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COORDINATION FOR PRESERVATION AND TRACEABILITY TECHNOLOGY INVESTMENT IN A COMPLEX FOOD SUPPLY CHAIN CONSIDERING BATCH DISPERSION

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Abstract. *Food-safety incidents have become more frequent in complex food supply chains, which incur great losses including both credibility losses and recall costs. In this paper, we develop a preservation and traceability technology investment decision model to minimize potential costs in a complex food supply chain. The comparison between decentralized and centralized equilibrium solutions shows that suppliers under-invest and manufacturers over-invest in a decentralized supply chain. Then, we depict the polygon of centralized solutions and analyze the impacts of different coordination mechanisms. Our results show that the internal coordination mechanism (e.g., recall cost-sharing contract) and external interventions, such as carbon tax policy and TT subsidy policy cannot coordinate the food supply chain. Furthermore, we propose an external intervention – the carbon tax and PT subsidy mechanism, which provides different tax rates or subsidy rates for suppliers and manufacturers, and illustrate its effectiveness in technology investment coordination.*

Keywords: Technology investment, Coordination mechanism, Food-safety, Food supply chain, Carbon tax

1. **Introduction.** Usually, food needs rigorous temperature-controlled management, and food supply chains are long and complex. Any logistics sector may make mistakes and cause food-safety incidents, which harm the reputation of food brands and lead to the disposure or recall of suspected contaminated food [1]. To reduce potential losses and guarantee food safety, food-safety technologies, including preservation technology (PT) and traceability technology (TT), should be adopted in food supply chains [2,3].

In extant studies, technology investment is optimized considering the tradeoff between investment cost and positive influences of investment, such as improving food freshness (PT investment) and reducing recall cost (TT investment) [4,5]. In addition, technology investment needs the collaborative efforts of supply chain members. Lee et al. [6] examine coordination mechanisms including investment cost-sharing, tax reduction and penalty for joint technology investment of supply chains. Chen et al. [7] propose a risk-sharing contract to coordinate supply chain RFID investment. With respect to PT investment and TT investment, Zhang et al. [8] study cooperative PT investment and Dai et al. [9] design an interest-sharing mechanism to coordinate TT investment. While PT and TT investment has not been coordinated simultaneously in extant studies, it will be discussed in our paper.

In a complex supply chain with batch dispersion, our concern is to reduce recall cost in food-safety incidents. Relevant research has laid a solid foundation for our research. Dupuy et al. [10] first propose the concept of batch dispersion and reduce recall cost by reducing batch size and batch mixing. Rong and Grunow [11] calculate the quantity of potentially recalled products when dealing with safety incidents. Dabbene and Gay

[12] and Yu and Nagurney [13] take losses in each logistics path or the whole process into consideration. Piramuthu et al. [14] study recall dynamics in a complex supply network through three visibility levels and consider liability allocation based on identification accuracy.

It is observed that little research studies PT and TT investment coordination, especially in a complex food supply chain. In order to minimize the costs of supply chain members and guarantee food safety, we develop a PT and TT investment decision model and analyze the performances of different coordination mechanisms. The rest of the paper is organized as follows. The next section presents the model formulation. Section 3 provides the decentralized and centralized equilibrium solutions and depicts the polygon of centralized solutions. The performances of internal and external coordination mechanisms are evaluated in Section 4. The final section states conclusions and future work.

2. **Model Formulation.** We assume that a complex food supply chain with batch dispersion consists of l suppliers ($i = 1, 2, 3, \ldots, l$), m manufacturers ($j = 1, 2, 3, \ldots, m$) and n retailers. Suppliers supply fresh food. Manufacturers process packed food and deliver it to retailers. Suppliers (manufacturers) are homogeneous. The tracking and tracing process is as follows.

