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Analysis of a traceability system for perishable food supply chains

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Introduction

- **Motivation**

- ❑ Greater attention to the quality and the safety of perishable food
- ❑ Perishable food waste
 - One-third of the global food supply is wasted, which equates to throwing out \$1 trillion each year (Cai, 2012)
 - Perishable food loss at grocery retailers can be as high as 15% because of damage and spoilage (Ferguson et al. 2007)
 - Inadequate temperature control, lack of dynamic pricing based on product value
- ✓ Emerging RFID technology & Traceability system

Introduction

- RFID-based traceability system for the perishable food supply chain



- ✓ Constant monitoring of temperature, volatiles, and time directly related to food ripeness
 - Collect real-time food quality information
 - Enhances food safety and provides instantaneous responses to variations in the food supply chain
 - Supports decision making of supply chain participants
- How the participants benefit from a traceability system?

Related Literature

<p>Karlsen et al. (2013) Martínez-Sala et al. (2009)</p>	<p>Food traceability system Mainly focused on related technologies and designing of a intelligent platform</p>	<p>Lack of quantitative research</p>
<p>Blackburn and Scudder(2009) Cai et al. (2010) Cai et al. (2012)</p>	<p>supply chain management of perishable products Devoted to the dynamic pricing and quality degradation of perishable food</p>	<p>Lack of food safety consideration</p>
<p>Liu et al. (2008) Wang and Li (2012)</p>	<p>Pricing policies based on dynamically identified food shelf life Focused on decision making of the retailer</p>	<p>Lack of decision making in a supply chain framework</p>

Objective

- This study conducts a **theoretical analysis of the RFID-enabled perishable food supply chain**, with consideration of the consumer perceptions of safety food.
- We develop the **decision mechanisms** for both centralized and decentralized supply chains and propose an incentive scheme to coordinate the supply chain.

