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Price Competition of Two Cassava Processing Manufacturers

Pavee Siriruk* and Salintip Pumpeam

Abstract— **Cassava is a crucial agricultural product which is used worldwide. The number of cassava processing plants has been increasing in the past decades. However, the yields of cassava in the agricultural sector to feed those manufacturers are not enough, creating competition scenarios between firms. The major incentive to draw farmers to sell their products to the firms is cassava buying price. This paper focuses on price strategy for two cassava processing firms. An algorithm to find the price equilibrium is proposed. The results show that the algorithm can find the price equilibrium in a timely fashion.**

Index Terms — **Game Theory; Price Strategy; Cassava.**

The following nomenclature will be used throughout this paper.

i and $\boldsymbol{I}$ Subindex and set of areas where farmers reside set $\boldsymbol{I} = \{1,2, \dots n\}$
j and $\boldsymbol{J}$ Subindex and set of firms, since we consider only two firms set $\boldsymbol{J} = \{A, B\}$
c_i Farmers' costs of cassava production in an area i ($ per ton)
o_i Farmers' costs of transportation to a firm in an area i ($ per kilometer)
q_i Total cassava production in an area i (tons)
$d_{i,j}$ Distance from an area i to firm j
C_j Total production and transportation costs of firm j ($ per ton)
s_j Processed cassava selling price of firm j ($ per ton)
P_j^t Cassava buying price of firm j
r_j The total amount of cassava which sells to firm j
$FP_{i,j}^t$ Profit of farmers living in area i and sell their products to firm j

I. INTRODUCTION

CASSAVA is a crucial agricultural product which is globally produced more than 200 million tons per year and has a market value more than $25,000 million per year worldwide. Every part of cassava from leaves to roots can be used to make a variety of products such as alcohol, cassava starch, cassava chips, cassava pellets, sweeteners, and bio-degradable products. In addition, cassava starch, cassava chips, and cassava pellets also act as raw materials for a number of food industries. All of these products signify potential of cassava in the worldwide market. Brazil is the world's largest cassava producer. However, Thailand is the world's largest cassava exporter and ranked fourth as a cassava producer [1]. The major exported cassava products of Thailand are cassava starch, cassava chips, and cassava pellets.

In the past, there are few cassava processing manufacturers in Thailand with excess raw materials to feed. All firms can make a huge amount of profits. Nowadays, cassava markets draw great attentions to many manufacturers due to high demand from many countries around the world. Demands for cassava in Thailand are high for both domestic use and export with an increase every year. The number of cassava processing plants has been increasing in the past decades including manufacturing plants for ethanol. Most of the plants have high production capacities. The yields of cassava in the agricultural sector to feed those manufacturers are not enough and volatile [2]. This means the investment in high production capacities is futile and does not generate more profits. Therefore, the competitions among manufacturers for cassava are drastically higher. The major incentive, drawing farmers to sell cassava to companies, is firms' cassava buying prices. If the firms set buying price too high, they will lose money. If the firms set buying price too low, only a few farmers will sell cassava to the firms. Therefore, price competition is a crucial issue that requires immediate attention.

In this paper, a case study of Thailand cassava processing plants is used. We will focus on price strategy for two cassava processing firms. Each firm has a fixed location. Farmer's areas around companies are also fixed. Farmers can only sell their products to one firm. We first collect data of all costs and revenue occurring to both farmers and cassava processing plants. Next, an algorithm to find the price equilibrium, the price that neither firms have incentives to move, is proposed.

The model that examines competition among retail stores in a spatial market, called the Maximum Capture Problem (MAXCAP), was developed by ReVelle [3]. The MAXCAP model was developed based on the classical Maximal Covering Location Problem of Church and ReVelle [4]. Another extension of the MAXCAP problem considered a model of competition between two profit-maximizing firms, which want to enter a spatial market by locating several retail facilities each. This paper presented a Pre-Emptive Capture Heuristic Algorithm to solve the model [5]. Plastria and Vanhaverbeke [6] presented aggregation approach is applied in particular to a Competitive Maximal Covering Location Problem and to a recently developed von Strackelberg model. Some empirical results show that the approach is quite effective.

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*Pavee Siriruk is with Department of Industrial Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand 30000 (phone: +66-81-470-7706; e-mail: pavee@g.sut.ac.th).

Salintip Pumpeam is a Mater student in Department of Industrial Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand 30000.

