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Inventory Model for Culture and Creative Product Through The Investment In Green Technology

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ABSTRACT
Industrial growth is one of the main aspects of a country's development. The risk associated with industrial development comprises higher pollution levels, overuse of natural resources and increased amounts of waste threat to ecosystems. Pollution caused by hazardous substances, production and transportation process from industry and the overuse of natural resources brings sustainable development at considerable risk. Culture and creative industries creates a new trend in the world and has its own identity. Although these industries are being successful, it also contributes to an impact of environmental sustainability, since different types of products are produced with various sizes and shapes under various production rates. As the production rate increases, emission to the environment also increases slightly. These emissions can be reduced to some extent by investment on green technologies. This paper develops a study of green inventory model for culture and creative products with emission reduction investment. Incorporation of green investment in reducing carbon emissions of the production process is considered. The proposed model maximizes the total profit of the system by finding the optimal solution for selling price, replenishment time interval, number of shipments and green investment amount. Finally, a numerical example is presented to explain the developed model.

Keywords Culture and creative industries · inventory · green technology investment · carbon reduction · environmental conservation.

1 Introduction

In order to maintain a perfect screening process and difficult situations related to the maintenance of good cultural quality and creative products in the production system, the rework process is a good solution to complement the existing shortcomings. Recently, the importance of the so-called cultural economy and the culture and creative industries is highly significant. Today, the cultural and creative industries are driving economic growth and global demand. The culture and creative industries apply the innovative thinking of individuals and groups as an extension of the modern economy, which creates and disseminates culture through industrial means or as intellectual property. The terms "cultural industry" and "creative industry" are basically interchangeable. Cultural industries have more to do with cultural heritage and traditional forms of creativity. Creative industries refer to various commercial activities related to the creation of knowledge and information. The cultural sector is classified into two parts: industrial and non-industrial sectors. Cultures are non-reproducible and aggregate the end products of consumption for the purpose of local consumption (concerts, art fairs, exhibitions) or mass reproduction, mass distribution and export (books, films, audio recordings). The parts of the cultural and creative industries are such as: the theatre, visual arts, cinema, TV, radio, music, publishing business, computer games, architecture, design, fashion and advertising. The cultural and creative industries (CCI) are characterized by several common features which are also specifications of this sector.

1. The assets are often short lived with a high risk ratio of failures over success.
2. The goods are marketed to local audiences with different languages but competing with international products.
3. The market is highly erratic, depending on fashion, trends and consumption uncertainties. Some sectors are driven hit (cinema and music for instance).
4. This field plays an important social role because it has attractive communication tools.

The industry relies primarily on fossil fuels for transportation and power generation. This leads to deforestation. These activities contribute to the release of greenhouse gases into the atmosphere. Among the

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greenhouse gases, CO2 plays an important role in global warming due to its high heat capture capacity and long atmospheric survival time. Consumer concerns about environmental issues and government regulations are forcing manufacturer to take green initiatives. Investments in green technology can reduce carbon emissions, lower carbon trading costs and subsidize carbon trading costs, subject to carbon emission regulations. Environmental conservation Costs - Measures investments and costs related to the prevention, reduction or avoidance of environmental impacts, the elimination of those impacts and recovery after natural disasters and other activities. Manufacturers are a major contributor to the carbon footprint of their final products. They can reduce their carbon footprint by changing production, stockpiling and transportation operations. Companies can also reduce their carbon footprint by investing directly in carbon reduction projects such as green vehicles, energy efficient warehousing and green manufacturing processes.

The remaining of the paper is organized as follows: Section 2 presents the literature review. Section 3 provides fundamental assumptions and notations. Section 4 describes the mathematical model. Section 5 illustrates a numerical example. Section 6 concludes the paper. A list of references is also provided.

