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The revenue and preservation-technology investment sharing contract in the fresh-product supply chain:A game-theoretic approach

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Abstract

This research considers a fresh-product supply chain consisting of a single-buyer and a single-supplier for deteriorating products where the market demand is dependent on the retail price and fresh rate of products. Firstly, in a competitive model, the primary decision variables (i.e., the supplier's wholesale price and preservation-technology investment and also buyer's order quantity and retail price) are determined. Afterward, a centralized model is developed to optimize the whole system so that all the players inthe supply chain reach equilibrium. Then, a combined incentive mechanism based on revenue and preservation-technology investment sharing is designed to motivate the members to participate in the centralized model. Finally, the proposed models are accredited with the data set of a real-life application. The results indicate that the designed contract is capable of coordinating the fresh-product supply chain under a wide variety of sharing rate. Moreover, the transactions in the centralized mode will have less Lost-of-Profit than the decentralized ones while it also has a higher whole channel's profit.

Keywords: Supply chain coordination, fresh product, preservation-technology investment, revenue and cost sharingcontract

1-Introduction

In the recent decade, there has been a great attention on the fresh-product supply chain management (FSCM) as a sub-component of the agriculture sector (Govindasamy and Thornsbury 1999, Fouayzi, Caswell et al. 2006, XIAO, Jian et al. 2008, Cai, Chen et al. 2010, Cai, Chen et al. 2013, Su, Wu et al. 2014, Nakandala, Lau et al. 2016). The main characteristics of this type of supply chain which distinguishes this one from the other supply chains are time limit during the supply chain process (perishable products), a variety of storage options, transportation methods (temperatures, humidity), various procedures in packaging, short preparation time, and dependency on the seasonal demand (Cook 1990). Fig. 1 shows fresh-product position in the product differentiation.

The fresh-product waste is a critical issue for the countries. For example in the food sector as an important part of the fresh produce, in developing countries, almost 42% of the food losses occur after the harvest and in the sales/transfer process.

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The wastage in the EU is about 90 million tons annually (Monier, Shailendra et al. 2012). The wastage in the food products belongs to industrialized countries is about 220 million ton while the total food production in sub- Saharan Africa is almost 225 million ton. Also the fruits and vegetable waste is about 15-30% of whole products produced in the world. In the case of fish and seafood in the developing countries, losses rates between 6-8% that the major part of this rate occurring during sales and transfer process (Gustavsson, Cederberg et al. 2011). The reports show that about one-third of the fresh-product is lost or wasted globally, something about 1.2 billion tons a year (Ala-Harja and Helo 2014). The cost of global fresh-product wastage was evaluated at about 750 billion dollars in 2007(Papargyropoulou, Lozano et al. 2014).

Investing in the preservation technologies, coordinating the supply chain members, and providing the feasible mechanisms for the adoption of integrated decision-making can greatly reduce these wastages(Buisman, Haijema et al. 2017). Indeed, the preservation technologies extend the quantity and quality of fresh products with deteriorating rate reduction in safe and sustainable methods.in another word, the preservation technology helps to regulate the market by reducing the waste, help to storage and save the fresh products for future demands or when the shortage happens, and avoid the fluctuations in the retail prices during the year.

Although the perishable rate of fresh products can be managed and decreased by investing in the various care technologies, the dedicated cost of these technologies is always the challenging issue. Therefore, the optimization of the FSCM by incorporating preservation-technology investment is a new opportunity for the research.

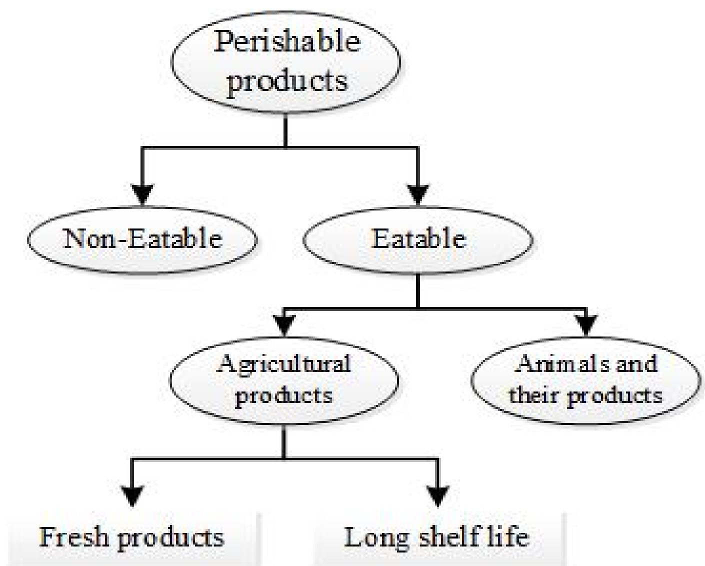

Fig. 1 Product differentiation(Adopted by (Shukla and Jharkharia 2013))

Generally, this paper presents a framework to coordinate the fresh-product decisions under preservation-technology activity while the demand is sensitive to the retail price and fresh and remaining rates. The proposed framework helps stakeholders to decide on the preservation-technology investment, wholesale price, retail price and order quantity. In brief, the main contributions that differentiate this study from similar works are as follows:

- Studying the fresh-product transactions in the supply chain coordination under uncertain multi-factor dependent demand by considering the preservation-technology investment.
- To create a more realistic model, the deterioration in both the quantity and quality of products are considered.

- Designing a combined revenue and preservation-technology investment sharing contract to coordinate the investigated supply chain and also analyzing the best options by the supply chain members.
- To verify the proposed model in practice, a case study is used based on data from 10 types of fresh products
- Providing the comprehensive sensitivity analysis for comparing the preservation-technology investment, order quantity, prices (wholesale and retail), and total profit in the decentralized, centralized, and coordinated modes.

The rest of the paper is organized as follows. We review the literature on coordination supply chain management and preservative technologies in Section 2. We also propose leader-follower Stackelberg game models in the two modes: (1) the decentralized decision-making, (2) the centralized decision-making in Section 3. In Section 4, we then propose the revenue and preservation-technology investment sharing contract to motivate the members to participate in the centralized decision-making. We then empirically test the proposed model with the numerical example in Section 5. Section 6 is devoted to conclusions and future research trends.

2-Literature review

In the past years, the integration and optimization of the perishable supply chain have attracted the attention of many researchers (Chen et al. 2005), (Chen et al. 2007), (Bisi and Dada, 2007), (Nahmias, 1977), (Pishvaee et al, 2010) and (Yu and Zhang , 2011). Moreover, along with the growing global competition, the use of quantitative methods is developed in the FSCM such as forecasting, pricing, data mining, etc.(LI, et al. 2012) and (Choi et al. 2016). These quantities methods help stakeholders to optimize important decisions such as the wholesale price, preservation-technology investment, fresh effort level, order quantity, and a retail price that significantly impact on the performance of the FSCM (Govindan et al. 2013). Under such a case, the trade will be beneficial for all stakeholders in the different aspects like price assurance, market boom, waste reduction, etc.

