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Amending Inventory Stratum for Technophile Endowment Nether Carbon Tax, Cap-and-Trade and Strict Carbon Limit Regulations

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ABSTRACT

To optimize the inventory level and technology investment under a carbon tax, cap-and-trade and strict carbon limit regulations, mathematical models are evolved. This paper focusses warehouse operations and transportation logistics systems as the sources of emissions. This study signifies that under the carbon regulations, profit and carbon emission reduction is proportional to the green technology investment and green technology promotion betides demand increase. This read-up-on also scrutinizes that for the carbon tax policy, the carbon price determines the total profit and the decreasing emission level ensures a lofty profit. On the contrary, carbon cap and carbon limit exempt total profit extremely.

Keywords: Sustainable inventory model · carbon taxation policy · cap-and-trade policy · limited carbon emission policy · green investment · weighted fuzzy goal programming.

1 Introduction

Apres the signing of the Paris Agreement in 2016, many countries have taken whack to reduce the harmful effects of carbon emissions to bring on climate change and global warming. Many investment programs and projects decisive to sustain low-carbon, development are emphasized and augmented by government and world organisations. A carbon-tax system is positioned by the government to enforce 'Greenhouse Gas' (GHG) emission limits to the company which depends on the amount of carbon-di-oxide (CO_2) emitted from their operations. In a cap-and-trade system, the government regulates the CO_2 emissions of all industries and synchronizes emission allowances between industries.

By law, many governments are encouraging to execute green industry practices. So, in the wake of reducing carbon emission many industries look for efficient methods like EOQ by contributing in additional environmentally friendly technologies and improved operations planning. This paper contemplates on precursory regulations and also other aspects of carbon emission reduction strategy like implementation of green technology and promoting green practice.
The following are the prime contributions of this paper:

(i) A technique to extract the optimal order quantity and green technology investment when companies make use of the occasion to elevate their environmental performance which is mandatory to maintain their profit.
(ii) Techniques like carbon tax, cap-and-trade and limited carbon cap promote the retailers to acknowledge to different carbon regulations.
(iii) This paper pins down the key factors that influence the total profit in low carbon EOQ models under discrete carbon regulations. It also investigates on the upshot of changes in costs and carbon regulations specifications owing to the efficiency and emission factors from the green technology.

By initiating a green technology investment many researchers have manifested a scaling down in the total carbon emission level in the view of the investment under a carbon cap-and-trade and carbon tax policies.
This read-up-on optimizes the green technology investment that accelerates the total profit.

2 Literature review

The EOQ model, being a pure economic model in classical inventory control theory aims at minimising the total cost under a deterministic setting. Arslan, M.C., Turkay, M., [1] showcases the triple bottom considerations of sustainability adjoining the traditional cost accounting. The recent works of Battini, D., Persona, A., Sgarbossa, F., [2], Chen, X., Benjaafar, S., Elomri, A.,[3] Datta, T.K., [4] have pinned the need to succour additional regulations in traditional inventory models so as to design "responsible inventory system". In view of Hovelaque, H., Bironneau, L., [5] EOQ model also promotes a condition under which it is possible to reduce emissions by modifying order quantities. In the paper, Investment strategy of emission reduction technology in a supply chain, the author presents a production inventory model under a carbon tax system. A novel method is proposed by Mashud, A.H.M., Roy, D., Daryanto, Y., Ali, Mishra,

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U., Wu, J.Z., Sarkar, B., M.H.,Mishra, U., Wu, J.Z., Tsao, Y.C., Tseng, M.L.,[6,7,8] focused to minimise the carbon emission considering the link between an inventory policy EOQ, total carbon emission and both rise in environmental dependent demands. Reduction of carbon dioxide by creating customer awareness for greener products to synchronize the preservation and green technology investment and create a discount on defective items were performed with numerical analysis by Tao, Z., Xu., J.,[9]. This hampers product deterioration and the retailing business. In line with Yang, Z., Lin, Y., [10] sustainable preservation technology and optimization model of selling price maximise the total profit. In modern competitive and transparent business, it is mandatory to maintain product quality on environmental performance. It is optimal to commit a production facility to every customer despite incurred additional cost. So, if the customers are demanding with regard to reduction of carbon emissions then the best policy can be to outline a supply chain with relatively high machine level. Furthermore, if the customers are prepared to go for a higher price for the product, it can result in carbon reduction per unit emissions.