2 Literature Review

The EOQ model is first introduce by F.W. Harris in the year 1913. After that many researchers extended this model to solve inventory problem. Teng, Chang and Goyal (2015) were added the idea of economy in that model demand is price sensitive and the production process is not always perfect in reality. Porteus (1986) was introduced the imperfect production in the basic EOQ model. An alternative solution was proposed by him for quality improvement by investment. Yang and Lo (2008) attempt to develop an inventory model for a single vendor and single buyer with process reliability consideration and permissible delay in payments. They conclude that both the yield variability and withdrawal timing are not significant factors. Ming-Feng Yang et al. (2017) built an integrated inventory model with imperfect reworking and carbon tax with cost. Nowadays, firms are trying to include environmental sustainability in their inventory decisions. Ng, Teck-Koon and Chen, Mu-Chen (2012) extended the model of Hua, Cheng and Wang (2011) and they introduced four EOQ inventory management models about carbon emission by incorporating carbon tax, carbon emissions permission, progressive taxation and regressive taxation. Ozlu (2013) discussed joint decisions on inventory replenishment and emission reduction investment under different emission regulations. Chuluunbaatar et al. (2014) proposes that cultural and creative industries (CCI) development is not only dependent on a predetermined group; as the active contributors of CCI development, should not be neglected because they aid significantly to the industries development. Hammami, Nouira and Frein (2015) built a multi echelon production inventory model which involves the effect of lead time, ordering frequency and capacity constraints. They analyzed with two cases such as carbon emissions tax and carbon emissions cap.

Zheng and Chan (2014) specified that culture and creative industries have been developing and growing in many parts of the world, especially in developed countries. Greffe (2016) introduced the economic thinking in CCI and to extract a more dynamic approach in cultural economics. Titan Emilia et al. (2008) pointed out the importance, objectives and characteristics of cultural and creative industries. Shen et al. (2012) analyzed that the development of cultural and creative industries supply chain need to focus on the overall planning and enhance the industrial chain. Min-Der Ko et al. (2017) thought the international transportation of the products would cause transportation risk, as a result, they built a two- echelon inventory and transportation risk model. Ming-Feng Yang et al. (2019) thought reworking process could be considered as a rescue to compensate for the imperfections present. Ming-Cheng Lo and Ming-Feng Yang develop an advanced inventory model to support the enterprises to boost their profit increasing and cost reduction. Tapan Kumar Datta (2017) enhanced a production inventory model under carbon tax system and suggested capital investment on green technology to reduce emissions. Marchi et al. (2018) developed a supply chain inventory model in a green environment with investment for learning in production and carbon emission reduction. Yeu-Shiang Huang et al.(2020) discussed an inventory management in supply chains with consideration of Logistics, green investment and different carbon emission policies. Kao (2018) built an inventory model for culture and creative products with the addition of carbon tax. Ritha (2019) introduced inventory model for culture and creative products with emission reduction investment. In contrast to the above literature this paper assimilates investment for green technology investment in production for the inventory model of culture and creative products.

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3 Notations and Assumptions

The following notations and assumptions are used in the proposed model.

Notations

U	Demand rate of culture and creative product
M	Production rate of culture and creative product
Q	Order quantity of buyer per lot
C_v	Vendor's production cost
C_B	Buyer's purchasing cost
A_v	Vendor's setup cost
A_B	Buyer's ordering cost
h_v	The unit holding cost for the vendor
h_B	The unit holding cost for the buyer
F	Transportation cost for each shipment
C_R	Repairing cost per item of imperfect quality for the vendor
P_d	The percentage of defective items in Q
I	The unit inspecting cost
S	The carbon tax in transportation per unit
C_1	The carbon tax of unit carbon emission
μ	The efficiency factor of carbon emission reduction
σ	The offset factor of carbon emission reduction
E_S	The carbon emissions from production setup
R_m	Remanufacturing cost per unit
C_{DW}	The total disposal cost of waste
E_C	The environmental conservation cost

Decision variable

R	Replenishment time interval between successive deliveries of the buyer
p	The unit selling price for the buyer
n	The total number of shipments per production run from the vendor to the buyer, a positive integer
G	The green technology investment

Assumptions

1. Infinite time horizon and there is a single vendor and single buyer for a single culture and creative product.
2. Assume that the demand function of culture and creative product is price dependent, then we set $U = \alpha p^{-\beta}$, with scaling factor $\alpha > 0$ and index of price sensitivity $\beta \geq 1$.
3. The relationship between production and demand rate is $U/M = \theta$, where $0 < \theta \leq 1$ is a constant and $M = 1/\theta U$. Production rate of culture and creative product M is demand dependent.
4. The relationship between the buyer's purchasing cost, buyer's selling price and vendor's production cost is $p \geq C_B \geq C_V$.

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5. Consecutive shipments are scheduled. Once the stock from previous shipment is consumed, the next shipment arrives.
6. Shortages are not permitted.
7. Carbon emissions occur in the processes of production, transportation, storage and recycling process.
8. In a single batch at the end of the vendor's 100% inspecting process, if imperfect quality items are found and the repair cost must be paid.
9. The produced items are continuously examined during the vendor's culture and creative production process.
10. Vendor plans to move towards a greener production system by investing on advance technologies, energy efficient machineries, non-conventional energy and so on.