In this regard, in focus of the FSCM based on newsvendor approaches which are related to this study, XIAO et al.,(2008) proposed coordination supply chain model under freight business and uncertainty and long distance transportation. They presented a mechanism based on cost-sharing contract to coordinate the members of supply chain. Sana (2012) presented a coordination model based on buy-back of damaged products to the principles while he focused on the volume flexibility and replenishment lot size. Cai et al. (2013) studied a supply chain in which a vendor supplied a fresh product and buyer purchased then sold it to consumers besides both types of perishability. A wholesale-price-discount sharing contract was presented to coordinate the entire sequence. Cao et al.,(2015) proposed the coordination of a supply chain including a single manufacturer and retailer under disruptions of demand. Jin and Luo, (2017) investigated a mathematical model based on the newsvendor financing model. Their proposed model considered the optimal order quantity under different information modes (i.e., symmetry and asymmetry). Li et al., (2017) considered the order policy of retailer and the procurement price of the manufacturer with commitment-option contracts while products were seasonal.

Generally, there are a few studies on perishable supply chain management that take into account the real characteristics of the transactions, such as the preservative technologies in the collaborative supply chain channels. Under the real condition, the freshness index of products depends on the preservation-technology condition and its investment level (Dye and Yang, 2016). Indeed, the preservation-technology investment can decrease the deterioration of product, increase the freshness rate of products, and consequently reduce the level of product waste. In another hand, the buyer's retail price and order quantity is very sensitive to the freshness rate of products. In this regard, (Affisco et al. 2002) studied the preservation-technology investment on the quality control and the decrease of setup cost. Lee (2008), considered preservation-technology investment under cost/profit mathematical models to obtain the Investment return and the remaining product quality. Hsu et al.(2010) developed a perishable supply chain under fixed demand in which the supplier is permissible to use the preservation-technology characteristics. Saha et al. (2017) considered a collaborative pricing and preservative technology condition for the perishable product while the demand was dependent on the price and time.

Despite recent efforts to improve the efficiency of FSCM and waste reduction, proper efficiency and output have not yet been gained (Ameknassi et al. 2016). Moreover, based on the conducted literature review, we found that there are few studies on coordination fresh-product mathematical models considering real characteristics of the transactions such as quality and quantity level of products, the role of preservative technology in the transactions, and also new and practical coordination mechanisms for the stakeholders in the FSCM models. Indeed, due to the inherent perishability and the wide variation in demand for these types of products, detailedplanning, and practical framework could help the supply chain members to properly make their challenging decisions including supplier's wholesale price and preservation-technology investment and also buyer's order quantity and retail price. Hence, to cover this gap, this research investigates a supplier-buyer game model for deteriorating products when the supplier invest in the preservative technology while the demand is sensitive to fresh rate, remaining rate, and retail price. Afterwards, a combined revenue-preservation technology contract is designed to coordinate the investigated supply chain. Also, the proposed contracts are analyzed under their own key parameters with different product types.

3-Problem description and modelling

This study investigates the supplier-buyer structure in the following procedure: First, fresh-products are supplied in the hall's fresh-product shop while the supplier determined the wholesale price and preservation-technology investment. Then, a buyer decides about the order quantity regarding the supplier's decisions. Afterward, the buyer determines the retail price for the product delivery to the customer. Fig. 2 shows a conceptual model of the investigated fresh- product channel in this research. The stochastic demand which depends on fresh rate $\lambda(\tau)$, the retail price p is defined as follows:

$D(p,\tau) = y\lambda(\tau)p^{-e}\varepsilon, \qquad e > 1$

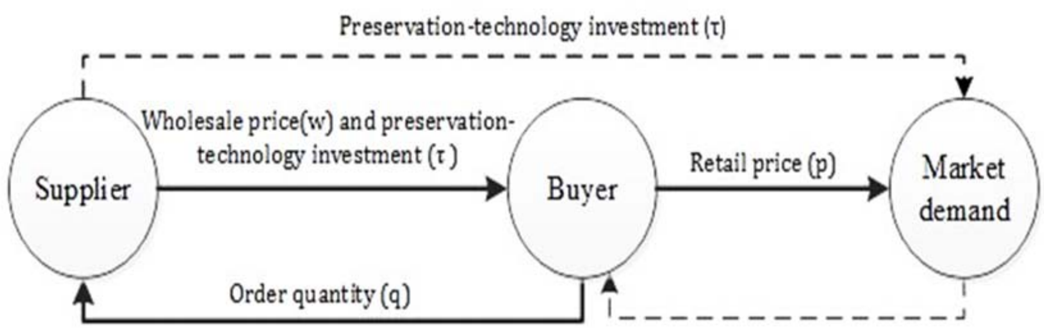

Fig. 2. The conceptual model

The main assumptions and notations list are presented as follows:

Assumptions:

1. Specifically, it is assumed $F(\tau,\varepsilon_1) = \lambda(\tau)\varepsilon_1$ and $G(\tau,\varepsilon_2) = g(\tau)\varepsilon_2$and also, both the fresh rate $\lambda(\tau)$ and remaining rate $g(\tau)$ are positive and increasing on τ. Thatis, increasing preservation-technology investment increases fresh and remaining rates.
2. A fresh rate $\lambda(\tau)$ is over [0, 1], where if $\lambda(\tau) = 1$, then the product is "completely fresh" and if $\lambda(\tau) = 0$, then the product is quietly corrupted.
3. A remaining rate $g(\tau)$ determined in the interval [0, 1] where if $g(\tau) = 1$, then the remaining product is %100 and also if$g(\tau) = 0$ then the remaining product is 0.
4. A fresh effort for reducing the deterioration rate to preserve the products is needed a cost. Hence, we define τ as a preservation-technology investment function per product unit. Function τ is strictly increasing, continuous, in the interval of$[\tau^l, \tau^u]$, and differentiable on τ.
5. The system consists of a single supplier that supplies a single-product in the fresh product supply chain by a single buyer.
6. The information is symmetric for all members, and the results are reported under an infinite time horizon

7. All costs including growing fresh products c_1 and transportation c_2 are known and constant.

Notations:

ε_1	A random variable that affectsthe fresh rate
ε_2	A random variable that affectsthe remaining rate
ε	A random variable that represents the changes in demand
y	The basic market
e	The Price elasticity
c_1	Growing cost per product unit
c_2	Transportation cost per product unit
τ	The preservation-technology investment for reducing the deterioration rate
τ^l	Given constant that states the minimum fresh effort
τ^u	Given constant that states the maximum fresh effort
$F(\tau,\varepsilon_1)$	The fresh rate function
$G(\tau,\varepsilon_2)$	The remaining rate function
p	The retail price
q	The order quantity
s	Stocking factor
w	The wholesale price
TP_b^{dec}	Buyer's total profit in the decentralized mode
TP_s^{dec}	Supplier's total profit in the decentralized mode
TP_{sc}^{dec}	Whole channel's profit in the decentralized mode
TP^{cen}	Total profit in the centralized mode

3-1-Decentralized decision-making mode

We will investigate the decision variables including the supplier's wholesale price w and preservation-technology investment$\tau$and also buyer's order quantity$q$ and retail price p with inverse inference approach. For ease of calculation, we assume that random values$(\varepsilon_1, \varepsilon_2)$ are given parameters. Also, the fresh and remaining rates are equivalent $\lambda(\tau)$ and$g(\tau)$, respictively. In this case, the optimization problem in the FSCM, as a follower, is formulated as follows:

$$TP_b^{dec}(p,q|w,\tau) = p[min(y\lambda(\tau)p^{-e}\varepsilon, g(\tau)q)] - wq \tag{1}$$

