competitive market affairs. So, some countries are focused on reducing carbon emission as it is considered to be the key factor for global warming. Most economists promote the carbon cap and carbon tax as an approach to reduce carbon emission. Moreover, the deterioration of any products can be controlled by investing in many preservation technologies as per their respective products. Keeping this in mind, an inventory model for deteriorating items is investigated under a carbon cap and carbon tax policy for a controllable carbon emission by investing in a green technology investment collaborating with preservation technology investment. The proposed model is studied for three cases: (i) with green technology investment, (ii) with preservation technology investment and (iii) with both green and preservation technology investment. The proposed article deals with stock dependent, price sensitive demand. A solution procedure has been proposed for defining the optimal strategies of cycle time, selling price, green technology investment and preservation technology investment that maximizes the total profit in each case. Additionally, numerical examples are studied to validate the model and managerial insights are carried with respect to key parameters.*

***Keywords****: Carbon emission, carbon cap, carbon tax, deterioration, preservation technology, green technology, price-stock dependent demand.*

**JEL Classification: C05**



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## 1. Introduction

The environment gets negatively affected by the quick growth of global industrialization due to toxic environments, global warming, ozone devastation and reduction of natural resources. So, sustainable development has become a major concern for a profitable business. In this context, the increase in Carbon emission is assumed to be one of the major reasons for global warming and climate change. Organizations related to conservation or environmental movements forcing companies to reduce their carbon emission to abolish such economic threats. Furthermore, many products are perished due to deterioration. As a result, regulating both the deterioration and the carbon emission is a major concern for the successful business. Moreover, above mentioned challenges can be declined by investing in preservation technology as well as green technology. Additionally, pricing is also a significant factor for a new or existing product for establishing customers or boosting legging sales. To address these types of situations our study focuses on developing a production inventory model for deteriorating items by investing in preservation technology and reduction of carbon emission under carbon cap and carbon tax by taking demand as a function of price and stock. Brief literature review of inventory model with deterioration and carbon emission are described in section 2. The notations and assumptions employed for developing an inventory model are introduced in section 3. Section 4 presents the mathematical model. Numerical solution is carried out in section 5. Managerial implications are proposed in section 6. Section 7 concludes the proposed model.