This paper analyses that the carbon price ascertains the total profit only when the decreasing reduction of carbon emission is achieved through carbon tax, cap-and-trade and strict carbon limit regulations. This read-on answers a total profit promoting green technology investment and green technology promotion to transpire demand increase.

3 Mathematical Model

3.1 Assumptions

(i) EOQ models with immense rejuvenation in which shortages are restricted are examined. In this approach all materials accepted at the inception of the inventory cycle in one delivery which is prevalent in the buyer's inventory system.
(ii) The carbon emission model is a pertinent problem for inventory management as there are many occasions from where carbon is produced. This model signifies a couple of reason like emitting carbon from the warehouse and from the transport system whereby inventories are shipped from the supplier to the retailer warehouse. As the vechile delivers the whole order size, the carbon emission reckons on the delivery distance and emission per unit distance.
(iii) Carbon reduction can be best achieved by the use of green technology. This reduction is propounded by a function $R(G)$ as $R(G) = aG - bG^2$ where $G \prec \frac{a}{b}$.
(iv) A positive influence can be promoted if demand is sustained by green technology investment $'G'$ customer demand for environmental convenience can be attained due to the increased promotion level.

Considering all the above perceptions in single-echelon EOQ models with the demand function $D(G,\gamma)$, this model examines green technology investment to mince the carbon emission as follows:
(i) Carbon taxation policy with investment for green technology
(ii) A cap-and-trade policy with investment for green technology
(iii) Limited carbon emissions policy with investment for green technology

3.2 Notations

i - Indication of instance
$R(G)$ - Function of carbon reduction
S_P - Selling price per unit of item
D_0 - Persistency in the market demand
D_1 - Coefficient sustainability of $R(G)$
a - Competancy factor of green technology
b - Emanation in green technology
D - Rate of demand
m - Demand sensitivity towards promotion where $0 \prec m \prec 1$
v - Level of promotion
d - Spacing shipment
T_E - Total emission
E_D - Amount of carbon emitted during the distribution process
E_S - Stockpile of carbon emission as a unit product

P_0 - Purchase cost per unit
C_1 - Carbon tax per unit carbon emission
C_2 - Carbon merchandise cost
T - Transportation cost
H - Holding cost per unit
U - Carbon emissions cap / ceiling in the cap-and-trade policy
W - Limit of carbon emission in the limited emission policy
t - Reclamation cycle
Q - Paramount stock available per cycle
G - Cost of Green investment

4 Mathematical Model

4.1 Profit Function Under Carbon Tax Regulation

The carbon tax and total carbon emissions are proportional to each other. So, the total carbon emission cost under carbon tax policy is

$$TP_1 = \frac{X_1}{t}$$

where $X_1 = G\alpha_1 + G^2\alpha_2 - \frac{G}{Q}\alpha_3 + \frac{G^2}{4}\alpha_4 - \frac{1}{Q}\alpha_5 + \alpha_6$

Here, $\alpha_1 = S_P t D_1 a - \frac{D_1 a H t^2}{2} - C_P t D_1 a + \frac{a E_S C_1 D_1 t^2}{2} - C_1 a - 1$

$$\alpha_2 = \frac{Ht^2 D_1 b}{2} + C_P t D_1 b + C_1 b - S_P t D_1 b - \frac{b E_S C_1 D_1 t^2}{2}$$
$$\alpha_3 = D_1 C_1 E_D da$$
$$\alpha_4 = D_1 C_1 E_D db$$
$$\alpha_5 = C_1 E_D dD_0 + C_1 E_D dmv$$
$$\alpha_6 = S_P t D_0 - \frac{D_0 H t^2}{2} - \frac{Ht^2 mv}{2} - C_P tmv + \frac{t^2(E_S C_1 D_0 + E_S C_1 mv)}{2} + S_P tmv$$

