

Investment decisions in a supply chain of fresh agricultural products

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Because of evolving attitudes toward increased health- conscious and better informed consumers, the freshness of agricultural products has become a key driver for retaining customer loyalty and store traffic.

Agro Products embraces a broad all-inclusive category of products related to AGRICULTURE.

Enterprises involved in agricultural supply chains can create employment, raise labor standards, bring the technology to increase agricultural production, reduce damage and pollution, and etc.

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Consumers consider color, odor, and texture as indicators of an overall quality and freshness of food.

INVESTMENT DECISIONS OF AN AGRICULTURE MANUFACTURER



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Retailers and manufacturers should rigorously monitor their associates and their own workforces to meet challenges in delivering and storing agricultural products.

Interrelationship can cause significant imbalances in bargaining power within the agricultural-product supply chain, which can lead to unfair trading practices.

Fairness indices



Coordination



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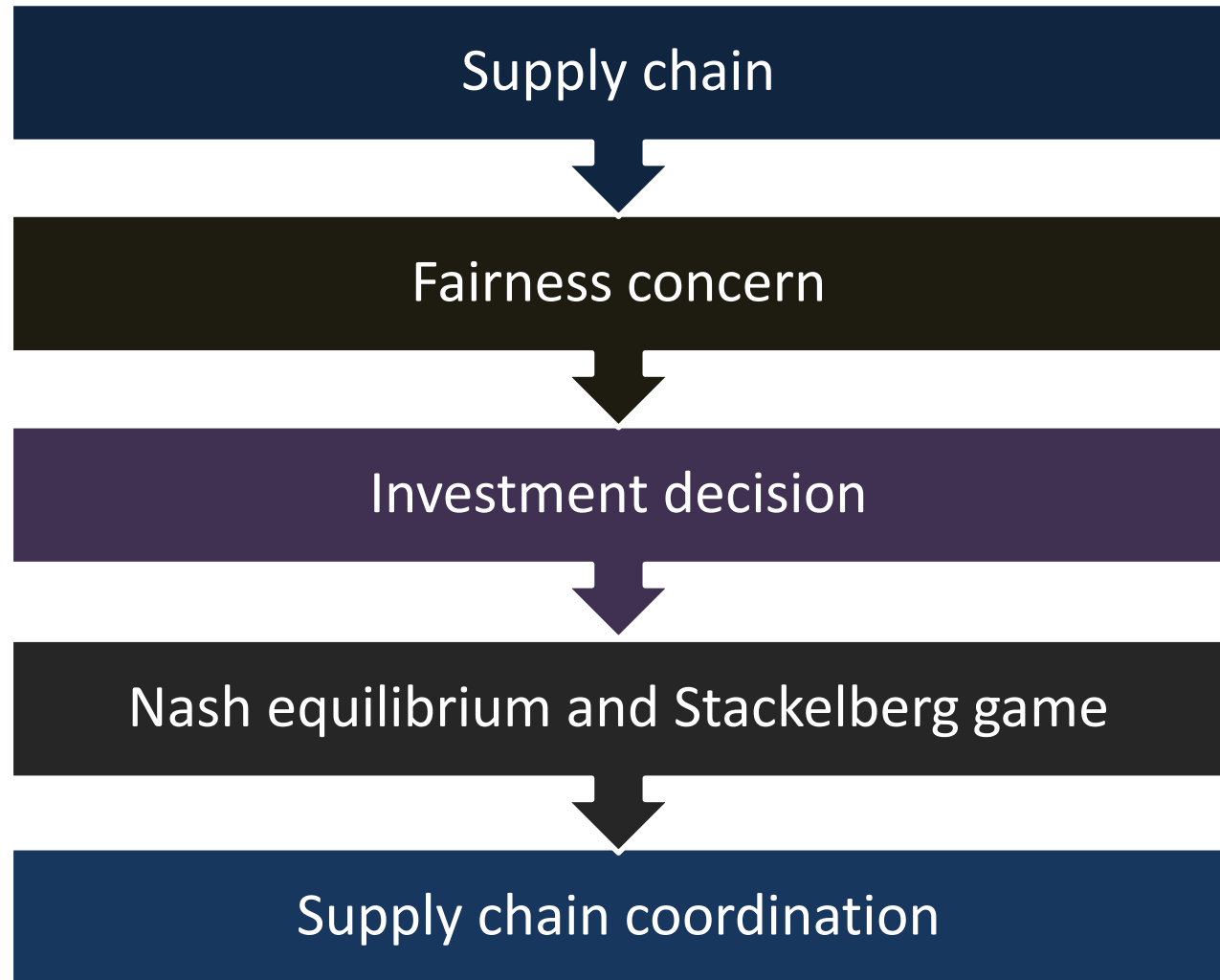
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- Consider a distribution channel with one manufacturer and one retailer
- The manufacturer produces agricultural-products and sells them to consumers through the retailer
- Market demand of the product depends on the retail price and the level of the freshness keeping effort devoted by the manufacturer and the retailer:

$$D(p, h, e) = a - bp + \theta\delta,$$

where θ represents the level of the freshness

- The function of the level of freshness is

$$\theta = \bar{\theta} + \gamma_1 e + \gamma_2 h$$

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The centralized scenarios

In centralized scenarios, both the manufacturer and retailer act together as a single system to maximize the entire supply chain profit. The central planner respectively optimizes the following problems for Scenarios MR, R, and M:

Scenario MR

$$\pi_{mr}^c = (p - c - t_c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\alpha_1 h^2}{2} - \frac{\alpha_2 e^2}{2}$$

Scenario R

$$\pi_r^c = (p - c)(a - bp + \delta(\bar{\theta} + \gamma_2 h)) - \frac{\alpha_1 h^2}{2}$$

Scenario MR

$$\pi_m^c = (p - c)(a - bp + \delta(\bar{\theta} + \gamma_1 e)) - \frac{\alpha_2 e^2}{2}$$



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Table 1 Optimal solutions of the centralized scenarios.

	Scenario MR	Scenario R	Scenario M
e^c	$\frac{\alpha_1 \gamma_1 \delta M}{\Delta_1}$	-	$\frac{\gamma_1 \delta M}{\Delta_3}$
h^c	$\frac{\alpha_2 \gamma_2 \delta M}{\Delta_1}$	$\frac{\gamma_2 \delta M}{\Delta_2}$	-
p^c	$\frac{\alpha_1 \alpha_2 M - (c + t_c) \Delta_1}{\Delta_1}$	$\frac{\alpha_1 M - (c + t_c) \Delta_2}{\Delta_2}$	$\frac{\alpha_2 M - (c + t_c) \Delta_3}{\Delta_3}$
π^c	$\frac{\alpha_1 \alpha_2 M^2}{2 \Delta_1}$	$\frac{\alpha_1 M^2}{2 \Delta_2}$	$\frac{\alpha_2 M^2}{\Delta_3}$
Q^c	$\frac{b \alpha_1 \alpha_2 M}{\Delta_1}$	$\frac{\alpha_1 b M}{\Delta_2}$	$\frac{\alpha_2 b M}{\Delta_3}$

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Proposition 1. In a centralized supply chain

- The supply chain system gains the maximum profit in Scenario MR.
- Consumer receives products at the highest freshness level in Scenario MR, but the consumer needs to pay higher price in Scenario MR compared to other scenarios.
- The sales volume of the supply chain system is largest in Scenario MR.



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The decentralized scenarios

- Each supply chain player maximizes utility.
- A manufacturer Stackelberg game to model strategic interactions within the supply chain in all three scenarios.

$$\pi_{rmr}^d = (p - w - t_c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\alpha_1 h^2}{2}$$
$$\pi_{mmr}^d = (w - c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\alpha_2 e^2}{2}$$

The utility functions of the retailer and the manufacturer with fairness concern index

$$U_{rmr} = \pi_{rmr}^d + \lambda_r(\pi_{rmr}^d - \bar{\pi}_{rmr}^d)$$

$$U_{mmr} = \pi_{mmr}^d + \lambda_r(\pi_{mmr}^d - \bar{\pi}_{mmr}^d)$$



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The **Nash bargaining solution** is the unique solution to a two-person bargaining problem that satisfies the axioms of scale invariance, symmetry, efficiency, and independence of irrelevant alternatives.

$$U_{rmr} = \frac{(2 + \lambda_m)(1 + \lambda_r)\pi_{rmr}^d}{2 + \lambda_m + \lambda_r} - \frac{\lambda_r(1 + \lambda_r)\pi_{mmr}^d}{2 + \lambda_m + \lambda_r}$$

$$U_{mmr} = \frac{(2 + \lambda_r)(1 + \lambda_m)\pi_{mmr}^d}{2 + \lambda_m + \lambda_r} - \frac{\lambda_m(1 + \lambda_m)\pi_{rmr}^d}{2 + \lambda_m + \lambda_r}$$

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Table 2 Equilibrium outcomes of decentralized decisions