## 2. Literature review

This section provides brief literature on the inventory model by considering deterioration, pricing strategies and carbon emission regulations. When sustainability seems to be a very serious matter, most of the firms have driven on reducing emission so it has drawn more academic attention. Pentico *et al.* (2009) investigated a deterministic EPQ model with a different partial backordering. Hua *et al.* (2011) addressed an approach of carbon emission to an inventory model by taking ordering cost and holding cost as the main source of emission. Wahab *et al.* (2011) offered an EOQ model for a two level supply chain to determine the optimal production-shipment with imperfect quality. Gosh *et al.* (2011) scrutinized an EOQ model for a perishable product with a pricing policy and backordering which depends on the waiting time for the next replenishment. Then after, Bouchery *et al.* (2012) expressed the method of sustainability in which carbon emissions are reduced to a single object which is not desirable. Dye and Hsieh (2012) established an inventory model with time-varying rate of deterioration and partial backlogging with effective investment in preservation technology. Benjaafar *et al.* (2013) developed an inventory model by associating carbon emission parameters with various parameters that accounts for carbon footprints. Chen *et al.* (2013) proposed an EOQ model under reduced emissions by modifying order quantities and discussed the effects of the magnitude of emission reduction. Hu and Zhou (2014) Scrutinized an inventory model under the manufacture's joint carbon emission reduction and pricing policy using the Stackleberg game approach. The authors studied the maximum profit due to the carbon emission policy. Toptal *et al.* (2014) studied an inventory model for joint decisions on inventory replenishment and carbon emission reduction investment with three different reductions like carbon cap, tax and cap-trade policies. The authors investigated an analytical comparison between investment prospects and different carbon emission regulation policies under costs and emissions. Lou *et al.* (2015) proposed an inventory model for carbon emission policies under emission reduction technology investment in a two-stage supply chain. From the perspective of a consumer, the authors found low-carbon products mean a higher price. Dye and Yang (2015) generalized the demand and default risk under the Carbon Cap-and-Trade policy in which the demand depends on the length of the credit period under consideration of sustainability. Finally, this work is extended to the carbon offset policy. Qin *et al.* (2015) developed the sustainable trade credit and inventory policies in which demand is credit sensitive and model is constructed under: without regulation, carbon cap-and-trade regulation, and carbon tax regulation. The authors analyzed from this article that Carbon trade price and carbon tax have a negative impact on the credit period. Hovelaque and Bironneau (2015) derived an EOQ model in which demand dependence upon emissions and price by taking carbon emission into consideration. The authors discussed an optimal policy for finding proficiency of environmental objects which is more substantial for cheaper and green-labeled products and the carbon tax will reduce total and marginal emissions. Sarkar and Saren (2016) described product inspection policy for an imperfect production system which randomly shifts to out of control state from i-control state. Dye and Yang (2016) proposed an inventory model for a deteriorating product with time and price sensitive demand under preservation technology. Datta (2017) developed a production-inventory model with green technology investment for reducing emissions under carbon tax strategy in which demand is price sensitive. Taleizadeh *et al.* (2018) analyzed the SPEQ model for carbon dioxide by investing in green technology investment. Tiwari *et al.* (2018) proposed an inventory model for deteriorating items with imperfect production by taking carbon emission. Wangsa *et al.* (2018) scrutinized the sustainable electrical supply chain system which includes a power generation system, transmission and distribution substations, and many customers by assuming demand is dependent on the price of electricity. Mishra *et al.* (2019) studied a sustainable electricity supply chain mathematical model in which demand is price sensitive where the price is a decision variable under setup cost and carbon emission. Daryanto *et al.* (2019) proposed a three-echelon supply chain for deteriorated items by assuming transportation and carbon emission reduction policies affecting fuel consumption. Bardhan *et al.* (2019) analyzed an inventory model for non-instantaneous deteriorating items by applying preservation technology in which demand is stock dependent. Li *et al.* (2019) defines a joint pricing, replenishment and preservation technology investment for non-instantaneous deteriorating items in which preservation technology affects both deterioration period and rate. Mishra *et al.* (2020) developed economic production quantity carbon tax and carbon cap for controlling carbon emission with shortages and without shortages in which shortages are partially and fully backlogging. Arash (2020) proposed a production system considering carbon emissions and deterioration of items by using green and preservation technology investment in which products are deteriorated at a constant rate and carbon is radiated due to setup and holding cost. Recently Mishra *et al.* (2021) established an economic order quantity under carbon cap and tax regulation for linear and non-linear price dependent demand. Ruidas *et al.* (2021) developed an imperfect production inventory model under the various carbon emission regulatory policies like tax, cap and purchase, cap and reward and strictly under permitted cap policy in which carbon emissions are interval numbers.

## 3. Notations and Assumptions

### 3.1 Notations

**Table 1. Parameters table**

| | |
|---|---|
| **Decision variables** | |
| $T$ | Cycle time |
| $P$ | Selling price |
| $G$ | Green technology investment |
| $\xi$ | Preservation technology investment |
| **Parameters** | |
| $A$ | Setup cost per cycle |
| $C_p$ | Production cost per cycle |
| $c$ | Unit purchase cost per cycle |
| $h(1+it)$ | Unit holding cost per cycle |
| $\theta$ | Deterioration rate |
| $e_{ceA}$ | Carbon emission amount due to setup cost per cycle |
| $e_{ceh}$ | Carbon emission amount due to holding on unit inventory per cycle |
| $\alpha$ | Fraction of carbon emission reduction after green technology investment |
| $e_{cT}$ | Carbon tax per cycle |
| $e_{cc}$ | Carbon cap |

| Expressions | |
|---|---|
| $TCE$ | Total carbon emission cost per cycle |
| $RSC$ | The revenue obtained due to selling extra carbon allowances |
| $Q$ | Economic order quantity |
| $TP$ | Total profit |
| $I(t)$ | Inventory level at any instant of time |
| $R(P,t)$ | Annual demand rate as function of time and selling price |

### 3.2 Assumptions

The following assumptions are used to formulate the model.

