An Agri-food Supply Chain Model to Empower Farmers as Supplier for Modern Retailer Using Corporate Social Responsibility Activities on Deteriorated Product

Wahyudi Sutopo, Muhammad Hisjam, and Yuniaristanto

Abstract— **In general, small-scale vegetables farmers have to deal with marketing and low selling price problems although they produce good quality of vegetables. The low prices are partly because of the market information asymmetry and the effect of quality deterioration. This paper proposes an agri-food supply chain (ASC) model that involves the corporate social responsibility (CSR) activities to empower the farmers in solving their internal problems. The CSR activities are designed to enhance business skills and to postpone the impact of deterioration. The Farmer Group and/or Cooperative (FGC) should be able to assist its members by marketing directly to the modern retailers (MR). Deterioration time and risk function are also included in the model to calculate the risk faced by the MR. Multi-objectives optimization programming is used to determine the amount and timing of supply, level of farmers training skills, quality improvement target, and the CSR total cost.**

Index Terms—**agri-food supply chain, corporate social responsibility, deteriorated product, supplier of modern retailer.**

I. Introduction

SMALL-scale vegetables farmers have to deal with marketing and low selling price problems although they produce good quality of vegetables. As a consequence, they are forced to sell their commodities at a very low price to the customers [1], [21], [22]. They may get better profit from their harvest if their group or cooperative could sell to modern retailers directly. As supplier, the Farmer Group and/or Cooperative (FGC) have to meet the relevant provisions of modern retail on product specifications, delivery terms, and internal business requirements [2], [3]. As supplier of the MR, the FGC must appropriate with some requirements related to buyer-supplier relationship [21], [22].

The case described in the previous paragraph can be seen as the integration of key business processes from the integrated system in agri-food supply chain (ASC) that consists of three main entities namely farmers, the FGC, and the modern retailers (MR), and also the customers as end users. The ASC is created by the organizations responsible for producing, processing, distribution, process, and marketing the commodities to the final consumers [4]. Moreover, the Government of the Republic of Indonesia regulates the MR to put into practice the environmental and social responsibility [5], [6], [23]. As a consequence, the MR must commit to take part in sustainable economic development, in order to improve the quality of life and environment, which will be beneficial for the company itself, the local community, and society in general. Thus, implementing the Corporate Social Responsibility (CSR) programs in the integrated system of ASC could solve the problem described in the first paragraph.

Several researches had been conducted to improve supply chain coordination [7], [8], to make business contracts [9], [10], and to understand the effect ASC improvements [2], [11], [12]. Nowadays firms are able to promote and implement the responsible business practices throughout its supply chain [13], [14]. Furthermore, many researchers have tried to develop the implementation of CSR program in supply chains. Firms engage in CSR activities as a way to enhance firm-supplier relationship [15], [16], to generate customer loyalty and manage their risk [17], [18], and to propose the guidance of CRS implementation in supply chain responsibility [19], [20]. However, none of them proposes a model to solve the problem by considering the internal and external problems of the small-scale vegetables farmers. Furthermore, all existing models do not consider the particular weaknesses of the small-scale farmers in accessing capital, adopting new technology, and managing internal business. Previous researches had been conducted to solve the internal problems of the small-scale vegetables, but they do not consider the effect of product deterioration [21], [22]. This paper proposes an ASC model that involves the CSR activities to empower the FGC as qualified supplier on deteriorated product. By allocating an amount of CSR budget, farmers can provide high quality vegetables to MR. As a result, deterioration time of sold vegetables can be lengthen hence the risk faced by MR can be reduced.

This paper is organized as follows. In Section 1, we describe the background of our research and describe the problems in the real system. In Section 2, we construct the problem formulation. In Section 3, we provide the mathematical model. In Section 4, we design the solution method and analysis. In Section 5, we deliver the conclusion and future research.

W. Sutopo, M. Hisjam, and Yuniaristanto are with the Laboratory of Logistics System and Business, Department of Industrial Engineering, Sebelas Maret University, Surakarta, 57126, INDONESIA. (Corresponding authors: phone/fax.+62-271-632110; e-mail: sutopo@uns.ac.id; mhisjam@yahoo.com; yuniaristanto@gmail.com).