The first statement denotes the buyer's income from the product sales and the second statement gives the purchasing cost of products. According to (Petruzzi and Dada 1999)theorem, the pricing problem can be changed into an optimization problem in which the price and order quantity replaced by the price and a stocking factor, regardless of the type of demand.Therefore, the order quantity is defined as $q = y\,\lambda(\tau)p^{-e}\varepsilon\, s$ for the multiplicative demand. Then, we can change decision variables from $TP_b^{dec}(p,q|w,\tau)$ to $TP_b^{dec}(z,q|w,\tau)$in *Eq. (1)*with converter$p = (\frac{y\lambda(\tau)s}{g(\tau)q})^{\frac{1}{e}}$ as follows:

$$TP_b^{dec}(s,q|w,\tau) = (\frac{y\lambda(\tau)s}{g(\tau)q})^{\frac{1}{e}}[min(y\lambda(\tau)p^{-e}\varepsilon, g(\tau)q)] - wq \tag{2}$$

Also, after taking the mathematical expectation of *Eq. (2)* on ε, buyer's profit can be rewritten as:

$$E\left[TP_b^{dec}(s,q|w,\tau)\right] = (a\lambda(\tau)z)^{\frac{1}{e}}(g(\tau)q)^{1-\frac{1}{e}}(1 - \int_0^{s_0}\left(1-\frac{x}{s}\right)f(x)dx - wq \tag{3}$$

Proposition1. For any given$e$, the optimal stocking factor can be obtained as (Cai, Chen et al. 2010) in the following procedure:

$$s_0\bar{F}(s_0) = (e-1)\int_0^{s_0} xf(x)dx \tag{4}$$

By substituting *Eq. (4)* into *Eq. (3)*, we have:

$$TP_b^{dec}(z,q|w,\tau) = \frac{e}{e-1}\left(ys_0\lambda(\tau)\right)^{\frac{1}{e}}(1-F(s_0))(g(\tau)q)^{1-\frac{1}{e}} - wq \tag{5}$$

Proposition2. In the multiplicative case with a given the preservation-technology investment $\tau$and wholesale price w, the buyer's best order quantity satisfies:

$$q^{*dec} = ys_0 g(\tau)^{e-1}\lambda(\tau)(1-F(s_0))^e(w)^{-e} \quad (6)$$

Proof. By setting the first-order derivative equation (5) on q equal to zero, we obtain the optimal order quantity q^{*dec}. Note that the second-order derivative equation (5) on q is negative and consequently *Eq. (5*) is concave.

$$\frac{\partial TP_b^{dec}(s,q|w,\tau)}{\partial q} = \frac{e}{e-1}\left(ys_0\lambda(\tau)\right)^{\frac{1}{e}}(1-F(s_0))g(\tau)^{1-\frac{1}{e}}\left(1-\frac{1}{e}\right)q^{-\frac{1}{e}} - w \quad (7)$$

$$\frac{\partial^2 TP_b^{dec}(s,q|w,\tau)}{\partial q^2} = -\frac{1}{e-1}\left(ys_0\lambda(\tau)\right)^{\frac{1}{e}}(1-F(s_0))g(\tau)^{1-\frac{1}{e}}\left(1-\frac{1}{e}\right)q^{-\frac{1}{e}-1} < 0 \quad (8)$$

Since $\lambda(\tau)$ and $g(\tau)$ are in the range [0, 1], it is obvious that $E\{\lambda(\tau)\}$ and $E\{g(\tau)\}$ are also in the range [0, 1]. In compared with durable products, we can say that "the order quantity increase" will result in a higher fresh and remaining rates (i.e., as the preservation-technology investment increases, the deterioration probability of the products will decrease, and finally, the buyer will order a higher quantity). Also, by setting equations (4) and (5) into $p = (\frac{y\lambda(\tau)s}{qg(\tau)})^{\frac{1}{e}}$, the optimal retail price can be obtained.

After determining the decision variables of the buyer, the supplier as a leader can optimize her/his profit function according to the feedback from the buyer's values. In this regard, by substituting the buyer's optimal order quantityq^* into the supplier's total profit, the supplier searches to maximize her/his profit by setting an optimal wholesale pricew^* . The expected total profit of the supplier can be expressed:

$$TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right) = wq^{*dec} - c_1q^{*dec} - (c_2q^{*dec}+\tau) \quad (9)$$

The first statement is revenue from selling the fresh products to the buyer; the second term represents the production cost per product unit (i.e., growing, harvesting, washing, sorting, and shipping of the fresh products), third terms denote the transportation cost, and the last one gives the preservation-technology investment. By substituting *Eq. (5)* into *Eq. (9)*, we arrive at the following result:

$$TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right) = \left(w-(c_1+c_2)\right)ys_0 g(\tau)^{e-1}\lambda(\tau)\left[\frac{1-F(s_0)}{w}\right]^e - \tau \quad (10)$$

Proposition3. For a given q, if $TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right)$ is a concave function, then there is only one wholesale price that maximize supplier's total profit. In this case, the optimal wholesale price is:

$$w^{*dec} = \frac{e}{e-1}(c_1+c_2) \quad (11)$$

Proof. For the stated order quantity q by the buyer, the first and second derivatives of $TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right)$on w can be derived as:

$$\begin{aligned}\frac{\partial TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right)}{\partial w} &= (-e+1)ys_0 g(\tau)^{e-1}\lambda(\tau)[1-F(s_0)]^e w^{-e} + e(c_1 \\ &\quad + c_2)ys_0 g(\tau)^{e-1}\lambda(\tau)w^{-e-1} \\ &= ys_0 g(\tau)^{e-1}\lambda(\tau)[1-F(s_0)]^e w^{-e}\left[(-e+1)+\frac{e(c_1+c_2)}{w}\right]\end{aligned} \quad (12)$$

$$\begin{aligned}\frac{\partial^2 TP_s^{dec}\left(w,\tau\middle|q^{*dec}\right)}{\partial w^2} &= -e(-e+1)ys_0 g(\tau)^{e-1}\lambda(\tau)[1-F(s_0)]^e w^{-e-1} - (e+1)e(c_1 \\ &\quad + c_2)g(\tau)^{e-1}\lambda(\tau)w^{-e-2} \\ &= eys_0 g(\tau)^{e-1}\lambda(\tau)[1-F(s_0)]^e w^{-e-1}\left[(e-1)-\frac{(e+1)(c_1+c_2)}{w}\right]\end{aligned} \quad (13)$$

The expression $(eys_0 g(\tau)^{e-1}\lambda(\tau)[1-F(s_0)]^e w^{-e-1})$ is positive for each $y>0, e>0, w>0$. Therefore, under condition of $(e-1)<\frac{(e+1)(c_1+c_2)}{w}$ that is true for transaction, $TP_s^{dec}(w,\tau|q^{*dec})$ reaches its maximum when its first-order condition equals zero. Since *Eq. (10)*is concave, then with givenc_1,c_2, and e, we can find the optimal wholesale price $w^{*dec}$by equating the first-order of *Eq. (10)*to zero. Also, by substituting the optimal wholesale price w^{*dec} into *Eq. (10)*, we have:

$$TP_s^{dec}(w^{*dec},\tau|q^{*dec})=\frac{[(1-F(s_0)]^e[ys_0 g(\tau)^{b-1}\lambda(\tau)]}{e\left((c_1+c_2)\frac{e}{e-1}\right)^{e-1}}-\tau \tag{14}$$

Proposition 4. For a given parameter *b*, the optimal preservation-technology investment$\tau^{*dec}$is the best solution of the following equation:

$$\left[\lambda(\tau^{*dec})(e-1)g'(\tau^{*dec})g(\tau^{*dec})^{e-2}=1-\lambda'(\tau^{*dec})g(\tau^{*dec})^{e-1}\right] \tag{15}$$

Proof. See Appendix A.