Serra and ReVelle [7] formulated the Maximum Capture Problem with Prices (PMAXCAP) as the maximum capture model extended with a price decision, presented a Competitive Price-Location Heuristic (A Bi-Level Heuristic Procedure) to solve the model. Serra and ReVelle [8] revisited this problem and presented a Hybrid Heuristic to solve it. Plastria and Vanhaverbeke [9] formulated a revenue maximization model and examination of the relationships between the maximal covering problems for different prices. They reveal properties of the deduced revenue maximization model and propose two solution procedures to solve it; full enumeration solution procedure and intelligent enumeration solution procedure. Another paper of Diakova and Kochetov [10] presented the problem of decision making on the facility location and pricing, and considered the mill pricing strategy. A two level local search heuristic based on the VNS framework is developed for nonlinear problem. In addition, the mathematical models for location and ricing decision under competition have been studied by Fischer [11].

The paper is organized as follows. In section two, a problem description is presented. The solution methodology is described in section three. In section four, the numerical example with preliminary results are shown. In section five, primary contributions of this work and conclustions are summarized.

II. Problem Description

Only two cassava processing manufacturers (set J) are considered in this paper. These firms try to buy cassava as much as possible from farmers, living in different areas (set I), around them. The locations of firms and farmers are fixed. Since the distance from farmers to firms ($d_{i,j}$) are fixed, these manufacturers solely compete based on firms' cassava buying price per ton (P_j^t).

The total costs in producing cassava of farmers, living in an area i, consists of costs of cassava production per ton (c_i) and transportation costs per ton (o_i), which are assumed to be equal in all areas. The total revenue of farmers, living in an area i, comes from selling cassava to manufacturers. The total cassava production of all farmers, who live in an area i, is assumed to be q_i. Farmers make decision to sell their cassava based on maximizing profits ($FP_{i,j}^t$) which are directly related to distance to the firm and firm's cassava buying price.

The total cost of cassava processing manufacturers (j) consists of total production and transportation costs per ton (C_j) and cassava buying price per ton (P_j^t). The revenue comes from selling processed cassava with the price per ton of s_j. The total amount of cassava (tons), which sells to firm j, are represented by r_j. The total production and transportation costs per ton and selling price of processed cassava are assumed to be equal to all firms. In competition between two firms, both will try to increase cassava buying price as high as possible in order to draw farmers' attention, while maximizing their profits. The profits of firms are denoted by $\pi_{m,j}^t$. Cassava buying price is very sensitive because it is mass production. Small increase in buying price means a large amount of money.

III. Solution Methodology

Firm j competes with firm j' by increasing cassava buying price. The algorithm consists of two stages, the initial and iterative stages. In the initial stage, farmers in different areas decide which firms they will sell cassava to. The minimum switch prices are calculated in this stage as well. The iterative stage increases cassava buying prices of one firm, while the other firm fixes its buying prices. This process continues until profits of the firm, which increases buying price, decreases. The algorithm is described below.

<u>*Initial Stage*</u>

1. Set $t = 0$.
2. Calculate maximum firm buying price $(p_j^u) = s_j - C_j$
3. Initial firm buying prices $P_j^0 < p_j^u$ and $P_{j'}^0 < p_j^u$ in this paper we will use market value as initial prices for both firms
4. Farmers in an area i make decisions to sell their products to firm j that offers them highest profit. The profits of farmers in area i, who sell their products to firm j, are calculated by
$$FP_{i,j}^0 = P_j^0 q_i - c_i q_i - o_i d_{i,j} q_i$$
for $i \in \boldsymbol{I}$ and $j \in \boldsymbol{J}$
5. For $i \in \boldsymbol{I}$
   If $FP_{i,j}^0 > FP_{i,j'}^0$, farmers in area i will sell their products to firm j. Subindex i will become a member of set $\boldsymbol{X}$.