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II. Problem Formulation

A. The Relevant System

ASC network which is considered as relevant system of the problem is depicted in Fig. 1. The members of FGC consist of several farmers which plant several types of vegetables. Each farmer delivers it to the FGC, and then the FGC sells the vegetable to modern retailers (MR). However due to restrictive quality specification imposed by MR, the FGC must conduct strict quality inspection before it can be sold to MR [21], [22]. Without improvement of the quality during distribution system, FGC can only sell a little part of their production to MR. On the other hand; MR needs adequate supply of vegetables to conduct their business. FGC can also sell their products directly to end customer. However, this option offers less attractive revenue.

In order to increase supply of vegetables, MR proposes CSR programs conducted by the division of human resource development (HRD) of the modern retailers as well as CSR benefits for empowering farmer. The CSR activities are designed to enhance business skills and to improve the quality of vegetables distribution system that is practiced by the FGC members. The objective of the CSR is not only to maximize the profit of farmers, but also to maximize CSR benefits for the modern retailers.

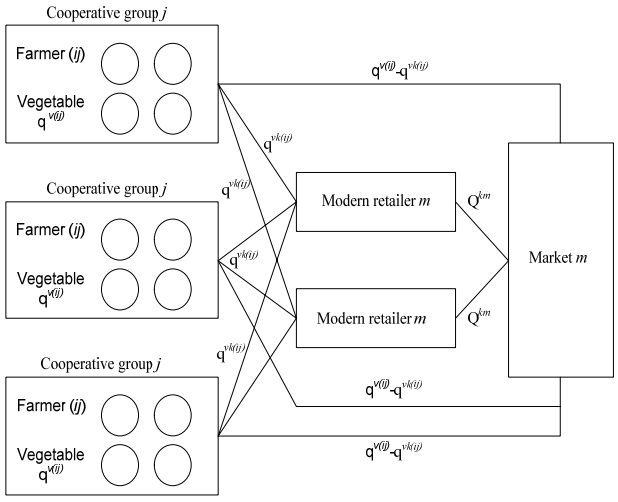

Fig. 1. ASC network of relevant system.

The decisions concern on the amount and timing of supply, level of farmers training skills, quality improvement target, and the CSR total cost. By allocating an amount of money to fund CSR activities, farmers can provide high quality vegetables to MR. As a result, deterioration time of sold vegetables can be lengthen hence the risk of vegetable decay faced by MR can be reduced.

From the description above, this paper tries to answer the following questions. First, how much must of CSR budget be allocated to business skills improvement of the farmers? Second, how much of CSR budget must be allocated to improve the quality of vegetables distribution system? Third, what is the effect of quality improvement to deterioration time of vegetables and the risk faced by MR?.

III. Model Development

The ASC model can be formulated by the mix integer linear programming (MILP). The following notations are used to develop the proposed model.

Indexes:

$t \in T$	period set
$i \in I$	farmer set
$j \in J$	cooperative group set
$k \in K$	modern retailer set
$m \in M$	consumer market set
$v \in V$	vegetable set

Parameters and Variables:

$q_t^{v(ij)}$	the quantity of the vegetables produced by farmer i in cooperative group j
$q_t^{vk(ij)}$	the quantity of the vegetables transacted by retailer k from farmer i in cooperative group j at period t.
p_t^{vmk}	price of vegetable v from retailer k to market m as the effect of CSR
$p_t^{vm(ij)}$	price of vegetables v transacted by market m from farmer i in cooperative group j
$p_t^{vk(ij)}$	price of vegetable v transacted by modern retailer k from farmer i in cooperative group j
p_t	price of vegetable v from retailer k to market m
$c_t^{v(ij)}$	production cost of farmer i in cooperative group j
$h_t^{(ij)}$	training fund received by farmer i in cooperative group j
$g_t^{v(ij)}$	quality improvement fund received by farmer i in cooperative group j
$\varpi^{(ij)}$	initial skill level of farmer i in cooperative group j
ϑ_t^k	CSR cost faced by modern retailer k
ϕ	maximum skill level of farmers business skill
p_t	normal selling price transacted by consumer from modern retailer
r_t	risk faced by modern retailer
α	skill level factor of farmers in quality improvement
y_0^{ij}	initial quality of vegetable produced by farmer i at cooperative group j
$g(y)$	function of vegetable selling price as CSR effects
$f(y)$	function of vegetable quality as CSR effects
$h(\tau)$	function of risk faced by modern retailer
Q_t^{km}	the quantity of the vegetables transacted between retailer k and each demand market m at time t
$F_t^{(ij)}$	training taken by farmer i at cooperative groups j in period t
$\psi_t^{v(ij)}$	quality improvement percentage of vegetable v farmer i at cooperative group j