	Scenario MR	Scenario R	Scenario M
e^d	$\frac{4\alpha_1\gamma_1\delta M}{\Psi_1}$	-	$\frac{2\gamma_1\delta M}{\Psi_3}$
h^d	$\frac{2\alpha_2\gamma_2\delta_1(2+\lambda_r)M}{\Psi_1}$	$\frac{2\gamma_2\delta M}{(4+\lambda_m)\Psi_2}$	-
w^d	$\frac{\alpha_2(2b\alpha_1-\gamma_2^2\delta^2)(2+\lambda_m)^2(2+\lambda_r)M}{b(2+\lambda_m+\lambda_r)\Psi_1}$	$\frac{(2+\lambda_m)^2M}{b(4+\lambda_m)(2+\lambda_r+\lambda_m)} + c$	$\frac{\alpha_2(2+\lambda_m)^2(2+\lambda_r)M}{(2+\lambda_r+\lambda_m)\Psi_3} + c$
p^d	$\frac{\alpha_1(2b\alpha_1(3+\lambda_m)-\gamma_2^2\delta^2(2+\lambda_m))M}{b\Psi_1} + c + t_c$	$\frac{(2b\alpha_1+(2+\lambda_m)\Psi_2)M}{b(4+\lambda_m)\Psi_2} + c + t_c$	$\frac{\alpha_2(3+\lambda_m)(2+\lambda_r)M}{\Psi_3} + c + t_c$
U_r^d	$\frac{2\alpha_1\alpha_2(1+\lambda_r)\Gamma_1M^2}{(2+\lambda_m+\lambda_r)\Psi_1^2}$	$\frac{2\alpha_1(2+\lambda_m)(1+\lambda_r)M^2}{(2+\lambda_m+\lambda_r)(4+\lambda_m)^2\Psi_2}$	$\frac{\alpha_2(1+\lambda_r)\Gamma_2M^2}{(2+\lambda_m+\lambda_r)\Psi_3^2}$
U_m^d	$\frac{2\alpha_1\alpha_2(2+\lambda_r)(1+\lambda_m)M^2}{(2+\lambda_m+\lambda_r)\Psi_1^2}$	$\frac{2\alpha_1(1+\lambda_m)M^2}{(2+\lambda_m+\lambda_r)(4+\lambda_m)\Psi_2}$	$\frac{\alpha_2(1+\lambda_m)(2+\lambda_r)M^2}{(2+\lambda_m+\lambda_r)\Psi_3}$
Q^d	$\frac{2b\alpha_1\alpha_2(2+\lambda_r)M}{\Psi_1}$	$\frac{2b\alpha_1M}{(4+\lambda_m)\Psi_2}$	$\frac{b\alpha_2(2+\lambda_r)M}{\Psi_3}$

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Proposition 2

- The manufacturer charges a higher wholesale price in Scenario MR than in Scenarios M or R. The wholesale price is also greater in Scenario M than in Scenario R. The retailer charges a higher price for the product in Scenario MR than in Scenarios M or R. The price of the product is greater in Scenario R than in Scenario M.
- The manufacturer places stronger emphasis on fresh-keeping measures in Scenario MR than in Scenario M. The retailer also places higher emphasis on fresh-keeping measures in Scenario MR than in Scenario R.
- For the manufacturer and retailer, each achieves a higher utility in Scenario MR than in Scenarios M or R.

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Proposition 3

- The fresh-keeping efforts of both channel members decrease as the fairness index increases.
- The sales volume of the supply chain decreases as the fairness index increases.

Proposition 4

- The utility of the manufacturer decreases as the fairness index of the retailer increases.
- The utility of the retailer decreases as the fairness index of the manufacturer increases.

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Supply chain coordination

We introduce contract mechanisms to remove inefficiency in supply chain and provide an approach to coordinate the members.

- Coordinating supply chain by using a revenue sharing coupled with investment cost sharing (RSIS) contract
- Coordinating supply chain by using an incremental quantity discount (IQD) contract



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- The RSIS contract is described by three parameters; wholesale price, retailer fresh-keeping investment cost sharing fraction, and revenue-sharing fractions.
- The manufacturer charges unit wholesale prices lower than the production costs and shares a percentage of the retailer investment cost.
- The retailer provides a fraction of revenue to the manufacturer.

$$\pi_{\text{rrsis}} = ((1 - \rho)p - w - t_c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{(1 - \eta)\alpha_1 h^2}{2}$$

$$\pi_{\text{mrsis}} = (\rho p + w - c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\eta\alpha_1 h^2}{2} - \frac{\alpha_2 e^2}{2}$$