Also, by substituting (4), (6), and (11) into (1), and also (6) and (11) into (12), respectively, the optimal buyer's total profit and optimal supplier's total profit in the decentralized modes are:

$$TP_b^{*dec}=\frac{[(1-F(s_0)]^e\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right]}{(e-1)\left((c_1+c_2)\frac{e}{e-1}\right)^{e-1}} \tag{16}$$

$$TP_s^{*dec}=\frac{[(1-F(s_0)]^e\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right]}{e\left((c_1+c_2)\frac{e}{e-1}\right)^{e-1}}-\tau^{*dec} \tag{17}$$

3-2-Centralized decision-making mode

The supply chains face many challenges due to those connections for resources and information. To overcome these challenges, supply chain members must be moved toward an integrated system. Hence, in this section, the optimal decision variables of the supplier and buyer are investigated under the centralized plan. The joint decision-making is now facing an optimization problem. The total profit function in the centralized decision-making mode can be expressed as follows:

$$\begin{aligned}TP^{cen}(p,q,\tau)&=p[min(y\lambda(\tau)p^{-e}\varepsilon,g(\tau)q)]-wq+wq-(c_1+c_2)q-\tau\\&=p[min(y\lambda(\tau)p^{-e}\varepsilon,g(\tau)q)]-(c_1+c_2)q-\tau\end{aligned} \tag{18}$$

With the same process of *Eq. (1) _ (3*) and repeating it for the *Eq. (18)*, the following result can be obtained:

$$TP^{cen}=\frac{e}{e-1}\left(ys_0\lambda(\tau)\right)^{\frac{1}{e}}(1-F(s_0))g(\tau)^{1-\frac{1}{e}}q^{1-\frac{1}{e}}-(c_1+c_2)q-\tau \tag{19}$$

The function structure of equation (19) is similar to the function of equation (3). Therefore, equation (19) can be analyzed like *equation (3) as the* following Proposition.

Proposition5. The optimal retail pricep^{*cen} and order quantityq^{*cen} in the centralized decision making mode are the same as those in Propositios 1 and 2 with a minor modification, *w* is changed by (c_1+c_2). The optimal values can be seen in the equations (20) *and (21) as follows*:

$$q^{*cen}=ys_0\lambda(\tau)g(\tau)^{e-1}(1-F(s_0))^e(c_1+c_2)^{-e} \tag{20}$$

$$p^{*cen}=\left(\frac{y\lambda(\tau)s_0}{q^{*cen}g(\tau)}\right)^{\frac{1}{e}} \tag{21}$$

Also, by substituting the optimal retail pricep^{*cen} and order quantity q^{*cen} into *Eq. (19)*, we have the following result with a series of simple math operations:

$$TP^{cen}(\tau) = \frac{[(1-F(s_0)]^e[ys_0 g(\tau)^{e-1}\lambda(\tau)]}{e-1(c_1+c_2)^{e-1}} - \tau \tag{22}$$

Proposition 6. For a given price elasticity *e*, the optimal preservation-technology investmentτ^{*cen} in the centralized mode is equal to decentralized one τ^{*dec}. Therefore, we can use τ^{*dec}in the centralized objective function.

Proof. The proof procedure is similar to the proof of Proposition4 and therefore ignores it.

Also, by substitutingp^{*cen} and q^{*cen}*, and*τ^{*cen}into *(19)*, the optimal profit function of the centralized mode is:

$$TP^{*cen} = \frac{[ys_0 g(\tau^{*cen})^{e-1}\lambda(\tau^{*cen})][(1-F(s_0)]^e}{e-1(c_1+c_2)^{e-1}} - \tau^{*cen} \tag{23}$$

By comparing the optimal decision variables in the decentralized and centralized modes, it can be concluded that if $(c_1+c_2) \leq w$ (that is true for any transaction), then $q^{*dec} \leq q^{*cen}$. On the other hand, the higher order quantity will decrease the retail price. It can be shown in the mathematical term as $p^{*cen} \leq p^{*dec}$. Also, by comparing the whole channel's profit in both the centralized and decentralized modes, we arrive the following result.

Proposition 7. For any given price elasticity $e > 1$**,** the centralized model improves the performance of whole channel's profit compared to the decentralized mode, i.e. $TP_{sc}^{*dec} \leq TP^{*cen}$.

Proof. Let $E = [ys_0\lambda(\tau)g(\tau)^{e-1}][(1-F(s_0)]^e$, the whole channel's profit in the decentralized mode is:

$$TP_{sc}^{*dec} = TP_b^{*dec} + TP_s^{*dec} = \frac{E}{(e-1)\left((c_1+c_2)\frac{e}{e-1}\right)^{e-1}} + \frac{E}{e\left((c_1+c_2)\frac{e}{e-1}\right)^{e-1}} - \tau^{*dec} \tag{24}$$

We multiply the whole channel's profit of the decentralized in $(\frac{e-1}{e-1})$. in this case, we have:

$$TP_{sc}^{*dec} = \left(\frac{e-1}{e}\right)^{e-1}\frac{E}{(e-1)(c_1+c_2)^{e-1}} + \left(\frac{e-1}{e}\right)^{e}\frac{E}{(e-1)(c_1+c_2)^{e-1}} - \tau^{*dec} \tag{25}$$

Under condition of $\left(\frac{e-1}{e}\right)^{e-1}\left(\frac{e-1}{e}\right)^{e} < 1$ that is true for any given price elasticity $e > 1$, the comparison of *Eqs. (23)* and *(25)* gives:

$$\underbrace{\frac{\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right][(1-F(s_0)]^e}{e-1(c_1+c_2)^{e-1}} - \tau^{*cen}}_{TP^{*cen}} > \underbrace{\left(\frac{e-1}{e}\right)^{e-1}\frac{E}{(e-1)(c_1+c_2)^{e-1}} + \left(\frac{e-1}{e}\right)^{e}\frac{E}{(e-1)(c_1+c_2)^{e-1}} - \tau^{*dec}}_{TP_{sc}^{*dec}} \tag{26}$$

As can be seen in equation (26), with a similar level of preservation-technology investment in the decentralized and centralized modes, more profit is obtained in the centralized mode. Therefore, the buyer's retail price and order quantity should be moved from (p^{*dec}, q^{*dec}) to (p^{*cen}, q^{*cen}). As a result, the profit of the buyer decreases due to changes of their optimal decision variables. Hence, a coordination mechanism is needed to motivate the buyer to participate in the centralized model.

4-Revenue and preservation-technology investment sharing contract (RPTS)

In the RS-PTI contract, the supplier first decreases the wholesale price *w*; then, the buyer returns a fraction (1-k) of its revenue to the supplier. Also, the buyer pledges to absorb a fraction k of the supplier's preservation-technology investment (See figure 3).