A. Vegetables Flow

The FGC consists of several farmers who inhabit the area nearby the cooperative and/or group, and a farmer cannot be a member of more than one cooperative and/or group. The FCG sell the vegetables to a local modern retailer (MR) with better price than to traditional market (TM). Therefore, not all vegetables produced by farmers can be sold to the modern retailer. The relationship between the quantity of the vegetables that produced by farmers and that can be sold to modern retailer can be expressed by (1). Modern retailer sells the vegetables acquired from the cooperatives groups to consumer market. Equation (2) states the sum of all vegetables sold to customer market less than or equal to the sum of all vegetables bought from all cooperative groups.

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$$\sum_{i\in I} q_t^{v(ij)} \geq \sum_{k\in K} q_t^{vk(ij)} \quad (1)$$

$$\sum_{m\in M} Q_t^{vmk} \leq \sum_{k\in K} q_t^{vk(ij)} \quad (2)$$

B. Quality Improvement Effects

The proposed model assumes that by improving quality of vegetable, the following are occurred: farmers can increase their volume of vegetables sold to MR, MR obtained high-quality vegetables from farmers thus improving its selling price to customer and reducing the risk. The relationship between the quantities of vegetable that can be sold to modern retailer with the quality of vegetable produced by farmers is depicted in Fig. 2. For instance, if the quality of vegetable produced by farmers is less than fifty percent, modern retailer will not buy it from farmers. As the quality of vegetable increases, modern retailer will buy some amount of vegetable. Suppose that the quality of vegetable is eighty percent then modern retailer will buy seventy percent of the vegetable produced by farmers, and the remaining vegetable is sold to traditional market. This relationship can be written as (3).

$$q_t^{vk(ij)} = f\left(y\right) q_t^{v(ij)} \quad (3)$$

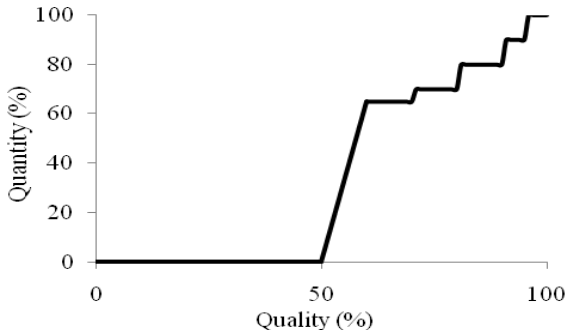

Fig. 2. Quantity of vegetables sold to MR as a function of quality.

As part of CSR commitments, modern retailer assists farmers to improve vegetable quality. By improving quality of the vegetable, farmers can sell their product to modern retailer with higher price than sell it to traditional market. Hence for farmers, CSR will benefit them with additional revenue. As for modern retailer, quality improvement can make modern retailer increase the selling price to consumer. Thus, both farmers and modern retailer will get advantage by CSR activities. Impact of quality improvement to selling price is expressed as (4).

$$p_t^{vmk} = g\left(y\right) p_t \quad (4)$$

Not only benefit does modern retailer get, but also it has to face the risk to conduct CSR activities. The risk caused by unsold vegetable that suffers from deterioration. In order to clarify this concept, Fig. 3 depicts the relationship between vegetable quality and deterioration time.

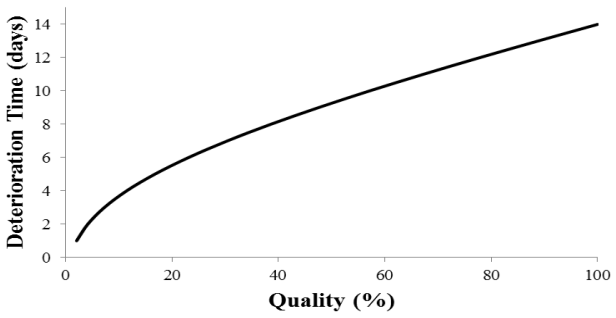

Fig. 3. Deterioration time as a function of vegetable quality.