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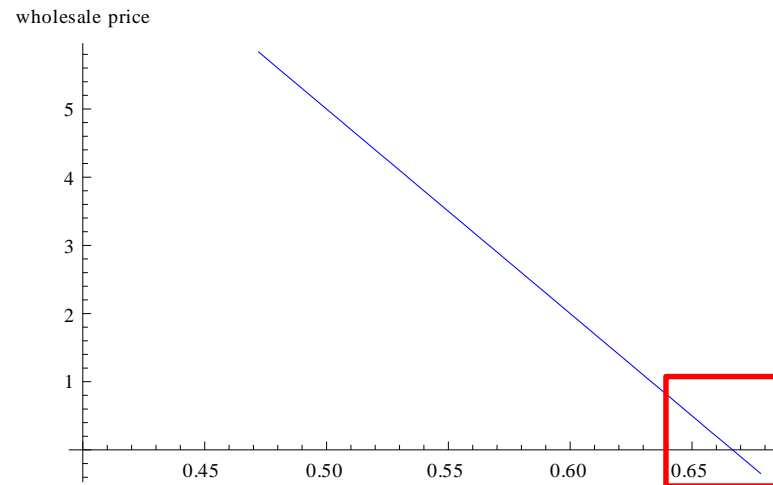
Proposition 5

Any arbitrary values of revenue or retailer investment cost sharing fraction

$$\rho = \eta \in [\rho_L, \min\{\rho_U, \frac{c}{c+t_c}\}]$$

coordinates the system perfectly and leads to acceptable outcomes for all the supply chain member.

Wholesale price of the manufacturer becomes negative as the revenue sharing fraction reaches towards upper bound.



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- The IQD contract can be described by two parameters; wholesale prices and quantity discount factor.
- The manufacturer provides incremental discounts based on the order quantity.
- The wholesale-price contract is a subset of the IQD contract.

$$\pi_{riqd} = (p - w - t_c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\alpha_1 h^2}{2} + \epsilon(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h))^2$$

$$\pi_{miqd} = (w - c)(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h)) - \frac{\alpha_2 e^2}{2} - \epsilon(a - bp + \delta(\bar{\theta} + \gamma_1 e + \gamma_2 h))^2$$

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Proposition 6

Any arbitrary values of discount factor

$$\epsilon \in [\epsilon_L, \epsilon_U]$$

coordinate the system perfectly and lead to acceptable outcomes for all the supply chain members.

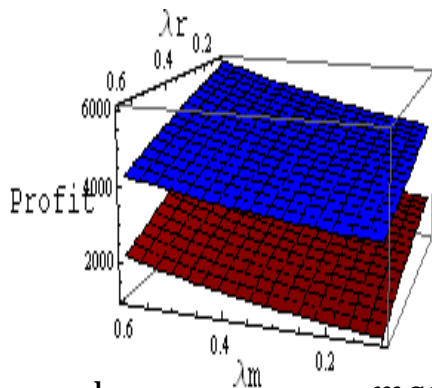


Fig. U_{rmr}^d (red) and U_{riqd}^{max} (blue)

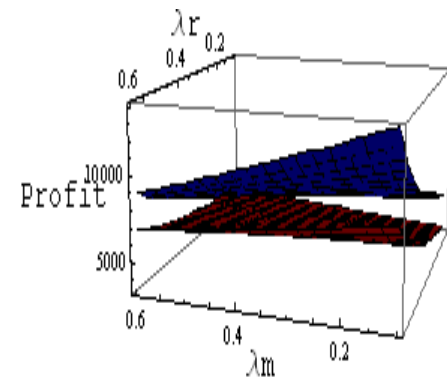


Fig. U_{mmr}^d (red) and U_{miqd}^{max} (blue)

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Proposition 7

The ratio of maximum profit gain in a agricultural product supply chain is equivalent to the ratio of fairness indices of supply chain members, i.e.

$$\Upsilon_m : \Upsilon_r = (1 + \lambda_m) : (1 + \lambda_r)$$

We can conclude that the fairness indices are decisive parameters to analyze the performance of coordination contract mechanism, the corresponding highest utility and investment decision in a supply chain of fresh agricultural products.

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- This study was developed in light of three major areas featured in the supply chain literature,
 - Investment decisions to maintain freshness of agricultural products
 - Fairness concerns of supply chain members
 - Contract-based mechanisms for supply chain coordination
- The research results indicate that efforts to keep products fresh decrease progressively when the fairness index decreases for either party.
- The increases in the fairness index of either party reduces the freshness and market demand of fresh agricultural products.
- The wholesale and retail prices increase progressively with an increase of fairness index.

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- The joint investment is always advisable for supply chain member.
- The RSIS contract leads to suboptimal and infeasible solution.
- The IQD coordination mechanism can be used effectively to coordinate the channel.
- The fairness indices are decisive parameters for determination of bargaining range of the contract parameter.



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