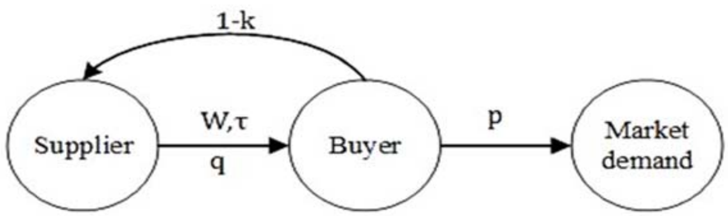

Fig 3. RS-PTI mechanism

The RS-PTI mechanism must be agreed by supply chain members. After that, the buyer determines the order quantity q that maximizes the following equation:

$$TP_b{}^{RS-PTI}(p,q|w,\tau) = kp\{min[(y\lambda(\tau)p^{-e}\varepsilon),(g(\tau)q)]\} - wq - k(c_2q+\tau) \quad (27)$$

The total profit of the supplier is as follows:

$$TP_s{}^{RS-PTI}(w,\tau|q) = wq - c_1q - (1-k)(c_2q+\tau) + (1-k)p\{min[(y\lambda(\tau)p^{-e}\varepsilon),(g(\tau)q)]\} \quad (28)$$

The order quantity q under coordinated mode is extracted such as the process of Eq. (2) - (8). In this case, the order quantity in the coordinated mode is:

$$q^{RS-PTI} = ys_0g(\tau)^{e-1}\lambda(\tau)(k(1-F(s_0))^e(w+kc_2)^{-e} \quad (29)$$

where the retail price is:

$$p^{RS-PTI} = \left(\frac{y\lambda(\tau)s_0}{q^{RS-PTI}g(\tau)}\right)^{\frac{1}{e}} \quad (30)$$

Proposition 8. The RS-PTI contract coordinates the investigated supply chain by obtaining the coordinated wholesale pricew^{RS-PTI}, preservation-technology investmentτ^{RS-PTI} , and designing the proper parameter k. In this case, the buyer's order quantity can shift to q^{*cen} to obtain higher whole channel's profit as discussed Section3. Hence, by comparing equation (29) with equation (20), we have $w^{RS-PTI} = kc_1$. Also, the optimal preservation-technology investmentτ^{RS-PTI} is obtained from the following equation:

$$(1-k)\lambda''(\tau)yp^{-e} = [(e-2)(e-1)g''(\tau)^{e-2}g(\tau) + \lambda''(\tau)g(\tau)^{e-2}] \quad (31)$$

Proof. By taking the first-order derivative of $E\left[TP_s{}^{RS-PTI}(w^{RS-PTI},\tau|q^{RS-PTI})\right]$ with respect to $\tau$and setting equal to zero, we can find the optimal valueρ. Also, by comparing equation (18) and equation (31), we find that by multiplying equation (15) in *(k+1)*, plus sentence$(k-1)\lambda''(\tau)yp^{-e}$, we arrive at *Eg. (31)*. In this case, if $0 \le k \le 1$, then $(k-1)\lambda''(\tau)yp^{-e} \le 0$. Therefore, it is proved that$\frac{\partial^2 E\left[TP_s{}^{RS-PTI}(w^{RS-PTI},\tau|q^{RS-PTI})\right]}{\partial\tau^2} < 0$.

$$\frac{\partial E\left[TP_s^{RS-PTI}(w^{RS-PTI},\tau|q^{RS-PTI})\right]}{\partial\tau} = (k+1)\left[ys_0\left(\frac{(e-1)}{(c_1+c_2)}\right)^{e-1}\left(\frac{1-F(s_0)}{e}\right)^{e}\right][(e-1)g'(\tau)g(\tau)^{e-2}\lambda(\tau) + \lambda'(\tau)g(\tau)^{e-1}] + (k-1)\lambda'(\tau)yp^{-e} \tag{32}$$

$$\frac{\partial^2 E\left[TP_s^{RS-PTI}(w^{RS-PTI},\tau|q^{RS-PTI})\right]}{\partial\tau^2} = -(k+1)\left[ys_0\left(\frac{(e-1)}{(c_1+c_2)}\right)^{e-1}\left(\frac{1-F(s_0)}{e}\right)^{e}\right][(e-2)(e-1)g''(\tau)^{e-2}\lambda(\tau) + \lambda''(\tau)g(\tau)^{e-2}] + (k-1)\lambda''(\tau)yp^{-e} \tag{33}$$

Both the buyer and the supplier accept the $RS-PTI$contract under conditions where their profits will not be less decentralized mode. Especially, the $RS-PTI$contract must satisfy the conditions$TP_b^{RS-PTI}(p,q|w,\tau) \geq TP_b^{dec}(p,q|w,\tau)$, $TP_s^{RS-PTI}(w,\tau|q) \geq TP_s^{dec}(w,\tau|q)$.Therefore, according to equations (1), (10), (27),(28) and $(w^{RS-PTI},\tau^{RS-PTI})$, the interval of sharing rate *k* is:

$$k \leq 1 - \frac{c_2 q^{*dec} - \tau^{*cen}}{p^{*cen}\left\{E\left[min\left(y\lambda(\tau^{*cen})\tau^{*cen^{-e}}\varepsilon\right),\left(g(\tau^{*cen})q^{*cen}\right)\right]\right\} - (c_1+c_2)q^{*cen} - \tau^{*cen}} \tag{34}$$

$$k \geq \frac{\left\{min\left[\left(y\lambda(\tau^{*cen})p^{*dec^{-e}}\varepsilon\right),\left(g(\tau^{*cen})q^{*dec}\right)\right]\right\} - c_1 q^{*dec}}{p^{*cen}\left\{E\left[min\left(y\lambda(\tau^{*cen})p^{*cen^{-e}}\varepsilon\right),\left(g(\tau^{*cen})q^{*cen}\right)\right]\right\} - (c_1+c_2)q^{*cen} - \tau^{*cen}} \tag{35}$$

To implement the RS-PTI contract, if we adopt a value of *k* that satisfies equations (47) and (48) and find the coordinated decision variables(w^{RS-PTI},τ^{RS-PTI}) , then all members of the supply chain in a coordinated mode will receive a decentralized minimum profit.

5-Case study and numerical results

In this section, the data set of Mazandaran fresh-product market in Iran has been used for numerical results of the proposed models. Iran has a remarkable agricultural sector among other industries (e.g., about 13% of GDP and 20% of the country's employment). The diverse climates of various regions in the country had provided a good condition to grow the fresh products(Amad 2012). Furthermore, in the country, about 2,000 plant and flower species are produced and also exports about 90000 tons flowers and more than 200 million cut flowers annual (Khojaste Nejad 2011). Intrinsic interest in floriculture, favorable regional conditions for export, and the appropriate infrastructure are key success factors for the development of this industry in the country(Riasi 2015). The growing cost and transportation cost per product unit are summarized in Table 1. Parameter *y* is the basic factor that evaluates the potential market size, and its value is equal to 500,000.The price elasticity *e* is 3. Variable ε is a random variable that shows the changes in the demand. We let f(x) and F(x) to denote the PDF and CDF of $\varepsilon \in [0, 1]$. Also, the functions of fresh and remaining rates are
$\lambda(\rho) = \propto^{(\tau/k)^k}$ $and\ g(\rho) = \beta^{(\tau/n)^n}$.