Each supplier (manufacturer) has a technology investment budget denoted as $I_s(I_m)$. They need to decide on an investment portfolio of PT and TT. We set the supplier i's and the manufacturer j's investment levels of TT as α_i and β_j, $\alpha_i, \beta_j \in (0, 1]$ [6]. Thus, the supplier i's and the manufacturer j's investment levels of PT are $\theta_i = 1 - \alpha_i$ and $\gamma_j = 1 - \beta_j$. The traceability of the supplying (manufacturing) sector is $T_s = \sum_{i=1}^{l} \alpha_i / l$ ($T_m = \sum_{j=1}^{m} \beta_j / m$). Because food is packed before selling, food-safety incidents occur in either supplying or manufacturing sectors. $p_i^s = p(\theta_i)$ and $p_j^m = p(\gamma_j)$ are defined as the occurrence probabilities of food-safety incidents in supplier i and in manufacturer j, which are negative to their PT investment levels [14,15].

Once food-safety incidents occur, food supply chains bear credibility losses and recall costs. C_l is the credibility loss of each supplier and manufacturer, $C_l = LT$. L is the credibility loss per unit time. T is the identification period and $T = t_0(1 - w_1 T_s - w_2 T_m)$. t_0 is the identification period without traceability. w_1 and w_2 denote the weight of suppliers and manufacturers and $w_1 + w_2 = 1$. In addition, suppliers' and manufacturers' recall costs are $C_r^s = (1 - T_s) g q_s$ and $C_r^m = (1 - T_m) g q_m$. g is the cost coefficient. q_s and q_m are the quantities of suspected contaminated food in each supplier and manufacturer. Because we assume food is sold instantaneously, retailers bear no recall cost.

The contaminated sector can be identified with TT investment. With the contaminated sector known to all, members in the same sector bear the equal recall cost. The expected total costs of each supplier and each manufacturer are shown in Equations (1) and (2). If food-safety incidents occur in the supplying sector, suppliers and manufacturers need to bear recall costs. While if incidents occur in the manufacturing sector, only manufacturers bear recall costs. In both cases, all suppliers and manufacturers bear credibility losses.

$$EC_s = \sum_{i=1}^{l} p_i^s (1 - T_s) g q_s + \left(\sum_{i=1}^{l} p_i^s + \sum_{j=1}^{m} p_j^m \right) C_l + I_s \tag{1}$$

$$EC_m = \left(\sum_{i=1}^{l} p_i^s + \sum_{j=1}^{m} p_j^m \right) (1 - T_m) g q_m + \left(\sum_{i=1}^{l} p_i^s + \sum_{j=1}^{m} p_j^m \right) C_l + I_m \tag{2}$$

For simplification we define $p_i^s = \frac{\alpha_i}{l+m}$, $p_j^m = \frac{\beta_j}{l+m}$, $w_1 = \frac{l}{l+m}$, $w_2 = \frac{m}{l+m}$ and $q_s = q_m$. The setting of homogeneous suppliers (manufacturers) implies that suppliers (manufacturers) will make the same decision ($\alpha = \alpha_i$ for $i = 1, 2, \ldots, l$; $\beta = \beta_j$ for $j = 1, 2, \ldots, m$). Then, the supply chain members' profits and the total profit are simplified as:

$$EC_s = \frac{l\alpha(1-\alpha)}{l+m} gq_s + \frac{(l\alpha + m\beta)(1 - w_1\alpha - w_2\beta)}{l+m} Lt_0 + I_s \quad (3)$$

$$EC_m = \frac{(l\alpha + m\beta)(1-\beta)}{l+m} gq_m + \frac{(l\alpha + m\beta)(1 - w_1\alpha - w_2\beta)}{l+m} Lt_0 + I_m \quad (4)$$

$$\begin{aligned} EC = &\frac{l^2\alpha(1-\alpha)}{l+m} gq_s + \frac{m(1-\beta)(l\alpha + m\beta)}{l+m} gq_m \\ &+ (l\alpha + m\beta)(1 - w_1\alpha - w_2\beta) Lt_0 + lI_s + mI_m \end{aligned} \quad (5)$$

3. **Equilibrium Analysis.** In this section, we obtain decentralized and centralized equilibrium solutions and depict the polygon of centralized solutions.

