May the force be with you.

Game Theory and Logistics:

Supply Chain Coordination through Cooperation Advertising with Reference Price Effect

Background

Purpose of the Paper

Objective: Propose a dynamic cooperative advertising model for a manufacturer-retailer supply chain

- **Cooperative Advertising:** "Cost sharing and promotion mechanism for manufacturers to affect retail performance" - Zhang et al.

- **Reference Price (r):** Price in the mind of the customer at the moment of the purchase.

  If $p < r$: Sense of Gain → Sales will Increase
  If $r > p$: Sense of Loss → Sales will Decrease
  such that p = Actual Price

- **Goodwill (G):** Accumulated desire of the customer to buy a specific product.

- **Nerlove-Arrow Model:** Monopolistic advertising model in which advertising is an investment
  - The advertising capital is a stock of goodwill
  - The price of a unit of goodwill is $1 such that a dollar of advertising expenditure increases goodwill by one unit

Problem to Address

The paper aims to study how the reference price effect, impacts a cooperative advertising program.

- Takes the reference price effect into account, which was not done in any of the cooperative advertising literature
  - Advertising can improve the product's brand image and the consumer's reference price simultaneously
    - The reference price has a significant impact on the consumer's buying behavior
    - Therefore it is necessary to study the reference price effect on a cooperative advertising program.

What is Game Theory?

- Game Theory allows for the quantification of strategic decisions usually when two or more players have conflicting interests
  - It can apply to a number of games:
    - Cooperative or Noncooperative
    - Competitive or Noncompetitive
    - Sequential or Simultaneous Decisions
  - Real World Example Usage:
    - **Economics**
      - Price setting & production setting within a competitive market
    - **Psychology: Theory of Social Situations**
      - Making your twins eat dinner in a timely manner
    - **Games:**
      - Chess & Poker

Methodology

Why game theory? It offers:
- Stable solutions that two firms won't deviate from (Non-optimal)
- Rational strategies for each firm whether or not they're cooperating

Applied game theory in the form of:
- The Stackelberg Model (Non-cooperative)
  - Chosen for its sequential decision making to highlight first mover advantage
- The Cooperative Model
  - Chosen to best balance the channel's performance

The Authors then took what they had learned from these two models to form:
- The Two-Way Subsidy (Two-way participation advertising contract)
  - **Subsidy***(noun) [suhb-si-dee]*- a contribution or gift of money to support an economic venture
  - The value in a two-way subsidy is to increase the reference price effect overall in the advertising model

The Stackelberg Model

Rules of the Game

Rules:
- Sequential Decisions
    - The retailer's choices are limited by the manufacturer's choice
    - Information is not shared between players
    - The manufacturer makes their choice under the assumption that the retailer will make the most rational choice
    - The game is noncooperative, but also noncompetitive in this case
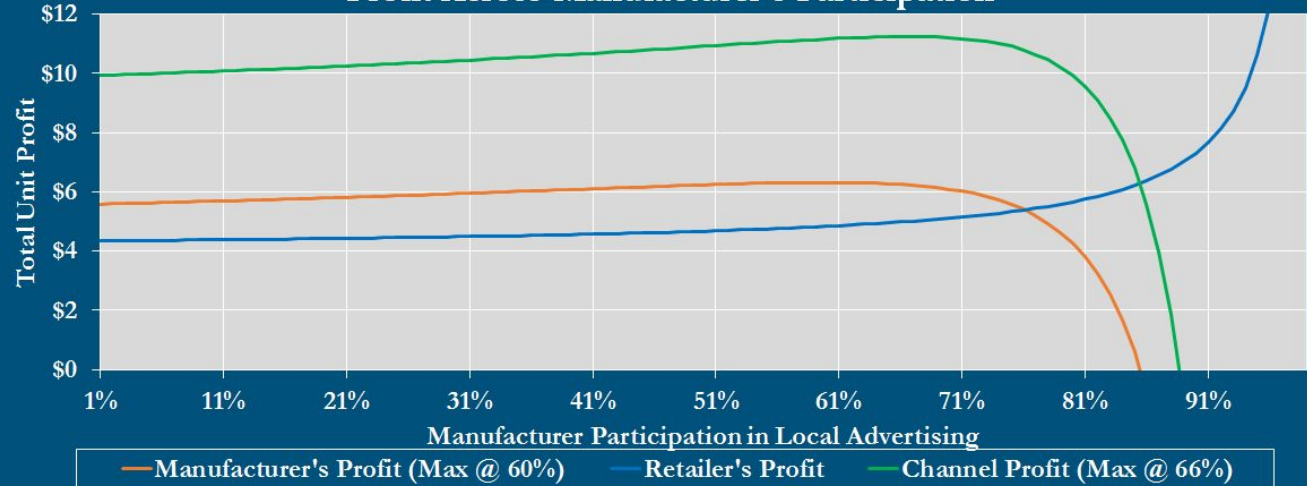
Goal:
- Individuals wish to maximize personal profits