1) The production inventory system considers single item.
2) Lead time is assumed to be negligible and disregarded.
3) This model considers deterioration. Deterioration rate is constant $\theta$ and disposal cost is not considered.
4) Demand is assumed to be stock dependent and price sensitive is given by $R(P,t)=a(1+bt-ct^2)P^{-\eta}$ where $a>0$ is scale demand, $0\le b<1$ is linear component of change demand rate with respect to time, $0\le c<1$ denotes quadratic rate of change of demand with respect to time, $P$ is a selling price per unit and $\eta>0$ represents price elasticity mark up .
5) Shortages are not allowed.
6) To protect the environment in terms of carbon emission, investment in green technology is to be considered. The fraction of reduction of average carbon emission is $f(G)=\alpha(1-e^{-mG})$ where $m$ the efficiency of green technology to reduce carbon emissions is $f(G)=0$ when $G=0$ and $f(G)\to\alpha$ when $G\to\infty$
7) To reduce the deterioration of the items, preservation technology is considered
8) $TCE$ is applied to the model using allowable carbon cap, when the retailer's carbon emission does not exceed the carbon cap, revenue is obtained from selling the extra allowance for carbon emission.

## 4. Mathematical model

To construct the production inventory model, the following notations given in Table 1 have been used throughout the article

In this section, a comprehensive inventory model is constructed for deteriorating items under carbon cap and carbon tax collaborative with green technology and preservation technology investment. Based on investment technology, the equation executed the change of inventory level.

$$\frac{dI(\mathrm{t})}{dt} = -R(\mathrm{P},\mathrm{t}) - \theta\,\mathrm{I}(\mathrm{t}),\quad 0 \le t \le T \tag{1}$$

With boundary condition $I(\mathrm{T}) = 0$, by solving equation in (1), we obtain

$$I_1(\mathrm{t}) = \mathrm{aP}^{-\eta}\left(\begin{array}{l}(1+\mathrm{bT}-\mathrm{cT}^2)\dfrac{\mathrm{e}^{\theta(\mathrm{T}-\mathrm{t})}}{\theta} - (\mathrm{b}-2\,\mathrm{cT})\dfrac{\mathrm{e}^{\theta(\mathrm{T}-\mathrm{t})}}{\theta^2} - 2\,\mathrm{c}\dfrac{\mathrm{e}^{\theta(\mathrm{T}-\mathrm{t})}}{\theta^3} - \dfrac{1}{\theta}\left(1+bt-ct^2\right)\\ +\dfrac{1}{\theta^2}\left(b-2ct\right)+\dfrac{2c}{\theta^3}\end{array}\right) \tag{2}$$

Thus the order quantity can be expressed as follow:

$$Q_1 = I_1(0) = \mathrm{aP}^{-\eta}\left((1+\mathrm{bT}-\mathrm{cT}^2)\frac{\mathrm{e}^{\theta T}}{\theta} - (\mathrm{b}-2\,\mathrm{cT})\frac{\mathrm{e}^{\theta T}}{\theta^2} - 2\,\mathrm{c}\frac{\mathrm{e}^{\theta T}}{\theta^3} - \frac{1}{\theta} + \frac{b}{\theta^2} + \frac{2c}{\theta^3}\right) \tag{3}$$

The relevant cost components are:

Ordering cost per cycle $OC = A$ (4)

Purchase cost is given by $PC = \dfrac{cQ_1}{T}$

$$PC = \frac{c\,\mathrm{aP}^{-\eta}}{T}\left((1+\mathrm{bT}-\mathrm{cT}^2)\frac{\mathrm{e}^{\theta T}}{\theta} - (\mathrm{b}-2\,\mathrm{cT})\frac{\mathrm{e}^{\theta T}}{\theta^2} - 2\,\mathrm{c}\frac{\mathrm{e}^{\theta T}}{\theta^3} - \frac{1}{\theta} + \frac{b}{\theta^2} + \frac{2c}{\theta^3}\right) \tag{5}$$