3.1. **Decentralized supply chain.** By solving first-order conditions of Equations (3) and (4), the optimal response functions in a decentralized supply chain are as follows [6].

$$\alpha_d = \frac{gq_s + Lt_0}{2gq_s + 2w_1Lt_0} - \frac{(mw_1 + lw_2)Lt_0}{2lgq_s + 2lw_1Lt_0} \beta_d \quad (6)$$

$$\beta_d = \frac{gq_m + Lt_0}{2gq_m + 2w_2Lt_0} - \frac{lgq_m + (mw_1 + lw_2)Lt_0}{2mgq_m + 2mw_2Lt_0} \alpha_d \quad (7)$$

From the above discussion, we obtain Proposition 3.1 describing the solution in a decentralized supply chain. The solution is shown in Figure 1.

Proposition 3.1. *The solution given by Equations (6) and (7) is a stable equilibrium.*

Proof: With the conditions $w_1 = \frac{l}{l+m}$ and $w_2 = \frac{m}{l+m}$, the relationship between the intercepts with the horizontal axis in two response functions is $\frac{gq_s+Lt_0}{2gq_s+2w_1Lt_0} < \frac{1}{2w_1} = \frac{m}{(m-l)w_1+l} < \frac{mgq_m+mLt_0}{lgq_m+(mw_1+lw_2)Lt_0}$. In addition, the relationship between the intercepts with the vertical axis in two response functions is $\frac{lgq_s+lLt_0}{(mw_1+lw_2)Lt_0} > \frac{l+m}{2m} = \frac{1}{2w_2} > \frac{gq_m+Lt_0}{2gq_m+2w_2Lt_0}$. Therefore, the patterns of response functions are shown in Figure 1 which guarantees the existence of a stable equilibrium.

From Equations (6) and (7), we obtain the TT investment levels of suppliers as

$$\alpha_d = \frac{(gq_s + Lt_0)/(2gq_s + 2w_1Lt_0) - (gq_m + Lt_0)(mw_1 + lw_2)Lt_0/[4l(gq_s + w_1Lt_0)(gq_m + w_2Lt_0)]}{1 - [lgq_m + (mw_1 + lw_2)Lt_0](mw_1 + lw_2)Lt_0/[4lm(gq_s + w_1Lt_0)(gq_m + w_2Lt_0)]}$$

and the manufacturers' TT investment levels as

$$\beta_d = \frac{(gq_m + Lt_0)/(2gq_m + 2w_2Lt_0) - (gq_s + Lt_0)[lgq_m + (mw_1 + lw_2)Lt_0]/[4m(gq_s + w_1Lt_0)(gq_m + w_2Lt_0)]}{1 - [lgq_m + (mw_1 + lw_2)Lt_0](mw_1 + lw_2)Lt_0/[4lm(gq_s + w_1Lt_0)(gq_m + w_2Lt_0)]}.$$

3.2. **Centralized supply chain.** In a centralized supply chain, the purpose is to maximize the total profit. Then, we obtain the response functions of Equation (5) as Equations (8) and (9). Proposition 3.2 is needed to depict the polygon of centralized solutions.

$$\alpha_c = \frac{lgq_s/(l+m) + mgq_m/(l+m) + Lt_0}{2lgq_s/(l+m) + 2w_1Lt_0} - \frac{lmgq_m/(l+m) + (mw_1 + lw_2)Lt_0}{2l^2gq_s/(l+m) + 2lw_1Lt_0} \beta_c \quad (8)$$

$$\beta_c = \frac{mgq_m/(l+m) + Lt_0}{2mgq_m/(l+m) + 2w_2Lt_0} - \frac{lmgq_m/(l+m) + (mw_1 + lw_2)Lt_0}{2m^2gq_m/(l+m) + 2mw_2Lt_0} \alpha_c \quad (9)$$