Firm 2 Qty \ Firm 1 Qty	25	50	75	100
25	$1013 , $1013	$845 , $1125	$760 , $1140	$505 , $1013
50	$1125 , $845	$900 , $900	$788 , $885	$450 , $675
75	$1140 , $760	$885 , $788	$760 , $760	$380 , $505
100	$1013 , $505	$675 , $450	$505 , $380	$0 , $0

The Formulation

- Profit factoring consumer sensitivity and memory
- Profit factoring consumer goodwill
- Profit factoring difference between reference price and actual price
- Profit factoring the benefit of manuf. advertising on reference price
- Profit factoring benefit of retailer advertising on reference price
- Profit factoring the cost of advertising

Equilibrium
Profit Across Manufacturer's Participation

Total Unit Profit vs Manufacturer Participation in Local Advertising

— Manufacturer's Profit (Max @ 60%) — Retailer's Profit — Channel Profit (Max @ 66%)

$$J_M = \frac{D_1 \rho_M \alpha}{\rho + \beta} + \frac{\rho_M D_2}{\rho + \delta} + \frac{\alpha \rho_M (r_{SSS} - p)}{\rho} + \frac{\rho_M G_{SSS}}{\rho}$$

$$+ \frac{\rho_M \lambda_1 \bar{a}}{\rho} + \frac{\rho_M \lambda_2 \bar{q}}{\rho} - \frac{\bar{a}^2}{2\rho} - \frac{\phi_1 \bar{q}^2}{2\rho}$$

$$J_R = \frac{D_1 \rho_R \alpha}{\rho + \beta} + \frac{\rho_R D_2}{\rho + \delta} + \frac{\rho_R \alpha (r_{SSS} - p)}{\rho} + \frac{\rho_R G_{SSS}}{\rho}$$

$$+ \frac{\rho_R \lambda_1 \bar{a}}{\rho} + \frac{\rho_R \lambda_2 \bar{q}}{\rho} - \frac{(1 - \phi_1) \bar{q}^2}{2\rho}.$$

What is it Good For?

PROS:

- Leader has the advantage, "first-mover" advantage.

- Both strategies lie upon the player's best response functions.

CONS:

- Requires an accurate understanding of the retailer
- Must assume that the retailer is rational
  - Otherwise the manufacturer could lose money
- Need to actively predict the effect of the retailer's decisions on your own

The Cooperative Model

Rules of the Game

Rules:

- Decisions are sequential, and <u>coordinated</u>
  - Information is <u>shared</u> between the players
  - Choices are determined together
  - The game is noncompetitive

Goal:

- Maximize the sum of both profits

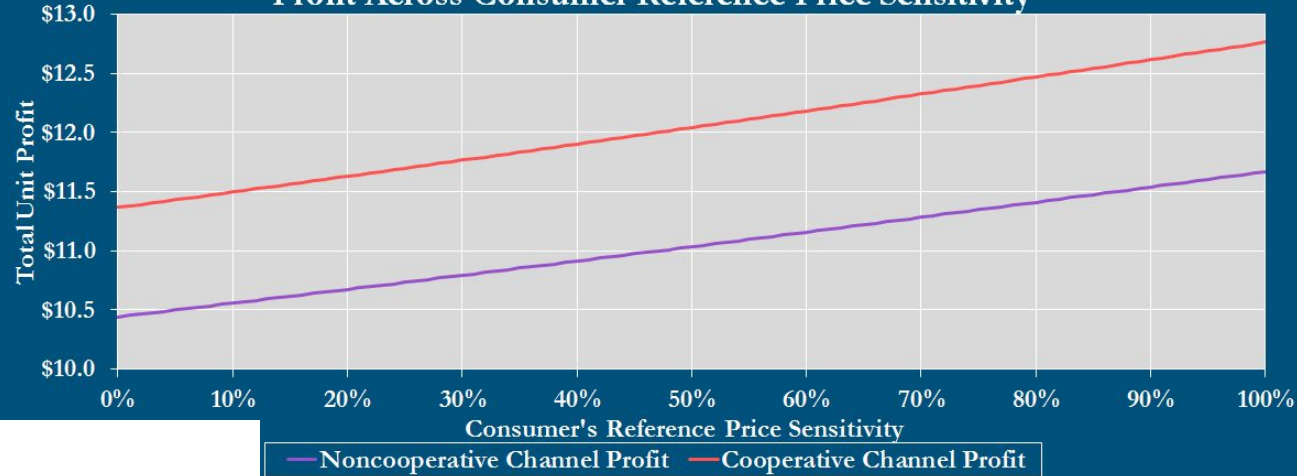| Firm 2 Qty \ Firm 1 Qty	25	50	75	100
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Cooperation Comparison
Profit Across Consumer Reference Price Sensitivity

- ☐ Profit factoring the cost of advertising

$$\tilde{J} = \frac{E_1(\rho_M + \rho_R)\alpha}{\rho + \beta} + \frac{(\rho_M + \rho_R)E_2}{\rho + \delta}$$

$$+ \frac{\alpha(\rho_M + \rho_R)(r_{CSS} - p)}{\rho} + \frac{(\rho_M + \rho_R)G_{CSS}}{\rho}$$

$$+ \frac{(\rho_M + \rho_R)\lambda_1 \tilde{a}}{\rho} + \frac{(\rho_M + \rho_R)\lambda_2 \tilde{q}}{\rho} - \frac{\tilde{a}^2}{2\rho} - \frac{\tilde{q}^2}{2\rho}$$

What is it Good For?

PROS:
- Achieve more efficient outcomes for the channel by acting together

- Control fairness issues

- Applied in bargaining situations

CONS:
- Requires accurate information and adequate predictions
  - For both firms and the channel
- Requires both firms be open to cooperating
  - Giving up a measure of control
  - Looking to mutual best interests
- Requires rationality from both firms

The Two-Way Subsidy

Rules of the Game

Rules:
- Costs are <u>shared</u> more equally
  - <u>Retailer subsidizes the manufacturer</u> and the manufacturer subsidizes the retailer
  - <u>Increases the reference price effect</u> through advertising
- Information is shared between the players
- Decisions may be made together <u>or</u> planned independently but still enacted sequentially
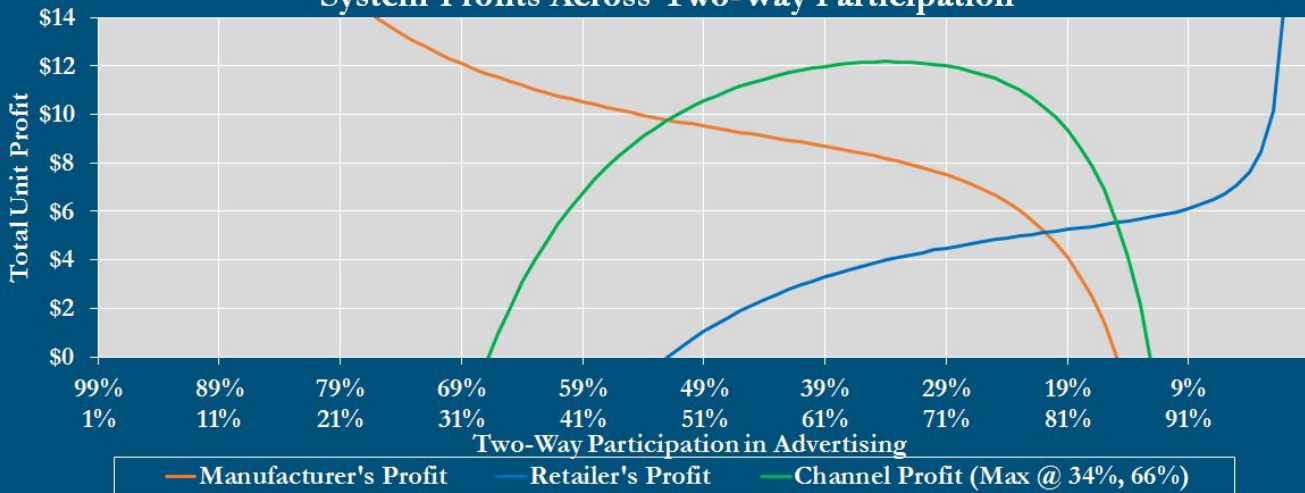
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Equilibrium
System Profits Across Two-Way Participation