Table1.The growing and transportation costs per unit of fresh-product

Products	c_1	c_2
Type 1	1390.6	323
Type 2	1090.4	476.2
Type 3	1437	481.1
Type 4	1073	406
Type 5	1212	360.2
Type 6	1354.2	432.5
Type 7	1133.1	362.3
Type 8	900	245
Type 9	3003	568
Type 10	1202.1	331.1

The optimal decision variables including supplier's wholesale w, preservation-technology investment τ and also buyer's order quantity$q$, and retail price$p$alongside their profits are calculated in the decentralized, centralized, coordinated modes (see tables 2)

Table 2. Optimal decision variables in the decentralized, centralized and coordinated modes

Decentralized mode	*w*	*τ*	*q*	*p*	*Supplier's profit*	*Buyer's profit*	*Channel's profit*
Product #1	2475.72	370.76	8314.96	3886.08	7460641.56	12747205.4	20207847.8
Product #2	2272.4	340.4	6404.12	3592.6	5273131	9191708	14464839
Product #3	2759.08	413.08	8486.08	3806.96	8483119	9671229	18154349
Product #4	2151.88	322	9068.44	2907.2	7071246	7446423	14517670
Product #5	2279.76	341.32	9281.88	3696.56	7667419	14296540	21963959
Product #6	2579.68	386.4	9334.32	4035.12	8725335	14763922	23489257
Product #7	2188.68	327.52	7293.76	3460.12	5784717	10083384	15868101
Product #8	1690.04	253	9519.24	2527.24	5830280	8658344	14488625
Product #9	5026.88	753.48	4512.6	7168.64	8218946	10504777	18723724
Product #10	2230.08	333.96	10192.68	3205.28	8236370	10810674	19047044
Centralized mode							
Product #1	------------	371.404	10254.32	3622.96	------------	------------	23154773.4
Product #2	------------	340.86	83590.28	3289.92	------------	------------	15007217
Product #3	------------	413.816	10313.2	3442.64	------------	------------	18443839
Product #4	------------	322.828	10131.04	2732.4	------------	------------	15390905
Product #5	------------	341.964	11027.12	3622.96	------------	------------	25802749
Product #6	------------	386.952	10613.12	3521.76	------------	------------	23501583
Product #7	------------	328.348	10235	3056.24	------------	------------	15998863
Product #8	------------	253.552	9888.16	2289.88	------------	------------	15524155
Product #9	------------	754.032	8394.08	6023.24	------------	------------	19041073
Product #10	------------	334.512	10331.6	2917.32	------------	------------	19761654
Coordinated mode							
Product #1	1097.56	419.612	10254.32	3622.96	8044442.28	15110330.2	23154773.4
Product #2	875.84	385.112	83590.28	3289.92	5534587	9472630	15007217
Product #3	1131.6	467.544	10313.2	3442.64	8714216	9729623	18443839
Product #4	862.96	364.78	10131.04	2732.4	7414643	7976262	15390905
Product #5	965.08	386.4	11027.12	3622.96	9324222	16478527	25802749
Product #6	1071.8	437	10613.12	3521.76	8737187	14764396	23501583
Product #7	915.4	370.76	10235	3056.24	5860797	10138067	15998863
Product #8	736	286.12	9888.16	2289.88	6798782	8725373	15524155
Product #9	2281.6	851.92	8394.08	6023.24	8501381	10539691	19041073
Product #10	959.56	377.2	10331.6	2917.32	8392590	11369064	19761654

Table 2 illustrates that the buyer's retail price in the centralized mode is significantly less than the one in the decentralized mode while the buyer's order quantity in the centralized mode is higher than that in the decentralized mode. Also, the whole channel's profit in the centralized mode is higher than that in the decentralized mode while the preservation-technology investment is the same in both modes. However, the buyer's profit reduces under the centralized model compared to the decentralized mode due to the high reduction in the retail price. Thus, the coordination agreement (i.e., RS-PTI contracts) is applied to motivate the buyer to shift from the lower whole channel's profit (decentralized mode) to the higher whole channel's profit (centralized mode).

Moreover, the whole channel's profit in the coordinated mode under RS-PTI contract is higher than those in the decentralized mode. Also, by implementing the RS-PTI contract, a win-win result is obtained while the optimal retail price and order quantity is equal to those amounts in the centralized mode. However, the wholesale price in the coordinated mode is significantly less than the decentralized mode. Moreover, in the centralized state, the level of preservation-technology investment is greater than the decentralized mode. This increases the product's quantitative and qualitative level and consequently reduces the product waste. In addition, at the level of k=0.8 under the RS-PTI contract, the supplier will benefit more than the buyer from the profit share.

In addition, several important parameters have a more significant impact on the decision-making process (e.g., sharing rate k, and price elasticity e. In another word, changing these parameters can seriously change the optimal decision variables, and consequently, the supply chain members may shift from one mode to another one. Therefore, in the following, a set of sensitivity analysis is conducted to provide significant insight regarding the changes of optimal decision variables in response to variations of input parameters.

5-1-The sensitivity analysis with sharing rate k

As an example, in the product type 8, the sensitivity of buyer's and supplier's profits in the decentralized and coordinated modes are shown under different values of sharing rates k (See Fig. 4). Fig. 4 shows that as the sharing rate k increases under the RS-PTI contract, the profit of the buyer in the coordinated mode increases while the buyer's profit in the decentralized mode is fixed. As a result, for each $k \geq 0.52$, the buyer's profit in the coordinated mode is higher than one in the decentralized mode. On the other hand, for all values of k, the supplier's profit in the coordinated mode is better than decentralized mode. Therefore, the RS-PTI contract can coordinate the investigated supply chain under wide range of sharing rate k (i.e., $0.52 \leq k \leq 1$).

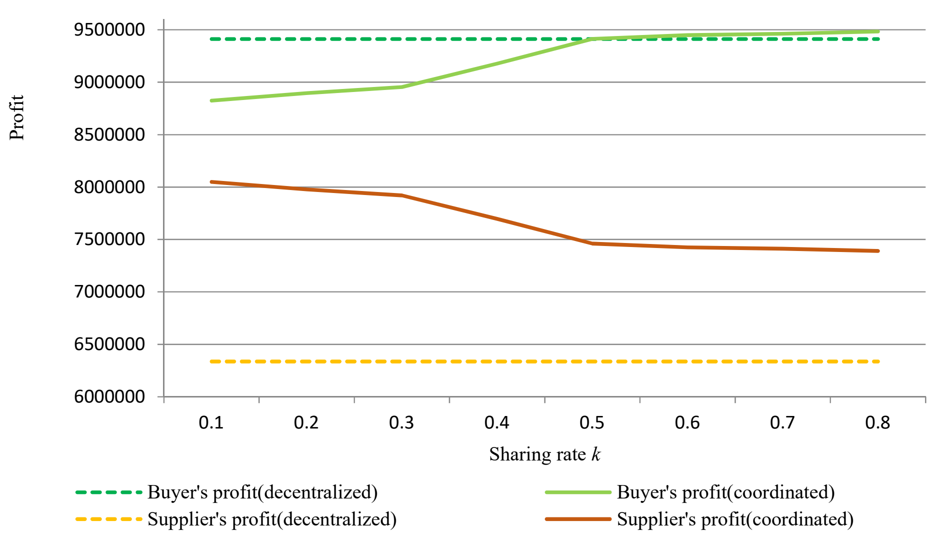

Fig4. The sensitivity of the member's profit with different sharing rates k

5-2- The sensitivity analysis with price elasticity b

To analyze the effect of price elasticity e, first, we define the Loss-of-Profit (LOP) under the absence of coordination mechanism among the members. In this case, we define variable LOP as follows:

$$LOP = 1 - \frac{TP_{sc}}{TP_i} \tag{36}$$

$$= 1 - \frac{\frac{\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right][(1-F(s_0)]^e}{(e-1)\left(\frac{e}{e-1}(c_1+c_2)\right)^{e-1}}}{\frac{\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right][(1-F(s_0)]^e}{e-1(c_1+c_2)^{e-1}} - \tau^{*cen}} - \frac{\frac{\left[\left[ys_0 g(\tau^{*dec})^{e-1}\lambda(\tau^{*dec})\right]\right][(1-F(s_0)]^e}{e\left(\frac{e}{e-1}(c_1+c_2)\right)^{e-1}} - \tau^{*dec}}{\frac{[ys_0 R(\tau^{*cen})^{e-1}\lambda(\tau^{*cen})][(1-F(s_0)]^e}{e-1(c_1+c_2)^{e-1}} - \tau^{*cen}}$$