Proposition 3.2. *The centralized equilibrium solution lies in the shadow in Figure 2.*

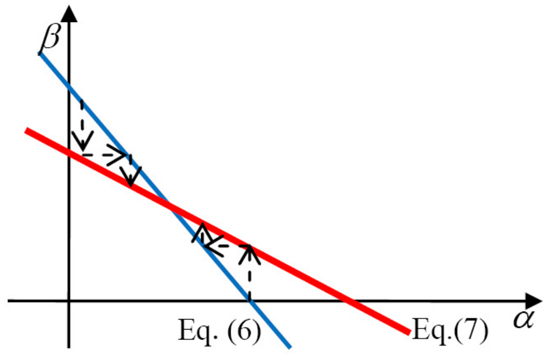


FIGURE 1. Decentralized solution

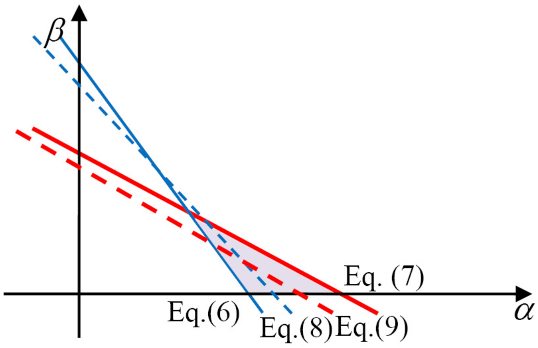


FIGURE 2. Centralized solution

Proof: In the first response function, with the condition $q_s = q_m$,

$$\frac{lgq_s/(l+m) + mgq_m/(l+m) + Lt_0}{2lgq_s/(l+m) + 2w_1Lt_0} = \frac{gq_s + Lt_0}{2lgq_s/(l+m) + 2w_1Lt_0} > \frac{gq_s + Lt_0}{2gq_s + 2w_1Lt_0}$$

holds. Moreover, the condition

$$-\frac{2l^2gq_s/(l+m)+2lw_1Lt_0}{lmgq_m/(l+m) + (mw_1 + lw_2)Lt_0} > -\frac{2lgq_s + 2lw_1Lt_0}{(mw_1 + lw_2)Lt_0}$$

always holds. Therefore, the intercept with the horizontal axis of centralized decisions is larger than that of decentralized decisions, and the slope is smoother than that of decentralized decisions. While in the second response function, the conditions

$$-\frac{lmgq_m/(l+m) + (mw_1 + lw_2)Lt_0}{2m^2gq_m/(l+m) + 2mw_2Lt_0} < -\frac{lgq_m + (mw_1 + lw_2)Lt_0}{2mgq_m + 2mw_2Lt_0}$$

and

$$\frac{mgq_m/(l+m) + Lt_0}{2mgq_m/(l+m) + 2w_2Lt_0} < \frac{gq_m + Lt_0}{2gq_m + 2w_2Lt_0}$$

always hold. Thus, the intercept with the vertical axis of centralized decisions is smaller than that of decentralized decisions, and the slope is steeper than that of decentralized decisions.

Figure 2 shows that suppliers invest more and manufacturers invest less in a centralized supply chain. Thus, coordination mechanisms are needed for the decentralized supply chain to achieve the optimal investment levels to maximize the supply chain-wide profit.

4. Coordination Mechanisms.

In this section, we analyze the impacts of internal and external coordination mechanisms, including the recall cost-sharing contract, carbon tax policy, TT subsidy policy and the carbon tax and PT subsidy mechanism.