Holding cost during the interval $[0,T]$ is given by $HC = \dfrac{1}{T}\displaystyle\int_0^T h(1+it)I_1(t)dt$ (6)

Sales Revenue $SR = (P-c)\displaystyle\int_0^T R(P,t)dt$

$$SR = \frac{(P-c)aP^{\eta}}{T}\left(1+\frac{bT}{2}-\frac{cT^2}{3}\right) \tag{7}$$

The total carbon emission cost per cycle is $TCE = \dfrac{e_{ceA}}{T} + \dfrac{e_{ceh}}{T}\displaystyle\int_0^T I_1(t)\,dt$ (8)

The revenue obtained due to selling extra carbon allowance is

$$RSC = e_{cT}\left(\mathrm{e}_{cc} - \mathrm{TCE}\left(1-\alpha\left(1-e^{-mG}\right)\right)\right) \tag{9}$$

**Case:I With green technology investment and without preservation technology investment**

The total profit in this case is calculated as follow:

$$TP_1 = SR - OC - PC - HC + RSG - G$$

$$TP_1 = \frac{(P-Cp)aP^{-\eta}\left(-\frac{1}{3}cT^3 + \frac{1}{2}bT^2 + T\right)}{T} - \frac{A}{T}$$

$$- \frac{CaP^{-\eta}\left(\frac{(-T^2c+Tb+1)e^{\theta T}}{\theta} - \frac{(-2Tc+b)exp(\theta T)}{\theta^2} - \frac{2ce^{\theta T}}{\theta^3} - \frac{1}{\theta} + \frac{b}{\theta^2} + \frac{2c}{\theta^3}\right)}{T}$$

$$+ \frac{1}{12}\frac{1}{T\theta^5}\left( ah\begin{pmatrix} 12kT\theta^3 + 12ce^{\theta T}T^2\theta^3 - 12e^{\theta T}bT\theta^3 - 24ce^{\theta T}T\theta^2 + 12kbe^{\theta T}\theta \\ -4kT^3c\theta^3 + 6kT^2b\theta^3 - 3kT^4c\theta^4 + 4kT^3b\theta^4 + 12e^{\theta T}b\theta^2 \\ -12ke^{\theta T}\theta^2 + 24cke^{\theta T} + 24ce^{\theta T}\theta - 4cT^3\theta^4 + 6bT^2\theta^4 \\ +6kT^2\theta^4 - 12e^{\theta T}\theta^3 + 12\theta^4T + 12ce^{\theta T}T^2k\theta^2 - 12e^{\theta T}bTk\theta^2 \\ -24ce^{\theta T}Tk\theta - 12b\theta^2 + 12k\theta^2 - 24ck - 24c\theta - 12bk\theta + 12\theta^3 \end{pmatrix} P^{-\eta} \right)$$

$$+ e_{cT}\left( \begin{matrix} e_{cc}\left( \begin{matrix} \frac{eceA}{T} - \frac{1}{6} \\ \frac{eceha\begin{pmatrix} -2T^3c\theta^3 + 6ce^{\theta T}T^2\theta^2 + 3T^2b\theta^3 - 6e^{\theta T}bT\theta^2 \\ -12ce^{\theta T}T\theta + 6T\theta^3 + 6e^{\theta T}b\theta - 6e^{\theta T}\theta^2 \\ +12ce^{\theta T} - 6b\theta + 6\theta^2 - 12c \end{pmatrix}P^{-\eta}}{\theta^4 T} \end{matrix} \right) \\ \left(1 - \alpha\left(1 - e^{-mG}\right)\right) \end{matrix} \right) - G \qquad (10)$$