4.2 Profit Function Under Cap-And-Trade Regulation

Assume that the government sets a limit $'U'$ for the total allowable carbon emissions. To achieve the total emissions from the related sources the retailer can sell the surplus at a rate of C_2 for which the retailer is expected to buy more allowances from other institutions or invest in green technology when it passes the limit U.
From the above assumptions, the total carbon emission cost under the cap-and-trade regulation is given by,

$$TP_2 = \frac{X_2}{t}$$

where $X_2 = G\beta_1 + G^2\beta_2 - \frac{G}{Q}\beta_3 + \frac{G^2}{4}\beta_4 - \frac{1}{Q}\beta_5 + \beta_6$

Here, $\beta_1 = S_P t D_1 a - \frac{D_1 a H t^2}{2} - C_P t D_1 a + \frac{a E_S C_2 D_1 t^2}{2} - C_2 a - 1$

$$\beta_2 = \frac{Ht^2}{2} D_1 b + C_P t D_1 b + C_2 b - S_P t D_1 b - \frac{b E_S C_2 D_1 t^2}{2}$$
$$\beta_3 = D_1 C_2 E_D da$$
$$\beta_4 = D_1 C_2 E_D db$$
$$\beta_5 = C_2 E_D dD_0 + C_2 E_D dmv$$

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$$\beta_6 = -C_P tmv + \frac{t^2(E_S C_2 D_0 + E_S C_2 mv)}{2} + C_2 U + S_P tD_0 + S_P tmv - \frac{D_0 Ht^2}{2} - \frac{Ht^2 mv}{2} - C_P tD_0$$

4.3 Profit Function Under Limited Carbon Emission Regulation

Here, the retailer adheres to a strict carbon emission limit W. By investing in green technology excessive carbon emissions must be checked. The difference between the sum of emitted carbon from all related sources and the reduction of carbon due to green technology investment must be equal to the marginal carbon emission limit W.
Hence, the inventory model under this strategy is contingent to the constraint,

$$TP_3 = \frac{X_3}{t}$$

where $X_3 = \varphi_1 - G\varphi_2 + G^2\varphi_3 + \psi\varphi_4 - \psi G\phi_5 + \psi G^2\varphi_6$

Here, $\varphi_1 = S_P tD_0 + S_P tmv - \frac{Ht^2}{2}D_0 - \frac{Ht^2}{2}mv - C_P tD_0 - \frac{E_D d}{t} - C_P tmv$

$$\varphi_2 = \frac{D_1 aHt^2}{2} + C_P tD_1 a + 1 - S_P tD_1 a$$

$$\varphi_3 = \frac{D_1 bHt^2}{2} - S_P tD_1 b + C_P tD_1 b$$

$$\varphi_4 = \frac{D_0 E_S t^2}{2} + \frac{mvE_S t^2}{2} - W$$

$$\varphi_5 = a - \frac{E_S t^2 aD_1}{2}$$

$$\varphi_6 = b - \frac{D_1 bE_S t^2}{2}$$

5 Solution Procedure

5.1 Fuzzy Goal Programming Approach

At the outlook, the objectives are transmuted into fuzzy goals by designating a hankering measure to each of them. Subsequently, the procurement of the highest membership value primarily to each of the fuzzy goal is considered.
Let the hankering measure be set to the k^{th} objective and the fuzzy goal will resemble as,
$Z_k(X) \geq g_k$ (for maximising $Z_k(X)$)
$Z_k(X) \leq g_k$ (for minimising $Z_k(X)$)
where $\geq, \leq$ indicate the fuzziness of the hankering measure and are to be understood as "essentially more than" and "essentially less than" in the sense of Zimmermann. Hence, the fuzzy linear fractional goal programming (FLGP) can be expressed as follows:
Find X
satisfying $Z_k(X) \geq g_k;\ k = 1, 2, ...K$
$Z_k(X) \leq g_k;\ k = 1, 2, ...K$
subject to: $AX \leq, =, or \geq b,\ X \geq 0$

On condition of fuzzy programming the fuzzy goals are identified by their amalogous membership function. For the k^{th} fuzzy goal $Z_k(X) \geq g_k$ the membership function μ_k can be recorded as,

$$\mu_k(X) = \begin{cases} 1, & if\ Z_k(X) \geq g_k \\ \frac{Z_k(X) - l_k}{g_k - l_k}, & if\ l_k \geq Z_k(X) \leq g_k \\ 0, & if\ Z_k(X) \leq l_k \end{cases}$$

For the k^{th} fuzzy goal $Z_k(X) W g_k$, the membership function μ_k is,

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$$\mu_k(X) = \begin{cases} 1, & if\ Z_k(X) \le g_k \\ \dfrac{U_k - Z_k(X)}{U_k - h_k}, & if\ h_k \le Z_k(X) \le U_k \\ 0, & if\ Z_k(X) \ge U_k \end{cases}$$

where U_k is the upper tolerance limit and $l_k \le g_k \le h_k \le U_k =$ real numbers.