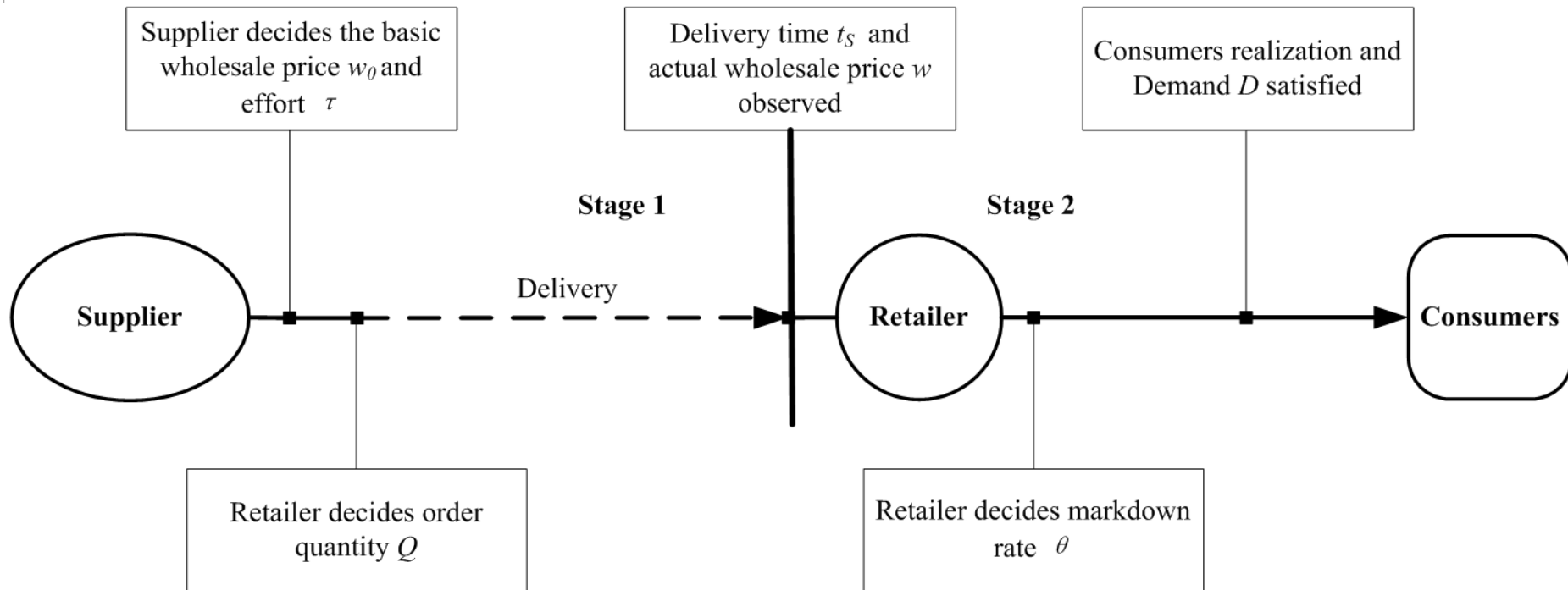
Problem Description

- Wholesale price agreement between the perishable food supplier and the retailer
 - **A two-stage problem** due to the variation quality of foods: In the first stage, before transportation, the supplier decides **a basic wholesale price**, whereas the retailer determines the order quantity. In the second stage, the supplier sets the **actual wholesale price** based on the quality of food.
- Customer demand depends on the price, the quality, and the safety of perishable food.

$$f(D_t) = A - \alpha p(t) + \beta q(t) + \gamma \tau$$

- A , the market scale parameter; α , price elasticity; β , demand sensitivity to quality; γ , demand expansion effectiveness to safety; τ , the effort on RFID for food safety

Problem Description



– Decision Variables

- Supplier: Wholesale prices, Investment effort on RFID
- Retailer: Order quantity, Price markdown rate

Optimal decision in the decentralized supply chain

- A two-stage Stackelberg Game

- The second stage

The demand in the i th price markdown period

$$D_i = \int_{T_i}^{T_{i+1}} f(D_t) dt = (T_{i+1} - T_i) \left[A - \alpha p_0(1 - i\theta) + \beta q_s - \frac{1}{2} \beta \lambda (T_{i+1} + T_i) + \gamma \tau \right]$$

Demand over period T $\sum_{i=0}^n D_i = (H_1 - \lambda \beta t_s + \gamma \tau) T + \alpha p_0 N_1 \theta$

The retailer's optimal price markdown rate $\theta^*(Q|t_s) = \frac{Q - (H_1 - \beta \lambda t_s + \gamma \tau) T}{\alpha p_0 N_1}$

- The first stage

The retailer's expected profit $\pi_D^R(Q|w, \tau) = E_{t_s} \left\{ \left(\sum_{i=0}^n p_i D_i \right) - wQ - \phi_R \tau^2 \right\}$

The supplier's expected profit $\pi_D^S(w, \tau) = E_{t_s} \{ (w - c) Q^*(w, \tau) - \phi_S \tau^2 \}$

Derive the optimal policy Q^*, w_0^* and τ^*

Supply chain coordination

- ❑ The supplier bears the risk that the food deteriorates in the delivery process as well as the risk of random delivery time
- ❑ The retailer should share some risks by providing appropriate compensation schemes
- ❑ Under the decentralized system, if the supplier sets the wholesale price equal to c , while the retailer agrees to give the supplier a compensation F such that $\pi^R(c, F) \geq \pi_D^R$ and $\pi^S(c, F) \geq \pi_D^S$, supply chain coordination is achieved.

Numerical Analysis

- The impact of consumer's food safety awareness on participants' decision policy and profits

Table 1 Optimal decisions varies with consumers' awareness of food safety

Increasing food safety awareness	γ	Centralized			Decentralized			The loss due to double marginalization
		τ_c	Q_c		τ	Q	w	
	1	3.19	624.54		2.63	289.70	5.50	19.15
	1.1	3.22	629.61		2.69	293.13	5.58	19.68
	1.2	3.25	634.73		2.75	296.67	5.66	20.22
	1.3	3.28	639.89		2.81	300.33	5.74	20.78
	1.4	3.31	645.10		2.87	304.12	5.83	21.35
	1.5	3.34	650.35		2.94	308.04	5.92	21.93
	1.6	3.37	655.65		3.00	312.11	6.01	22.53
	1.7	3.40	661.00		3.07	316.32	6.10	23.14
	1.8	3.43	666.38		3.15	320.70	6.20	23.76
	1.9	3.46	671.82		3.22	325.23	6.30	24.39