**Case:II With preservation technology investment and without green technology investment**

The inventory level at any instant of time $t$ obtained as follow:

$$I_2(t) = aP^{-\eta}\left(\begin{array}{l}\dfrac{\left(-cT^2+bT+1\right)\mathrm{e}^{\theta \mathrm{e}^{-i\xi}(T-t)}}{\theta \mathrm{e}^{-i\xi}} - \dfrac{\left(-2cT+b\right)\mathrm{e}^{\theta \mathrm{e}^{-i\xi}(T-t)}}{\theta^2\left(\mathrm{e}^{-i\xi}\right)^2} - 2\dfrac{c\mathrm{e}^{\theta \mathrm{e}^{-i\xi}(T-t)}}{\theta^3\left(\mathrm{e}^{-i\xi}\right)^3}\\ -\dfrac{-ct^2+bt+1}{\theta \mathrm{e}^{-i\xi}} + \dfrac{-2ct+b}{\theta^2\left(\mathrm{e}^{-i\xi}\right)^2} + 2\dfrac{c}{\theta^3\left(\mathrm{e}^{-i\xi}\right)^3}\end{array}\right) \quad (11)$$

The order quantity in this case is derived by following equation

$$Q_2 = I_2(0) = aP^{-\eta}\left(\begin{array}{l}\dfrac{\left(-cT^2+bT+1\right)\mathrm{e}^{\theta \mathrm{e}^{-i\xi}T}}{\theta \mathrm{e}^{-i\xi}} - \dfrac{\left(-2cT+b\right)\mathrm{e}^{\theta \mathrm{e}^{-i\xi}T}}{\theta^2\left(\mathrm{e}^{-i\xi}\right)^2} - 2\dfrac{c\mathrm{e}^{\theta \mathrm{e}^{-i\xi}T}}{\theta^3\left(\mathrm{e}^{-i\xi}\right)^3}\\ -\dfrac{1}{\theta \mathrm{e}^{-i\xi}} + \dfrac{b}{\theta^2\left(\mathrm{e}^{-i\xi}\right)^2} + 2\dfrac{c}{\theta^3\left(\mathrm{e}^{-i\xi}\right)^3}\end{array}\right) \quad (12)$$

Hence, the total profit in this case is

$$TP_2 = SR - OC - PC - HC + RSG - \xi \quad (13)$$

**Case:III With preservation technology and green technology investment**

When the manufacturer invest both preservation and green technology together the profit function is

$$I_3(t) = aP^{-\eta}\left(\begin{array}{l}\dfrac{\left(-T^2c+Tb+1\right)\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}(T-t)}}{\theta 1 \mathrm{e}^{-i\xi}} - \dfrac{\left(-2Tc+b\right)\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}(T-t)}}{\theta 1^2\left(\mathrm{e}^{-i\xi}\right)^2} - 2\dfrac{c\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}(T-t)}}{\theta 1^3\left(\mathrm{e}^{-i\xi}\right)^3}\\ -\dfrac{-ct^2+bt+1}{\theta 1 \mathrm{e}^{-i\xi}} + \dfrac{-2ct+b}{\theta 1^2\left(\mathrm{e}^{-i\xi}\right)^2} + 2\dfrac{c}{\theta 1^3\left(\mathrm{e}^{-i\xi}\right)^3}\end{array}\right) \quad (14)$$

$$Q_3 = aP^{-\eta}\left(\begin{array}{l}\dfrac{\left(-T^2c+Tb+1\right)\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}T}}{\theta 1 \mathrm{e}^{-i\xi}} - \dfrac{\left(-2Tc+b\right)\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}T}}{\theta 1^2\left(\mathrm{e}^{-i\xi}\right)^2} - 2\dfrac{c\mathrm{e}^{\theta 1 \mathrm{e}^{-i\xi}T}}{\theta 1^3\left(\mathrm{e}^{-i\xi}\right)^3}\\ -\dfrac{1}{\theta 1 \mathrm{e}^{-i\xi}} + \dfrac{b}{\theta 1^2\left(\mathrm{e}^{-i\xi}\right)^2} + 2\dfrac{c}{\theta 1^3\left(\mathrm{e}^{-i\xi}\right)^3}\end{array}\right)$$

The total profit in this case is given by

$$TP_3 = SR - OC - PC - HC + RSG - \xi - G \quad (15)$$

## 5. Numerical analysis

In this section, numerical example is presented to illustrate our inventory model and results. The objective is to maximize the total profit which can be obtained by the following procedures.