4.1. **Internal coordination mechanism.** We first evaluate the performance of the recall cost-sharing contract, which is an internal coordination mechanism between suppliers and manufacturers [16]. When food-safety incidents occur in the manufacturing sector, suppliers share manufacturers' recall costs. s is the portion of the manufacturers' recall costs undertaken by suppliers. Then, we solve the first-order conditions and obtain the response functions of suppliers and manufacturers as follows:

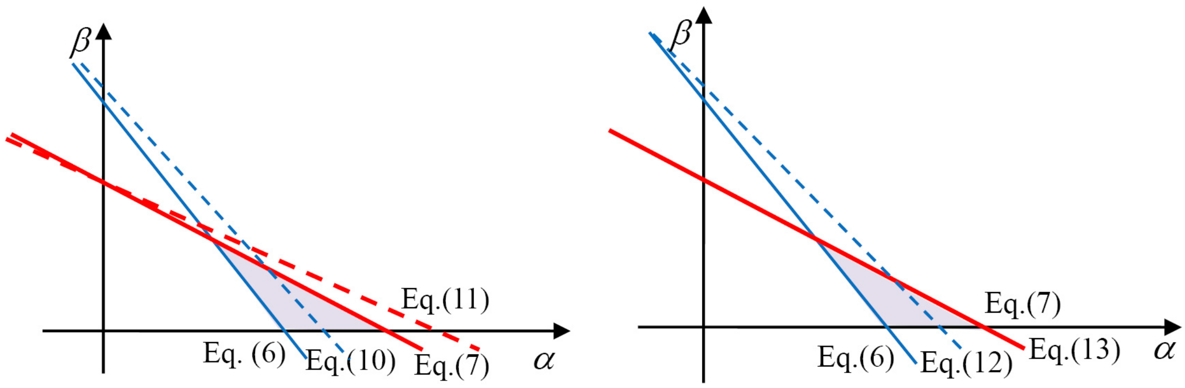
$$\alpha_{cs1} = \frac{gq_s + smgq_m/l + Lt_0}{2gq_s + 2w_1Lt_0} - \frac{smgq_m + (mw_1 + lw_2)Lt_0}{2lgq_s + 2lw_1Lt_0}\beta_{cs1} \tag{10}$$

$$\beta_{cs1} = \frac{gq_m + Lt_0}{2gq_m + 2w_2Lt_0} - \frac{(1 - sm/l)lgq_m + (mw_1 + lw_2)Lt_0}{2mgq_m + 2mw_2Lt_0}\alpha_{cs1} \tag{11}$$

While when food-safety incidents occur in the supplying sector, manufacturers share the suppliers' recall costs. The same s is the manufacturers' sharing portion of the suppliers' recall costs. Then, the response functions are shown in Equations (12) and (13) and Figure 3.

$$\alpha_{cs2} = \frac{(1 - ls/m)gq_s + Lt_0}{2(1 - ls/m)gq_s + 2w_1Lt_0} - \frac{(mw_1 + lw_2)Lt_0}{2(1 - ls/m)lgq_s + 2lw_1Lt_0}\beta_{cs2} \tag{12}$$

$$\beta_{cs2} = \frac{gq_m + Lt_0}{2gq_m + 2w_2Lt_0} - \frac{lgq_m + (mw_1 + lw_2)Lt_0}{2mgq_m + 2mw_2Lt_0}\alpha_{cs2} \tag{13}$$



(a) Suppliers share the manufacturers' recall costs. (b) Manufacturers share the suppliers' recall costs.

FIGURE 3. Solutions under the recall cost-sharing contract

Proposition 4.1. *The equilibrium solution under the recall cost-sharing contract is beyond the polygon of centralized equilibrium solutions (See Figure 3).*

Proposition 4.1 reveals that the recall cost-sharing contract cannot coordinate the supply chain. Similar to the proof of Proposition 3.2, we can achieve Proposition 4.1.

4.2. **External intervention mechanisms.** As external interventions, governments' carbon tax policy and technology subsidy policy impose impacts on technology investments.