In fuzzy programming the highest degree of membership function is 1. Hence for the above defined membership function the pliable membership goals with the hankering measure can be panned as:

$$\frac{Z_k(X) - l_k}{g_k - l_k} + d_k^+ - d_k^- = 1$$

$$\frac{U_k - Z_k(X)}{U_k - h_k} + d_k^- - d_k^+ = 1$$

where $d_k^-(\ge 0)$ and $d_k^+(\le 0)$ with $d_k^- d_k^+ = 0$ are the under deviation and over deviation respectively from the hankering measure.

We observe that the membership goal in the above equation is inherently non-linear in nature and this may create computational impediment in the solution process. To avoid such problems, the linearisation of membership goals must be carried out. Let us express the k^{th} membership goal as follows:

$$C_k X + d_k^-(d_k X + \beta_k) - d_k^+(d_k X + \beta_k) = G_k, d_k^-$$

where $C_k = L_k C_k - L_k' d_k$ and $G_k = L_k' \beta_k - L_k \beta_k$

Taking $D_k^- = d_k^-(d_k X + \beta_k)$ and $D_k^+ = d_k^+(d_k X + \beta_k)$ the goal expression can be linearized as,

$$C_k X + D_k^- - D_k^+ = G_k$$

with $D_k^- D_k^+ \ge 0$ and $D_k^- D_k^+ = 0$, since $d_k^-, d_k^+ \ge 0$ and $d_k X + \beta_k \succ 0$

Presently to minimise d_k^- implies to minimise $D_k^- / (d_k X + \beta_k)$ which is also a non-linear expression. Also when a membership goal is fully achieved $d_k^- = 0$ and when its achievement is zero $d_k^+ = 1$. So to involve $d_k^- \le 1$ in the solution we need to impose the following constraints:

$$D_k^- / (d_k X + \beta_k) \le 1 \Rightarrow d_k X + D_k^- \le \beta_k$$

Currently the goal programming model formulation becomes

Find X so as to

$$\text{Minimise} \quad Z = \sum_{k=1}^{K} W_k^- D_k^-$$

$$\text{satisfying} \quad C_k X + D_k^- - D_k^+ = G_k$$

$$\begin{aligned} \text{subject to}: \ & AX \ge b \\ & -d_k X + D_k^- \le \beta_k \\ & X \ge 0, D_k^-, D_k^+ \ge 0 \ \ for\ k = 1, 2, ...K \end{aligned}$$

where Z is the fuzzy achievement function comprising of the weighted under deviational variables in which the numerical weights $W_k^-(\ge 0), k = 1, 2, ...K$ are the respective significance of achieving hankering measure of the respective fuzzy goals conditional to the constraint set.

Now, for the respective significance of the fuzzy goals the weighing scheme can be used to set the values $W_k^-, (k = 1, 2, ...K)$ and the W_k^- can be ascertained as,

$$W_k^- = \begin{cases} \dfrac{1}{g_k - l_k}, & \text{for max fuzzy goal} \\ \dfrac{1}{U_k - h_k}, & \text{for min fuzzy goal} \end{cases}$$

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5.2 Proposed Weighted Fuzzy Additive Goal Programming Formulation

Here we phase in a new weighted fuzzy goal programming method for fuzzy goal programming problem by introducing only under-deviational variables d_k^- in the goal constraint for the fuzzy multi objective goal programming problem with the hankering measure $k = 1, 2, ...K$. Then this fuzzy goal programming method is used to achieve the highest degree of membership for each of the goals using min-max operator. The weights are attached to the fuzzy operator using the above membership function. The weighted fuzzy additive goal programming technique is formulated as:

$$\text{Minimise } \frac{X_i}{t} \quad for\ i = 1, 2, 3$$

$$\text{subject to}: D\tilde{S}_P + \lambda mv \le W$$

$$\lambda\psi G + \tilde{H} b \le E_S$$

$$\text{and } \lambda, Q \succ 0$$

6 Numerical Example

6.1 Profit Function Under Carbon Tax Regulation

a = 5; b = 0.5; OC = 100/unit; v = Rs.20/unit; m = 0.3; P_0 = Rs.3.8667/unit; T = Rs.1.0033/unit; H = Rs.0.6983/unit; d = 160.9; E_D = 0.3; E_S = 0.2; D_0 = 30; D_1 = 10; S_P = Rs.14.3333/unit; C_1 = Rs.15/unit; Q = 263.57; G = Rs.4.87/unit; E = 75.7375; $R(G)$ = 12.4916

TP_1^* = Rs.797.8166

6.2 Profit Function Under Cap-And-Trade Regulation

a = 5; b = 0.5; OC = 100/unit; v = Rs.20/unit; m = 0.3; P_0 = Rs.3.8667/unit; T = Rs.1.0033/unit; H = Rs.0.6983/unit; d = 160.9; E_D = 0.3; E_S = 0.2; D_0 = 30; D_1 = 10; S_P = Rs.14.3333/unit; C_2 = Rs.12/unit; U = 4; Q = 255.67; G = Rs.4.88/unit; E = 76.6136; $R(G)$ = 12.4928

TP_2^* = Rs.972.9810

6.3 Profit Function Under Limited Carbon Emission Regulation

a = 5; b = 0.5; OC = 100/unit; v = Rs.20/unit; m = 0.3; P_0 = Rs.3.8667/unit; T = Rs.1.0033/unit; H = Rs.0.6983/unit; d = 160.9; E_D = 0.3; E_S = 0.2; D_0 = 30; D_1 = 10; S_P = Rs.14.3333/unit; W = 10; ψ = 5; Q = 242.35; G = Rs.4.89/unit; E = 78.2386; $R(G)$ = 12.4930

TP_3^* = Rs.1208.2302

Conclusion

A company's attempt to bring down carbon emissions through inventory planning and technology investment under carbon emission regulations like carbon tax, cap-and-trade and carbon limit is explored in this paper. To maintain the company's maximum profit, exquisite resolutions with respect to the order size and the amount of investment per cycle are constructed. This paper focusses on increasing customer demand with respect to the company's green technology investment and the promotion of its green performance.

References

1. Arslan, M.C., Turkay, M., 2013, EOQ revisited with sustainability considerations found. Comput. Decis. Sci, **38**(4), 223-249.
2. Battini, D., Persona, A., Sgarbossa, F., 2014. A Sustainable EOQ model: theoretical formulation and applications. Int. J. Prod. Econ. **149**, 145-153.
3. Chen, X., Benjaafar, S., Elomri, A., 2013. The carbon-constrained EOQ. Oper. Res. Lett. 41, 172-179.

JOURNAL OF ALGEBRAIC STATISTICS
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https://publishoa.com
ISSN: 1309-3452

4. Datta, T.K., 2017. Effect of green technology investment on a production-inventory system with carbon tax. Adv. Oper. Res., 4834839.
5. Hovelaque, H., Bironneau, L., 2014. The carbon-constrained EOQ model with carbon emission dependent demand. Int. J. Prod. Econ. **164**, 285-291.
6. Mashud, A.H.M., Roy, D., Daryanto, Y., Ali, M.H., 2020b. A sustainable inventory model with imperfect products, deterioration and controllable emissions. Mathematics **8**(11), 2049.
7. Mishra, U., Wu, J.Z., Sarkar, B., 2020a. A sustainable production inventory model for a controllable carbon emissions rate under shortages. J. Cleaner. Prod. **256**, 120268.
8. Mishra, U., Wu, J.Z., Tsao, Y.C., Tseng, M.L., 2020b. Sustainable inventory system with controllable non-instantaneous deterioration and environmental emission rates. J. Cleaner. Prod. **244**, 118807.
9. Tao, Z., Xu., J., 2019. Carbon regulated EOQ models with consumer's low-carbon awareness. Sustainability **11**, 1004.
10. Yang, Z., Lin, Y., 2020. The effects of supply chain collaboration on green innovation performance: an interpretive structural modeling analysis. Sustain. Prod. Consumpt. **23**, 1-10.