**Step:1** Differentiating equations (10), (13) and (15) partially with respect to the decesion variables $P, T, \xi$ and $G$.

**Step:2** Assign the values to all inventory parameters other than decession variables.

**Step:3** Taking all these equations equal to zero in oreder to get solutions.

The following example is considered to validate the model.

$a = \$2000$ per order, $b = 0.3$, $c = 0.5$ per cycle, A = 50 per order, h = 0.5 per unit,

k = 0.10, C =10, $e_{ceA} = 4$ per cycle, $e_{ceh} = 3$ per cycle, $e_{cT} = 5$ per cycle,

Cp = 2 per cycle, $e_{cc}$ =200 per cycle, $\alpha$=0.2, m =0.2, $\theta$ = 0.18, $\eta$ = 1.6, i =0 .5

**Table 2. Numerical experiment**

| Decision variables → | Selling price $P$ | Cycle time $T$ | Green technology $G$ | Preservation technology $\xi$ | Total profit $TP$ |
|---|---|---|---|---|---|
| Green technology investment | 58.76 | 1.21 | 2.59 | - | 1042.63 |
| Preservation technology investment | 60.13 | 1.39 | - | 2.04 | 1028.18 |
| Both green and preservation technology investment | 56.36 | 1.26 | 2.89 | 2.04 | 1050.76 |

The results from numerical examples exposed in Table 2, shows that the total optimum profit is maximum in case of both green and preservation technology investment as compared to individual case of green technology investment and preservation technology investment.

## 6. Managerial Insights

**Case: I**

The obtained optimal values of the proposed model are further calculated for the potential inventory key parameters under total carbon emission and the revenue obtained due to selling extra carbon allowances. The impact of these inventory parameters is summarized in the following figures.

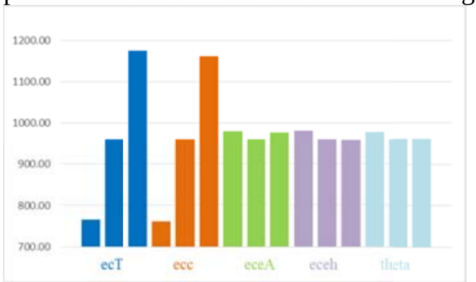


**Figure 1(a) RSC**

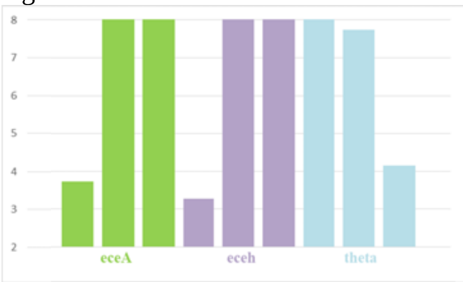


**Figure 1(b) TCE**

**Figure 1 with green technology investment**

From Fig 1(a) and 1(b) it can be shown that Carbon tax and carbon cap are the most sensitive parameters for the revenue obtained due to selling extra carbon allowances ($RSC$) in the case of green technology investment. Carbon emission amount due to setup cost and due to holding cost have negative impact on $RSC$ whereas, the total carbon emission cost ($TCE$) is increased with increses in these parameters. With the increses in the inventory parameter $\theta$, both $RSC$ and $TCE$ decreases. So carbon cap and carbon tax plays a crucial role in economic performance as well as the environmental execution.