4.2.1. *Carbon tax or TT subsidy.* Under carbon tax policy, carbon tax is proportional to the amount of emissions [17]. Because refrigeration is the main source of emissions, there is a positive correlation between carbon tax and PT investment. Moreover, under TT subsidy policy, subsidy is offered by the government to reduce TT investment cost [18]. Hence, TT investment cost is negatively correlated with TT subsidy rate. Let λ be carbon tax rate or TT subsidy rate. The response functions under two policies are the same:

$$\alpha_p = \frac{lgq_s + lLt_0 - \lambda I_s(l + m)}{2lgq_s + 2lw_1Lt_0} - \frac{(mw_1 + lw_2)Lt_0}{2lgq_s + 2lw_1Lt_0}\beta_p \tag{14}$$

$$\beta_p = \frac{mgq_m + mLt_0 - \lambda I_m(l+m)}{2mgq_m + 2mw_2Lt_0} - \frac{lgq_m + (mw_1 + lw_2)Lt_0}{2mgq_m + 2mw_2Lt_0}\alpha_p \tag{15}$$

Proposition 4.2. *The equilibrium solution is beyond the polygon of centralized equilibrium solutions under carbon tax policy or traceability technology subsidy policy implemented by governments (See Figure 4).*

Proposition 4.2 reveals that carbon tax policy and TT subsidy policy cannot coordinate the supply chain. The proof is similar to that of Proposition 3.2 and is omitted here.

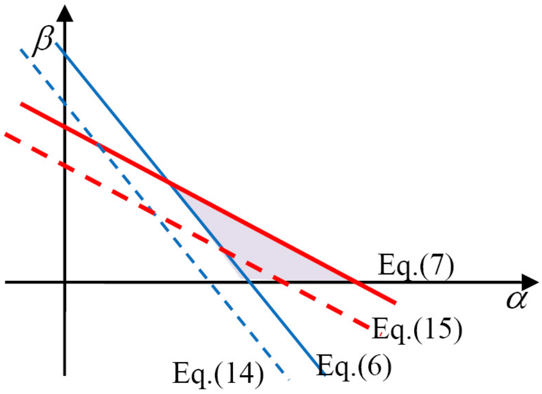


FIGURE 4. Solution under carbon tax policy or TT subsidy policy

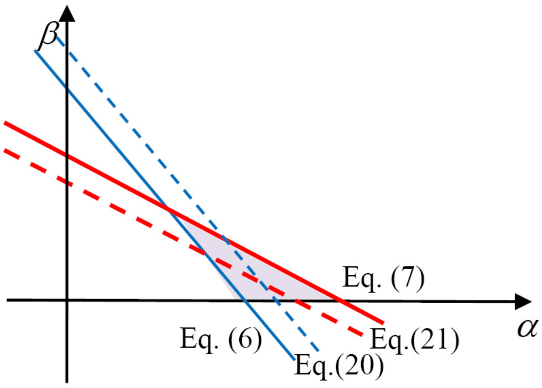


FIGURE 5. Solution under the carbon tax and PT subsidy mechanism

4.2.2. *Carbon tax and PT subsidy mechanism.* The mechanism is a combination of carbon tax policy [17] and PT subsidy policy [18].

(1) We assume that the carbon tax rate (λ) is the same for suppliers and manufacturers. The PT subsidy rate of suppliers (r_s) is higher than their carbon tax rate, and the PT subsidy rate of manufacturers (r_m) is lower than their carbon tax rate, which is $r_s > \lambda_s = \lambda_m > r_m$. Then, the costs of each supplier and each manufacturer are:

$$EC_s = \frac{l\alpha(1-\alpha)}{l+m}gq_s + \frac{(l\alpha + m\beta)(1 - w_1\alpha - w_2\beta)}{l+m}Lt_0 + I_s - (r_s - \lambda)(1-\alpha)I_s \tag{16}$$

$$EC_m = \frac{(l\alpha + m\beta)(1-\beta)}{l+m}gq_m + \frac{(l\alpha + m\beta)(1 - w_1\alpha - w_2\beta)}{l+m}Lt_0 + I_m + (\lambda - r_m)(1-\beta)I_m \tag{17}$$