Numerical Analysis

- The impact of deterioration rate on pricing and ordering decisions

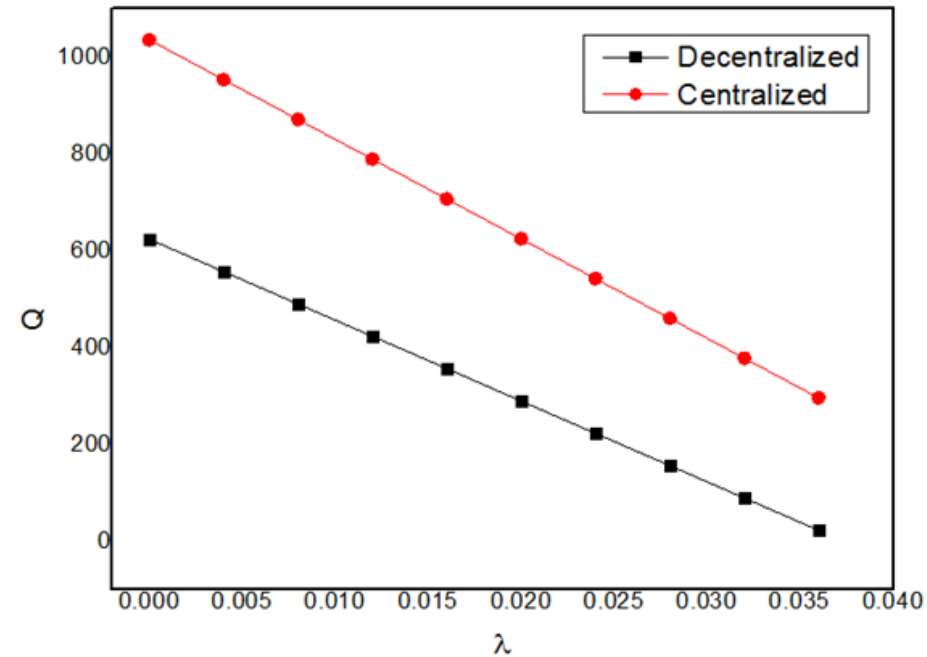
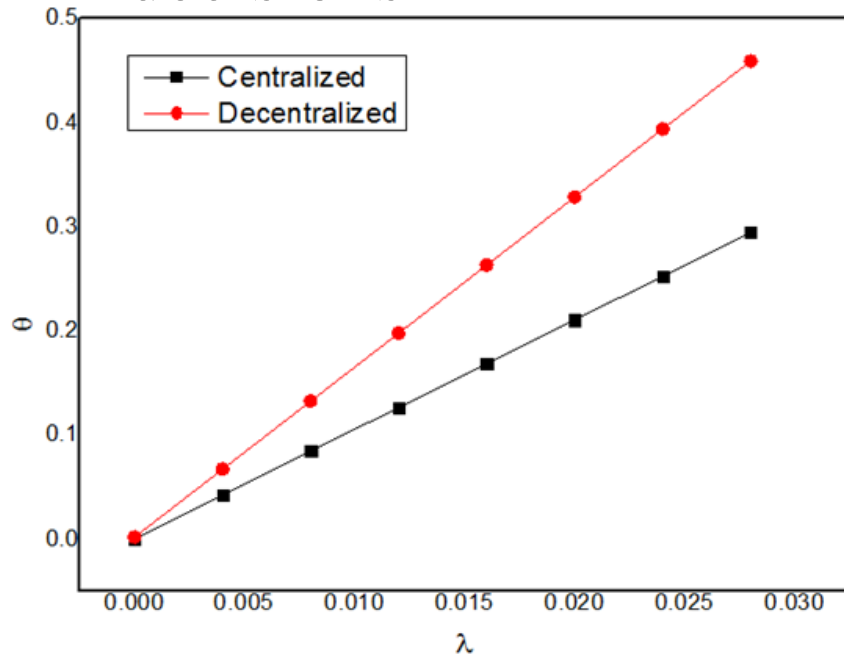


Figure 2. Markdown rate θ with respect to deterioration rate λ Figure 3. Order quantity Q with respect to deterioration rate λ

Provide a high discount rate for food with high deterioration rate

Frequent ordering with low order quantity for perishable food

Conclusion

- This study developed a decision-making mechanism for a perishable food supply chain when demand depends on the price, the quality, and the safety of perishable food.
- The loss due to double marginalization increases when consumers are more willing to pay for safety food.
- A high level of food safety awareness is a key factor for the successful penetration of food traceability system.

Thank you