**Case: II**

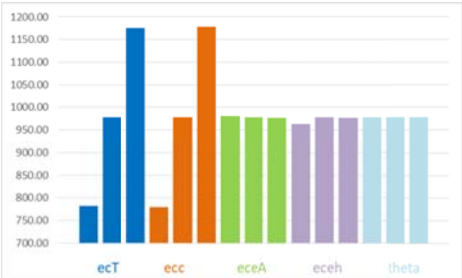


**Figure 2(a) RSC**

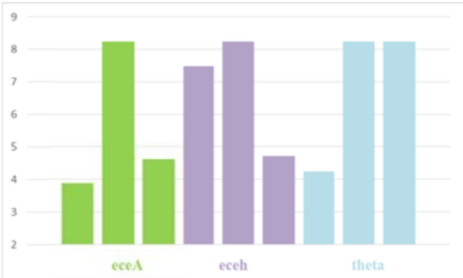


**Figure 2(b) TCE**

**Figure 2 with preservation technology investment**

In the case of preservation technology, Fig. 2(a) and 2(b) show that if the value of inventory parameters, carbon tax and carbon cap increases, $RSC$ will increase. For, carbon emission due to setup cost, carbon emission due to holding cost and $\theta$ have reasonable effect on $RSC$. $TCE$ increases with increases in carbon emission due to set up cost and $\theta$, in contrast $TCE$ decrease with carbon emission due to holding cost. From that, we can conclude that deterioration of products decreases, the sales revenue increases. Thus the proposed model recommends decreasing the number of defective items, increases the total profit. Hence, to stimulate total profit, preservation technology is an essential tool to mitigate the deterioration and saves more items.

**Case: III**

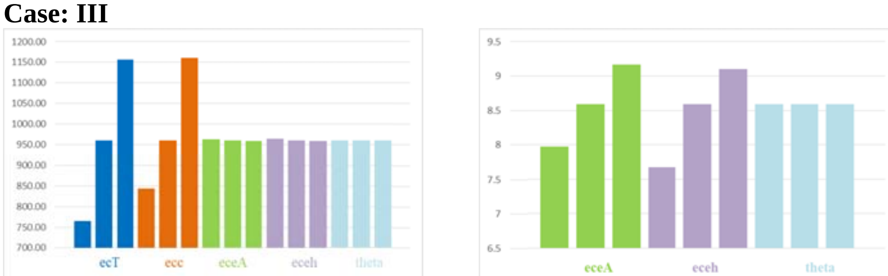


**Figure 3(a) RSC** **Figure 3(b) TCE**

**Figure 3 with green and preservation technology investment**

The increases in the carbon cap and carbon tax, the higher revenue obtained due to selling extra carbon allowances. Increasing the carbon emission due to set up cost and holding cost leads to a decrease in $RSC$, whereas it raised the $TCE$. Inventory parameter $\theta$ have a marginal effect on both $TCE$ and $RSC$. So the higher carbon cap and tax is offered, one can accumulate more revenue by selling the surplus carbon emission allowance, hence the business can emit carbon less, the more revenue can be obtained through carbon cap-and-tax is shown in Fig. 3(a) and 3(b).

## 7. Conclusions

Proposed model investigated the joint emission reduction investment and pricing decisions for a production inventory model for deteriorating items and scrutinized the impact of carbon cap and carbon tax on these decisions and profit. The goal was accomplished by investing in green technology and preservation technology. The main objective of the proposed model is to identify the optimal production, pricing, replenishment and investment tactics to reduce carbon emission as to maximize the total profit. It throws lights to some practical implication of the analysis by providing sensitivity analysis of total carbon emission ($TCE$) and revenue obtained due to selling extra carbon allowances

($RSC$) with certain inventory parameters like carbon cap, carbon tax, carbon emission due to setup cost, carbon emission due to holding cost and deterioration rate. Furthermore, we represent a numerical example to demonstrate the solution procedures. The higher the coefficient of carbon reduction such as green technology investment and preservation technology investment, mitigate the carbon emission that leads to accumulating more revenue from cap-and-tax so more profit is acquired. The more the investment in carbon reduction that is more beneficial to the business. The following aspect can be extended for future work. First carbon emission reduction policies such as carbon offset and carbon quota can be studied. Furthermore, other carbon emission sources can be assumed like carbon emission due to manufacturing, transportation, destruction of obsolete items and shortages. Additionally, demand can be taken as carbon emission dependent or also be credit sensitive.

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