(2) In another case, we assume that the PT subsidy rate (r) is the same for suppliers and manufacturers. The carbon tax rate of suppliers (λ_s) is lower than their PT subsidy

rate, and the carbon tax rate of manufacturers (λ_m) is higher than their PT subsidy rate, which is $\lambda_m > r_m = r_s > \lambda_s$. Then, the costs of each supplier and each manufacturer are:

$$EC_s = \frac{l\alpha(1-\alpha)}{l+m}gq_s + \frac{(l\alpha+m\beta)(1-w_1\alpha-w_2\beta)}{l+m}Lt_0 + I_s - (r-\lambda_s)(1-\alpha)I_s \quad (18)$$

$$EC_m = \frac{(l\alpha+m\beta)(1-\beta)}{l+m}gq_m + \frac{(l\alpha+m\beta)(1-w_1\alpha-w_2\beta)}{l+m}Lt_0 + I_m + (\lambda_m - r)(1-\beta)I_m \quad (19)$$

By solving first-order conditions, the response functions in both cases are the same:

$$\alpha_e = \frac{lgq_s + lLt_0 + (r_s-\lambda_s)(l+m)I_s}{2lgq_s + 2lw_1Lt_0} - \frac{(mw_1+lw_2)Lt_0}{2lgq_s+2lw_1Lt_0}\beta_e \quad (20)$$

$$\beta_e = \frac{mgq_m + mLt_0 - (\lambda_m - r_m)(l+m)I_m}{2mgq_m + 2mw_2Lt_0} - \frac{lgq_m + (mw_1+lw_2)Lt_0}{2mgq_m+2mw_2Lt_0}\alpha_e \quad (21)$$

Proposition 4.3. *The equilibrium solution lies in the polygon of centralized equilibrium solutions under the carbon tax and PT subsidy mechanism (See Figure 5).*

Proof: In the first response function, the condition $\frac{lgq_s+lLt_0+(r_s-\lambda_s)(l+m)I_s}{2lgq_s+2lw_1Lt_0} > \frac{gq_s+Lt_0}{2gq_s+2w_1Lt_0}$ always holds. Therefore, the intercept with the horizontal axis of the solution under this mechanism is larger than that of decentralized solution. Moreover, in the second response function, the condition $\frac{mgq_m+mLt_0-(\lambda_m-r_m)(l+m)I_m}{2mgq_m+2mw_2Lt_0} < \frac{gq_m+Lt_0}{2gq_m+2w_2Lt_0}$ always holds. Therefore, the intercept with the vertical axis of the solution under this mechanism is smaller than that of decentralized solution. In addition, in both response functions, the slopes do not change.

Proposition 4.3 reveals that suppliers invest more and manufacturers invest less under the carbon tax and PT subsidy mechanism than in decentralized supply chains, that is, the solution lies in the polygon of centralized solutions. Therefore, the carbon tax and PT subsidy mechanism can coordinate supply chain members' technology investment.

5. **Conclusions.** Food-safety incidents have become more and more frequent in complex food supply chains, which cause great losses to supply chain members, including credibility losses and recall costs. Moreover, food-safety concerns have put preservation, tracking and tracing at the center of discussions on the development of a sustainable food supply chain. In this paper, we develop a preservation and traceability technology investment decision model to minimize potential costs for food supply chain members. The equilibrium solutions show that the optimal technology investments are different from decentralized and centralized perspectives. Suppliers under-invest and manufacturers over-invest in a decentralized supply chain. Furthermore, we depict the polygon of centralized equilibrium solutions and evaluate the performances of internal and external coordination mechanisms. It is shown that the recall cost-sharing contract, which acts as an internal coordination mechanism cannot coordinate the food supply chain.

Technology investment in food supply chains should receive appropriate attention from governments. Meanwhile, carbon policies are vital for the sustainable development of food supply chains. The analysis of external interventions shows that carbon tax policy and TT subsidy policy cannot coordinate the food supply chain. However, the carbon tax and PT subsidy mechanism, which provides different tax rates or subsidy rates for suppliers and manufacturers, is proved to be effective in technology investment coordination.