As seen in equation (36), the value of LOP is increasing with respect to e in both the decentralized and centralized modes. Also, the price elasticity e has a high impact on the value of LOP. Hence, the amounts of LOP are drawn for the decentralized and centralized modes under different price elasticity e (see figure5)

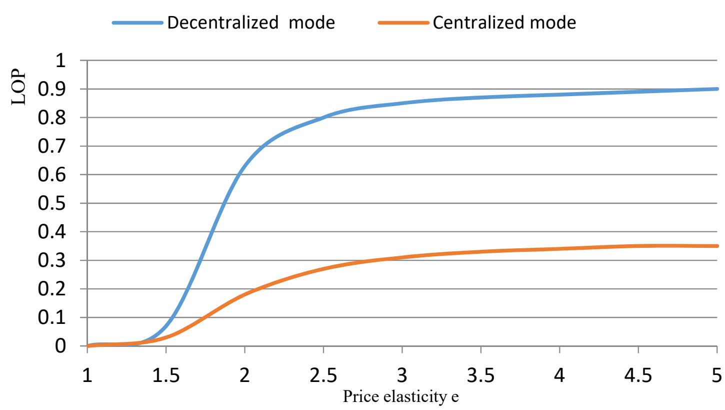

Fig 5. The impact of different price elasticity b on LOP in both the decentralized and centralized modes

The price changes have a greater impact on the decentralized mode compared to the centralized mode. Therefore, in the case of market demand that is more sensitive to the price; the amount of LOP in the decentralized mode will be greater than the centralized mode.Since the optimal preservation-technology investment ρ is strongly dependent to price elasticity b, then the impact of different price elasticity b on the preservation- technology investment ρ under centralized mode is drawn in figure 6.

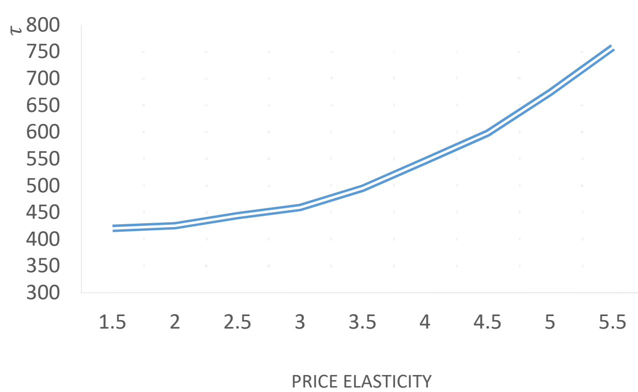

Fig 6. The impact of different price elasticity b on the preservation- technology investment ρ under decentralized and centralized mode

The output of figure 6 shows that as the price elasticity b of demand increases, the level of preservation-technology investment ρ will increase. In addition, the preservation-technology investment ρ will grow exponentially with price elasticity b greater than 3.

6-Conclusions

This paper is the first study aimed at providing application of preservation-technology investment in the fresh-product coordination model. We propose a framework to optimize the fresh-product transactions in the decentralized and centralized modes under multiplicative uncertain demand. The proposed framework helps the supply chain members to obtain the supplier's wholesale price and preservation-technology investment and also buyer's order quantity and retail price in two modes. Also, for the first time, the different approaches are used in the problem-solving process to extract the decision variables in each mode.

To verify the proposed model in practice, a data of market in Mazandaran province in Iran has utilized to illustrate the effects of different scenarios on the specified fresh-product channel. The results suggest the following results:

- The whole channel's profit in the centralized mode is higher than that in the decentralized mode while the preservation-technology investment in the centralized mode is equal to the decentralized ones.
- The buyer's order quantity in the centralized mode is higher than those in the decentralized mode. However, the buyer's profit reduces under the centralized model compared to the decentralized mode due to lower prices, and therefore he/she will refuse to participate in the joint decision-making model. To resolve the channel conflict, a practical combined contract based on the revenue and preservation investment sharing is developed to motivate the buyer to move from locally optimal solution (decentralized mode) to the globally optimum solution (centralized model).
- As the sharing rate k increases in the RS-PTI contract, the profit of the buyer in the coordinated mode increases while the buyer's profit in the decentralized mode is fixed. As a result, for each$k \geq 0.52$, the buyer's profit in the coordinated mode is higher than one in the decentralized mode. On the other hand, for all values of k, the supplier's profit in the coordinated mode is better than decentralized mode. Therefore, the RS-PTI contract can coordinate the investigated supply chain members under wide range of sharing rate k (i.e., $0.52 \leq k \leq 1$).
- The Lost-of-Profit in the decentralized mode will be greater than the centralized mode.
- As the price elasticity e of demand increases, the level of preservation-technology investment will increase. In addition, the preservation- technology investment will grow exponentially for each$e \geq 3$.Therefore, investing in the preservative technologies is not cost-effective for the high elastic products. As a result, it's better to outsource the preservation of such products.

It is noteworthy that the proposed model is applicable to the whole perishable products with minor modifications. Consideration of the multiple buyers and competition among them is an important extension. Also entering the role of third-party logistics provider can be a future direction.

References

Affisco, J. F., Paknejad, M. J., & Nasri, F. (2002). Quality improvement and setup reduction in the joint economic lot size model. *European Journal of Operational Research*, *142*(3), 497-508.

Ala-Harja, H., & Helo, P. (2015). Reprint of "Green supply chain decisions–Case-based performance analysis from the food industry". *Transportation Research Part E: Logistics and Transportation Review*, *74*, 11-21.

Amad, M. J. (2012). *Agriculture, Poverty and Reform in Iran (RLE Iran D)*. Routledge.

Ameknassi, L., Aït-Kadi, D., & Rezg, N. (2016). Integration of logistics outsourcing decisions in a green supply chain design: a stochastic multi-objective multi-period multi-product programming model. *International Journal of Production Economics*, *182*, 165-184.

Bisi, A., & Dada, M. (2007). Dynamic learning, pricing, and ordering by a censored newsvendor. *Naval Research Logistics (NRL)*, *54*(4), 448-461.

Buisman, M. E., Haijema, R., & Bloemhof-Ruwaard, J. M. (2017). Discounting and dynamic shelf life to reduce fresh food waste at retailers. *International Journal of Production Economics*.

Cao, E., Zhou, X., & Lü, K. (2015). Coordinating a supply chain under demand and cost disruptions. *International Journal of Production Research*, *53*(12), 3735-3752.

Cai, X., Chen, J., Xiao, Y., Xu, X., & Yu, G. (2013). Fresh-product supply chain management with logistics outsourcing. *Omega*, *41*(4), 752-765.