4 Mathematical formulation

An inventory model for culture and creative products is considered with single vendor and single buyer. The imperfect quality items were reworked immediately and becomes 100% perfect. To enhance the environmental performance of supply chain, the vendor has been made investment in green technology to reduce carbon emissions. In this model, we would combine the total annual revenue of the supplier and the total annual profit of the buyer. Integrate them to obtain the joint total annual profit for the vendor and the buyer in culture and creative industries.

Vendor's Profit

The total annual profit of vendor is given by
$TP_V(n, p, Q) =$ Total revenue – production cost – setup cost – inspecting cost – repairing cost – holding cost – carbon emission from production setup.

$$TP_V(n, p, Q) = U(C_B - C_V) - \frac{A_V U}{nQ} - UI - UP_d C_R - \frac{C_V h_V Q\left[n(1-\theta) - 1 + 2\theta\right]}{2} - \frac{C_1 E_S U}{nQ} \qquad (1A)$$

Buyer's profit

The total annual profit of buyer is given by
$TP_B(n, p, Q, R) =$ Sales revenue – ordering cost – transportation cost – holding cost – Carbon tax

$$TP_B(n, p, Q, R) = Up - UC_B - \frac{A_B U}{Q} - \frac{F}{R} - \frac{C_B h_B Q}{2} - sn \qquad (2A)$$

Integrated profit of the system without green technology investment

The joint total profit of the system is obtained by adding the profit of vendor and buyer, then

$$JTP(n, p, Q) = TP_V(n, p, Q) + TP_B(n, p, Q, R)$$

$$JTP(n, p, Q) = U(p - C_V - 1 - P_d C_d) - \frac{Q}{2}\left[C_B h_B + C_V h_V (n(1-\theta) - 1 + 2\theta\right]$$
$$- \frac{U}{nQ}\left[A_V + C_1 E_S\right] - \frac{U}{Q}\left[A_B\right] - \frac{F}{R} - sn \qquad (3A)$$

Replace $Q = UR$ and $U = U(p) = a\,p^{-\beta}$ by the assumptions of the model. After substitution the expected joint total profit is given by

$$EJTP(n, p, R) = a\,p^{-\beta}\left\{p - C_V - I - P_d C_R - \frac{R}{2}\left[C_B h_B + C_V h_V (n(1-\theta) - 1 + 2\theta)\right]\right\}$$
$$- \frac{1}{nR}\left[A_V + C_1 E_S\right] - \frac{1}{R}\left[A_B + F\right] - sn \qquad (4A)$$

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Determination of optimal replenishment time interval R for any given n and p

Obtaining the first partial derivative of $EJTP(n, p, R)$ with respect to R and equating to zero, we get

$$\frac{\partial EJTP(n, p, R)}{\partial R} = 0$$

$$R^* = \sqrt{\frac{2\left[\frac{1}{n}\left(A_V + C_1 E_S\right) + \left(A_B + F\right)\right]}{\alpha\, p^{-\beta}\left[C_B h_B + C_V h_V\left(n(1-\theta) - 1 + 2\theta\right)\right]}} \tag{5A}$$

Now

$$A(n) = \sqrt{\frac{2\left[\frac{1}{n}\left(A_V + C_1 E_S\right) + \left(A_B + F\right)\right]}{\left[C_B h_B + C_V h_V\left(n(1-\theta) - 1 + 2\theta\right)\right]}} \tag{6A}$$

and

Therefore

$$R^* = \frac{1}{\sqrt{\alpha\, p^{-\beta}}} A(n) \tag{7A}$$

Determination of the optimal price p for any given n and R

Substitute $R^* = \frac{1}{\sqrt{\alpha\, p^{-\beta}}} A(n)$ in $EJTP(n, p, R)$ of Eq. (4A). Then take the partial derivative of $EJTP(n, p, R)$ with respect to p, we get

$$\frac{\partial EJTP(n, p, R)}{\partial p} = \alpha\, p^{-\beta} - \alpha\beta\, p^{-\beta-1}\left(p - C_V - I - P_d C_R\right) + \frac{\beta}{2}\sqrt{\alpha\, p^{-\beta-2}}\left\{\begin{array}{l}\frac{A(n)}{2}\left[C_B h_B + C_V h_V\left(n(1-\theta) - 1 + 2\theta\right)\right] \\ + \frac{1}{A(n)}\left[\frac{1}{n}\left(A_V + C_1 E_S\right) + \left(A_B + F\right)\right]\end{array}\right\} \tag{8A}$$

Equating the above equation to zero and solving the equation, we get the optimum selling price.