The research has some limitations for further investigations. Food deterioration has not been considered in the model, which is desirable to be incorporated. Moreover, we assume a single level of tracing visibility. Our research may need the model with multiple levels of tracing visibility for future research.

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REFERENCES

[1] A. Marucheck, N. Greis, C. Mena and L. Cai, Product safety and security in the global supply chain: Issues, challenges and research opportunities, *Journal of Operations Management*, vol.29, nos.7-8, pp.707-720, 2011.

[2] M. Fritz and G. Schiefer, Tracking, tracing, and business process interests in food commodities: A multi-level decision complexity, *International Journal of Production Economics*, vol.117, no.2, pp.317-329, 2009.

[3] P. H. Hsu, H. M. Wee and H. M. Teng, Preservation technology investment for deteriorating inventory, *International Journal of Production Economics*, vol.124, no.2, pp.388-394, 2010.

[4] C. Y. Dye, The effect of preservation technology investment on a non-instantaneous deteriorating inventory model, *Omega*, vol.41, no.5, pp.872-880, 2013.

[5] J. B. Dai, L. Fan, N. K. S. Lee and J. Li, Joint optimisation of tracking capability and price in a supply chain with endogenous pricing, *International Journal of Production Research*, vol.55, no.18, pp.5465-5484, 2017.

[6] J. Lee, U. S. Palekar and W. Qualls, Supply chain efficiency and security: Coordination for collaborative investment in technology, *European Journal of Operational Research*, vol.210, no.3, pp.568-578, 2011.

[7] S. Chen, H. Wang, Y. Xie and C. Qi, Mean-risk analysis of radio frequency identification technology in supply chain with inventory misplacement: Risk-sharing and coordination, *Omega*, vol.46, pp.86-103, 2014.

[8] J. Zhang, G. Liu, Q. Zhang and Z. Bai, Coordinating a supply chain for deteriorating items with a revenue sharing and cooperative investment contract, *Omega*, vol.56, pp.37-49, 2015.

[9] H. Dai, M. M. Tseng and P. H. Zipkin, Design of traceability systems for product recall, *International Journal of Production Research*, vol.53, no.2, pp.511-531, 2015.

[10] C. Dupuy, V. Botta-Genoulaz and A. Guinet, Batch dispersion model to optimise traceability in food industry, *Journal of Food Engineering*, vol.70, no.3, pp.333-339, 2005.

[11] A. Rong and M. Grunow, A methodology for controlling dispersion in food production and distribution, *OR Spectrum*, vol.32, no.4, pp.957-978, 2010.

[12] F. Dabbene and P. Gay, Food traceability systems: Performance evaluation and optimization, *Computers and Electronics in Agriculture*, vol.75, no.1, pp.139-146, 2011.

[13] M. Yu and A. Nagurney, Competitive food supply chain networks with application to fresh produce, *European Journal of Operational Research*, vol.224, no.2, pp.273-282, 2013.

[14] S. Piramuthu, P. Farahani and M. Grunow, RFID-generated traceability for contaminated product recall in perishable food supply networks, *European Journal of Operational Research*, vol.225, no.2, pp.253-262, 2013.

[15] X. Wang, D. Li and C. O'Brien, Optimisation of traceability and operations planning: An integrated model for perishable food production, *International Journal of Production Research*, vol.47, no.11, pp.2865-2886, 2009.

[16] Arshinder, A. Kanda and S. G. Deshmukh, Supply chain coordination: Perspectives, empirical studies and research directions, *International Journal of Production Economics*, vol.115, no.2, pp.316-335, 2008.

[17] S. Benjaafar, Y. Li and M. Daskin, Carbon footprint and the management of supply chains: Insights from simple models, *IEEE Trans. Automation Science and Engineering*, vol.10, no.1, pp.99-116, 2013.

[18] J. B. Sheu and Y. J. Chen, Impact of government financial intervention on competition among green supply chains, *International Journal of Production Economics*, vol.138, no.1, pp.201-213, 2012.