Cai, X., Chen, J., Xiao, Y., & Xu, X. (2010). Optimization and coordination of fresh product supply chains with freshness-keeping effort. *Production and Operations Management*, *19*(3), 261-278.

Chen, F. (2007). Auctioning supply contracts. *Management Science*, *53*(10), 1562-1576.

Chen, R. R., Roundy, R. O., Zhang, R. Q., & Janakiraman, G. (2005). Efficient auction mechanisms for supply chain procurement. *Management Science*, *51*(3), 467-482.

Choi, C. Y., Takekawa, J. Y., Liu, Y., Wikelski, M., Heine, G., Prosser, D. J., ... & Xiao, X. (2016). Tracking domestic ducks: A novel approach for documenting poultry market chains in the context of avian influenza transmission. *Journal of integrative agriculture*, *15*(7), 1584-1594.

Cook, R. (1990). Challenges and opportunities in the US fresh produce industry. *Journal of Food Distribution Research*, *21*(1), 67-74.

Dye, C. Y., & Yang, C. T. (2016). Optimal dynamic pricing and preservation technology investment for deteriorating products with reference price effects. *Omega*, *62*, 52-67.

Evans, D. (2012). Beyond the throwaway society: ordinary domestic practice and a sociological approach to household food waste. *Sociology*, *46*(1), 41-56.

Fouayzi, H., Caswell, J. A., & Hooker, N. H. (2006). Motivations of fresh-cut produce firms to implement quality management systems. *Review of agricultural economics*, *28*(1), 132-146.

Govindan, K., Popiuc, M. N., & Diabat, A. (2013). Overview of coordination contracts within forward and reverse supply chains. *Journal of Cleaner Production*, *47*, 319-334.

Govindasamy, R., & Thornsbury, S. (1999). Theme Overview: Fresh Produce Marketing: Critical Trends and Issues.

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R. V., & Meybeck, A. Global food losses and food waste [recurso electrónico]: extent, causes and prevention.

Hsu, P. H., Wee, H. M., & Teng, H. M. (2010). Preservation technology investment for deteriorating inventory. *International Journal of Production Economics*, *124*(2), 388-394.

Jin, W., & Luo, J. (2017). Optimal inventory and insurance decisions for a supply chain financing system with downside risk control. *Applied Stochastic Models in Business and Industry*, *33*(1), 63-80.

Khojaste Nejad, A. (2011). Studying the difficulties of flower and plants producers in Iran and giving solutions.

Lee, H. H. (2008). The investment model in preventive maintenance in multi-level production systems. *International Journal of Production Economics*, *112*(2), 816-828.

Li, J. C., Zhou, Y. W., & Huang, W. (2017). Production and procurement strategies for seasonal product supply chain under yield uncertainty with commitment-option contracts. *International journal of production economics*, *183*, 208-222.

LI, G. Q., XU, S. W., LI, Z. M., SUN, Y. G., & DONG, X. X. (2012). Using quantile regression approach to analyze price movements of agricultural products in china. *Journal of Integrative Agriculture*, *11*(4), 674-683.

Monier, V., Mudgal, S., Escalon, V., O'Connor, C., Gibon, T., Anderson, G., ... & Morton, G. (2010). Preparatory study on food waste across EU 27. European Commission, Directorate-General for the Environment.

Nahmias, S. (1977). On ordering perishable inventory when both demand and lifetime are random. *Management Science*, *24*(1), 82-90.

Nakandala, D., Lau, H., & Zhao, L. (2017). Development of a hybrid fresh food supply chain risk assessment model. *International Journal of Production Research*, *55*(14), 4180-4195.

Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & bin Ujang, Z. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, *76*, 106-115.

Petruzzi, N. C., & Dada, M. (1999). Pricing and the newsvendor problem: A review with extensions. *Operations research*, *47*(2), 183-194.

Pishvaee, M. S., Farahani, R. Z., & Dullaert, W. (2010). A memetic algorithm for bi-objective integrated forward/reverse logistics network design. *Computers & operations research*, *37*(6), 1100-1112.

Riasi, A. (2015). Barriers to international supply chain management in Iranian flower industry. *Management Science Letters*, *5*(4), 363-368.

Saha, S., Nielsen, I., & Moon, I. (2017). Optimal retailer investments in green operations and preservation technology for deteriorating items. *Journal of Cleaner Production*, *140*, 1514-1527.

Sana, S. S. (2012). A collaborating inventory model in a supply chain. *Economic Modelling*, *29*(5), 2016-2023.

S Shukla, M., & Jharkharia, S. (2013). Agri-fresh produce supply chain management: a state-of-the-art literature review. *International Journal of Operations & Production Management*, *33*(2), 114-158.

Su, J., Wu, J., & Liu, C. (2014). Research on coordination of fresh produce supply chain in big market sales environment. *The Scientific World Journal*, *2014*.

XIAO, Y. B., Jian, C. H. E. N., & XU, X. L. (2008). Fresh product supply chain coordination under CIF business model with long distance transportation. *Systems Engineering-Theory & Practice*, *28*(2), 19-34.

Yu, J., & Zhang, S. (2011). Optimal trade policy in tariff games with inside money. *Economic Modelling*, *28*(4), 1604-1614.

Appendix A.

Proof of Proposition 4. By setting the first-order derivative of equation (14) at the point τ equal to zero, we can obtain the optimal preservation-technology investmentτ^{*dec}.Note that the second-order derivative of equation (14) with respect to τ is negative, which implies that it is a concave function. This is shown in the following procedure:

$$\frac{\partial E\left[TP_s^{dec}\left(w^{*dec},\tau\middle|q^{*dec}\right)\right]}{\partial\tau} = \left[ys_0\left(\frac{(e-1)}{(c_1+c_2)}\right)^{e-1}\left(\frac{1-F(s_0)}{e}\right)^{e}\right]\left[(e-1)g'(\tau)g(\tau)^{b-2}\lambda(\rho) + \lambda'(\tau)g(\tau)^{b-1}\right] \tag{A1}$$

$$\frac{\partial^2 E\left[TP_s^{dec}\left(w^{*dec},\tau\middle|q^{*dec}\right)\right]}{\partial\tau^2} = -\left[ys_0\left(\frac{(e-1)}{(c_1+c_2)}\right)^{e-1}\left(\frac{1-F(s_0)}{e}\right)^{e}\right]\left[(e-2)(e-1)g''(\tau)^{e-2}\lambda(\tau) + \lambda''(\tau)g(\tau)^{e-2}\right] \tag{A2}$$

Based on the assumption that a distribution has an increasing failure rate if, $f'(\rho) \geq -\frac{f^2(\tau)}{\bar{F}(\tau)}, g'(s) \geq -\frac{g^2(\tau)}{\bar{G}(\tau)}$ **,** therefore, for each $a > 0$, $e > 1$, $(c_1 + c_2) > 0$, we have $\left[ys_0\left(\frac{(e-1)}{(c_1+c_2)}\right)^{e-1}\left(\frac{1-F(s_0)}{e}\right)^{e}\right] > 0$ and $[(e-2)(e-1)g''(\tau)^{e-2}\lambda(\tau) + \lambda''(\tau)g(\tau)^{e-2}] < 0$, then the function $\frac{\partial^2 E\left[TP_s^{dec}\left(w^{*dec},\tau\middle|q^{*dec}\right)\right]}{\partial\tau^2}$ is negative. This proves concavity state**.**