Legend: Manufacturer's Profit — Retailer's Profit — Channel Profit (Max @ 34%, 66%)

X-axis: Two-Way Participation in Advertising
Y-axis: Total Unit Profit

$$\hat{J}_M = \frac{F_1 \rho_M \alpha}{\rho + \beta} + \frac{\rho_M F_2}{\rho + \delta} + \frac{\alpha \rho_M (r_{LSS} - p)}{\rho} + \frac{\rho_M G_{LSS}}{\rho}$$
$$+ \frac{\rho_M \lambda_1 \hat{a}}{\rho} + \frac{\rho_M \lambda_2 \hat{q}}{\rho} - \frac{(1 - \hat{\phi}_2)\hat{a}^2}{2\rho} - \frac{\hat{\phi}_1 \hat{q}^2}{2\rho}$$

$$\hat{J}_R = \frac{F_1 \rho_R \alpha}{\rho + \beta} + \frac{\rho_R F_2}{\rho + \delta} + \frac{\alpha \rho_R (r_{LSS} - p)}{\rho} + \frac{\rho_R G_{LSS}}{\rho}$$
$$+ \frac{\rho_R \lambda_1 \hat{a}}{\rho} + \frac{\rho_R \lambda_2 \hat{q}}{\rho} - \frac{\hat{\phi}_2 \hat{a}^2}{2\rho} - \frac{(1 - \hat{\phi}_1)\hat{q}^2}{2\rho}$$

What Problems Does it Solve?

- Channel members can make their decisions cooperatively or separately while achieving an improved stable channel decision
- Incentive for both parties to behave rationally and to not deviate from the equilibrium

- It raises more issues though:
    - Raises retailer risk
        - Spending more on advertising
        - Chance of spending more money than their profit
    - Requires the manufacturer to create an incentive for the retailer to buy-in to the two-way subsidy

Logistical Elements

- Supply-Chain Coordination
  - **Stackelberg** - Manufacturer sets the rules and coordinates by prediction
  - **Cooperative** - Rules set together, supply chain coordinated communally
  - **Two-Way Subsidy** - Rules set by manufacturer with retailer buy-in
- Collaboration Incentives
  - **Stackelberg** - Not required as collaboration is not a necessity
    - Retailer decisions are limited by manufacturer decisions
  - **Cooperative** - May be needed to a limited extent to secure retailer involvement
    - Retailer may need convincing initially.
  - **Two-Way Subsidy** - Absolutely needed to ensure retailer cooperation
    - Retailer stands the chance to lose money, and will need a reason to collaborate.
- Information Sharing
  - Only Stackelberg does not require this.

Criticism of the Paper

- Equations
  - 41 equations are extensive and intimidating
  - Remembering what each of the variables and parameters represent became difficult
  - There were undefined variables → see equations (38) and (39)
  - There were no units defined for the parameters and variables

- They didn't share any model limitations.

- There is no data but still have two graphs with results.

coffee time

Thoughts

Discussion Questions

- Do you think that reference price has an effect on sales? And does advertising have an impact reference price?
- Under which conditions would one model perform better?
- How might the addition of multiple retailers and manufacturers to the game make a difference?
- Is this analysis even useful in an industry use?
  - Sheer amount of information
- Questions of your own??