Vendor's Profit

The total annual profit of culture and creative product of vendor is given by

$TP_V(n, p, Q, G) =$ Total revenue – production cost – setup cost – inspecting cost – repairing cost – holding cost – green technology investment – environmental conservation cost – remanufacturing cost – carbon emission from production setup – disposal cost + carbon reduction for green technology.

$$TP_V(n, p, Q, G) = U(C_B - C_V) - \frac{A_V U}{nQ} - UI - UP_d C_R - \frac{C_V h_V Q\left[n(1-\theta) - 1 + 2\theta\right]}{2} - \frac{C_1 E_S U}{nQ} - \frac{R_m U}{Q} - \frac{C_{DW} U}{Q} - \frac{E_C U}{Q} - G + C_1\left(\mu G - \sigma G^2\right) \tag{1B}$$

Buyer's profit

The total annual profit of culture and creative product of buyer is given by

$TP_B(n, p, Q, R) =$ Sales revenue – ordering cost – transportation cost – holding cost – Carbon tax

$$TP_B(n, p, Q, R) = Up - UC_B - \frac{A_B U}{Q} - \frac{F}{R} - \frac{C_B h_B Q}{2} - sn \tag{2B}$$

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Integrated profit of the system with green technology investment

The joint total profit of the system is obtained by adding the profit of vendor and buyer, then

$$JTP(n,p,Q,G) = TP_V(n,p,Q,G) + TP_B(n,p,Q,R)$$

$$JTP(n,p,Q,G) = U(p - C_v - 1 - P_d C_d) - \frac{Q}{2}[C_B h_B + C_v h_v(n(1-\theta) - 1 + 2\theta] - \frac{U}{nQ}[A_v + C_1 E_S] - \frac{U}{Q}[R_m + C_{DW} + E_C + A_B] - \frac{F}{R} - G + C_1(\mu G - \sigma G^2) - sn \quad (3B)$$

Replace $Q = UR$ and $U = U(P) = \alpha p^{-\beta}$ by the assumptions of the model. After substitution the expected joint total profit is given by

$$EJTP(n,p,R,G) = \alpha p^{-\beta}\left\{p - C_v - 1 - P_d C_R - \frac{R}{2}[C_B h_B + C_v h_v(n(1-\theta) - 1 + 2\theta)]\right\} - \frac{1}{nR}[A_v + C_1 E_S] - \frac{1}{R}[R_m + C_{DW} + E_C + A_B + F] - G + C_1(\mu G - \sigma G^2) - sn \quad (4B)$$

Determination of G for any given n, p and R

Taking the first partial derivative of $EJTP(n,p,R,G)$ with respect to G and equating to zero, we get

$$\frac{\partial EJTP(n,p,R,G)}{\partial G} = 0$$

$$G^* = \frac{C_1\mu - 1}{2C_1\sigma} \quad (5B)$$

Determination of optimal replenishment time interval R for any given n, p and G

Obtaining the first partial derivative of $EJTP(n,p,R,G)$ with respect to R and equating to zero, we get

$$\frac{\partial EJTP(n,p,R,G)}{\partial R} = 0$$

$$R^* = \sqrt{\frac{2\left[\frac{1}{n}(A_v + C_1 E_S) + (R_m + C_{DW} + E_C + A_B + F\right]}{\alpha p^{-\beta}\left[C_B h_B + C_v h_v(n(1-\theta) - 1 + 2\theta\right]}} \quad (6B)$$

Now

$$A(n) = \sqrt{\frac{2\left[\frac{1}{n}(A_v + C_1 E_S) + (R_m + C_{DW} + E_C + A_B + F\right]}{\left[C_B h_B + C_v h_v(n(1-\theta) - 1 + 2\theta\right]}} \quad (7B)$$

and

Therefore

$$R^* = \frac{1}{\sqrt{\alpha p^{-\beta}}} A(n) \quad (8B)$$

Determination of the optimal price p for any given n, p and G

Substitute $R^* = \frac{1}{\sqrt{\alpha p^{-\beta}}} A(n)$ in $EJTP(n,p,R,G)$ of Eq. (4B). Then take the partial derivative of $EJTP(n,p,R,G)$ with respect to p, We get