   If $FP_{i,j}^0 < FP_{i,j'}^0$, farmers in area i will sell their products to firm j. Subindex i will become a member of set $\boldsymbol{Y}$.
   End FOR
6. For $k \in \boldsymbol{Y}$
   Calculate minimum switch price (cp_k) that farmers in an area i will make a sell to firm j instead of j' by using the following formula
$$cp_k = \frac{\left|\pi_{k,j}^0 - \pi_{k,j'}^0\right|}{q_i}$$
   END FOR

<u>*Iterative Stage*</u>

7. Set $t = t + 1$
8. FOR $m \in \boldsymbol{Y}$
   - Include m in set $\boldsymbol{X}$ as a new subindex
   - Let r_j be the total amount of cassava which sells to firm j. r_j can be calculated by
$$r_j = \sum_{i \in X} q_i$$
   - Calculate new buying price of firm j as follows
$$P_j^t = P_j^{t-1} + cp_m + \in,$$
   where $\in$ is a very small number, such as 0.01.
   - Calculate new profit of firm j after including a new subindex m as follows
$$\pi_{m,j}^t = s_j r_j - C_j r_j - P_j^t r_j$$
   -Exclude m from set $\boldsymbol{X}$.
   END FOR
9. Choose subindex m which yields the highest profit ($\pi_{m,j}^t$) from step 8 and includes subindex m in set

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$\boldsymbol{X}$ permanently as well as eliminate it from set $\boldsymbol{Y}$ permanently.

10. FOR $n \in \boldsymbol{Y}$
    IF $cp_m > cp_n$, THEN n becomes a member of set $\boldsymbol{X}$ and eliminate it from set $\boldsymbol{Y}$ permanently.
    END IF
    END FOR
11. IF $Y = \{\emptyset\}$ OR $\pi_{m,j}^{t} < \pi_{m,j}^{t-1}$, THEN STOP.
    Otherwise, go to step 7.
    END IF

After completing one iteration, firm j is switched to the other firm and follow the initial and iterative stages. This process continues until the equilibrium price is obtained.

IV. Numerical Examples

Two cassava processing manufacturers, firms A and B, and twelve cultivated areas, area 1 to 12, are considered in this section. The total cassava production in each area and distance from each area to firms A and B are described in Table 1.

TABLE I
Distances and Cassava Production in Each Area

Area	Distance (Km)		Total Cassava Production (tons)
	Firm A	Firm B	
1	65	50	3,700
2	48	28	1,380
3	15	6	1,200
4	30	15	1,000
5	15	13	1,500
6	40	44	1,600
7	25	30	3,000
8	15	35	2,750
9	20	35	2,000
10	80	90	2,925
11	100	150	1,000
12	100	150	3,000

Farmers' costs of cassava production and transportation to a firm in an area i are assumed to be \$32.67 per ton and \$0.22 per kilometer, respectively.

Total production and transportation costs for each firm are assumed to be \$22.15 per ton. The processed cassava selling price for each firm is assumed to be \$99.17 per ton. The cassava market price is assumed to be \$64.33 per ton.

The algorithm, described in section III, is deployed. After step 5, the results show that farmers in areas 6, 7, 8, 9, 10, 11, and 12 sell their products to firm A. The farmers in areas 1, 2, 3, 4, and 5 sell their products to firm B. The profits of firms A and B are \$111,339.18 and \$206,383.28, respectively. Both firms will take turn increasing theirs cassava buying price. The results are shown in Table 2.

TABLE II
Results of Price Competition between Firms A and B

Iteration	t	Firm	Areas Captured	Buying Price	Profits (\$)
1	5	B	1,2,3,4,5,6,7,8,9,10	68.75	173,928
2	5	A	6,7,8,9,10,11,12	67.87	148,824.03
3	3	B	1,2,3,4,5,6,7,10	70.08	113,058.87
4	4	A	6,7,8,9,10,11,12	69.2	127,232.52
5	3	B	1,2,3,4,5,6,7,10	71.4	91,427.57
6	4	A	6,7,8,9,10,11,12	70.52	105,641.03
7	2	B	1,2,3,4,5,6,7	71.63	72,060.22
8	3	A	6,7,8,9,10,11,12	70.74	102,033.40
9	2	B	1,2,3,4,5,6,7	71.85	69,094.32
10	3	A	6,7,8,9,10,11,12	70.97	98,425.78

From Table 2, iterations 7 and 9 show that firm B has captured the same areas but the total profits are decreased. Thus, firm B should set cassava buying price to \$71.63 per ton and stop increasing the buying price. At this price, farmers in areas 1, 2, 3, 4, and 5 will make a sell to firm B. The same logic applies to firm A. Firm A should set its buying price to \$70.74 per ton and captures areas 6, 7, 8, 9, 10, 11, and 12.

V. Conclusions

This paper has studied the price strategy for two cassava processing firms with fixed locations. The algorithm to find the price equilibrium was proposed. The case study of two firms and twelve cultivated areas were considerd. The results showed that the proposed algorithm found the equilibrium price in ten iterations.

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