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$$\frac{\partial EJTP(n,p,R,G)}{\partial R} = \alpha p^{-\beta} - \alpha\beta p^{-\beta-1}(p - C_v - 1 - P_d C_R) + \frac{\beta}{2}\sqrt{\alpha p^{-\beta-2}}\left\{\frac{A(n)}{2}[C_B h_B + C_v h_v(n(1-\theta) - 1 + 2\theta)] + \frac{1}{A(n)}\left[\frac{1}{n}(A_v + C_1 E_S) + (R_m + C_{DW} + E_C + A_B + F)\right]\right\} \tag{9B}$$

Equating the above equation to zero and solving the equation, we get the optimum selling price.

Optimal solution procedure

To find optimal values n, p, R and G for this model, we could follow solution procedure. The solution procedure is well known as dichotomy as in Algorithm. Numerical example is illustrated to validate the proposed inventory model.

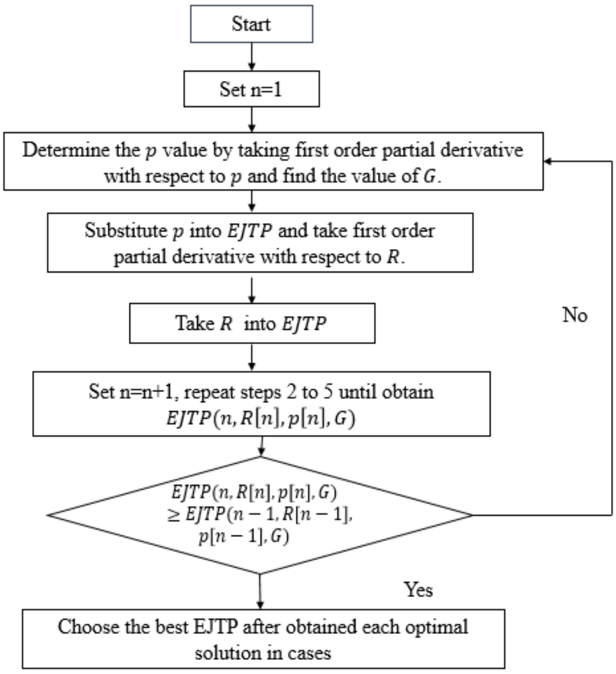

Fig.1 Algorithm chart

The algorithm used to find the optimal decision variables is as follows:

Step 1: $n = 1$

Step 2: Determine the p value by taking first-order partial derivative with respect to p of Eq. (9B) and find the value of G from Eq. (5B)

Step 3: Make use of the value of p to find R from Eq. (6B)

Step 4: Evaluate $EJTP(n, p, R, G)$ from Eq. (4B)

Step 5: Set $n = n+1$

Step 6: If $EJTP(n, R[n], p[n], G) \geq EJTP(n-1, R[n-1], P[n-1], G)$, then go to step 5. Otherwise go to Step 7.

Step 7: The optimal solution is (n^*, p^*, R^*, G^*) where $(n^*, p^*, R^*, G^*) = (n-1, P[n-1], R[n-1], G)$.

5 Numerical Example

The following are parameters of this model.

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a	80000	β	1.5
θ	0.625	E_C	$ 3.5
C_v	$ 3.5/unit	P_d	0.07
C_B	$ 5.5/unit	I	$ 1/unit
A_v	$ 300/order	s	$ 0.05/unit
A_B	$ 10/order	C_1	$ 1.6
h_v	0.06	μ	12
h_B	0.2	σ	0.01
F	$ 80	E_S	10
C_R	$ 2/unit	R_m	$ 2.5
		C_{DW}	$5

Without green technology investment, the optimal expected joint total profit is
n^* = 7 R^* = 0.33691 P^* = $ 14.792 $EJTP^*$ = $ 13,430.1

With green technology investment, the optimal solution obtained is given below:
n^* = 7 G^* = $ 5175.625 R^* = 0.33691 p^* = $ 14.792 Q^* = 492.8406 $EJTP^*$ = $ 18,605.725

6 Conclusion

In this paper, a vendor-buyer integrated inventory model for culture and creative products is investigated with green investment to reduce carbon emissions from the production.Investing in green technologies can yield more returns than the normal investment on production. The investment has been made to move towards green technologies which are environmental friendly. The optimal solution for the replenishment time interval, selling price, order quantity, green investment amount and number of shipments are determined which maximizes the profit of the integrated system.

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