This relationship is expressed as:

$$y = a\exp^{-\left[c/(\tau+b)\right]} \quad (4)$$

where y denotes quality of vegetable, τ denotes deterioration time of vegetable, whereas a, b, and c are parameters [10]. For instance, modern retailer buys vegetable with category of seventy percent which will deteriorate in twelve days. After twelve days, vegetable becomes outdated hence it can not be sold to consumer. Thus, if and all parameters in (5) are known, the risk faced by modern retailer is a function of deterioration time and can be calculated by the expression in (5).

$$r_t = h\left(\tau\right) \quad (5)$$

C. The ASC Model

The ASC model can be formulated as constrained MILP. It consists of two objective functions that must be minimized, *i. e.* MR profit and farmers' profit. Equation (6) consists of two parts. The first three terms belong to farmers' objectives and the remaining terms belong to MR objective.

Objective function:

$$\begin{aligned}\text{Max } & \sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{j\in J}\sum_{i\in I} p_t^{vk(ij)} q_t^{vk(ij)} - \sum_{t\in T}\sum_{v\in V}\sum_{j\in J}\sum_{i\in I} c_t^{v(ij)} q_t^{v(ij)} \\ & + \sum_{t\in T}\sum_{v\in V}\sum_{m\in M}\sum_{j\in J}\sum_{i\in I} p_t^{vm(ij)}\left(q_t^{v(ij)} - q_t^{vk(ij)}\right) + \sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{m\in M} p_t^{vmk} Q_t^{km} \\ & - \sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{j\in J}\sum_{i\in I} p_t^{vk(ij)} q_t^{vk(ij)} - \sum_{t\in T} \vartheta_t^k - \sum_{t\in T} p_t^{vk(ij)} q_t^{vk(ij)} r_t\end{aligned} \quad (6)$$

Constraints:

$$\sum_{t\in T} \vartheta_t^k = \sum_{t\in T}\sum_{v\in V}\sum_{j\in J}\sum_{i\in I} \psi_t^{v(ij)} g_t^{v(ij)} + \sum_{t\in T}\sum_{j\in J}\sum_{i\in I} F_t^{(ij)} h_t^{(ij)} \quad (7)$$

$$\sum_{i\in I} q_t^{v(ij)} \geq \sum_{k\in K}\left(f\left(y\right) + \alpha F_t^{(ij)}\right) q_t^{vk(ij)}, \forall t, j, v \quad (8)$$

$$\sum_{m\in M} Q_t^{vmk} \leq \sum_{k\in K} q_t^{vk(ij)}, \forall t, j, v \quad (9)$$

$$\sum_{t\in T} \vartheta_t^k \leq CSR \quad (10)$$

$$\sum_{t\in T}\sum_{j\in J}\sum_{i\in I} \varpi^{(ij)} + F_t^{(ij)} \leq \phi \quad (11)$$

$$f\left(y\right) + \alpha F_t^{(ij)} \leq 1, \forall t \quad (12)$$

$$\psi_t^{v(ij)} = f(y) - y_0^{ij} \quad (13)$$

$$F_t^{(ij)} \in \mathbb{Z}_+, \alpha_t^{(ij)} \geq 0, \psi_t^{v(ij)} \geq 0, \forall i, j, t \quad (14)$$

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The first term in (6) represents the revenue of farmers from selling vegetables to modern retailer. The second term represents the production cost, whereas the last term represents revenue from selling to traditional market. The fourth and remaining terms of (6) belong to MR objective. The forth term represents revenue, the fifth represents the purchasing cost, the total CSR cost, and the last term represents the risk cost.

The total CSR cost that the modern retailer have to deal with is expressed in (17), which states that the total CSR cost is equal to the sum of the vegetables quality improvement cost and the farmers skill enhancement cost. The first term of the right hand side of (7) expresses the cost for improving vegetables which can be obtained by multiplying the quality improvement percentage and the associated improvement cost. The vegetables flows transacted by modern retailer from farmers balance is defined in (8). The vegetables flows transacted by consumer market from modern retailer are expressed in (9). It stated that the sum of the vegetables bought by all consumer markets must not exceed the quantity bought by modern retailer. Modern retailer spends budget for CSR activities. The amount of the budget is limited to the amount of the CSR budget authorized by modern retailer owner as in (10). Equation (11) states that the training level taken by farmer added with the current level must not exceed the maximum skill level determined by the modern retailer. Quality improvement and farmer's skill enhancement effects to quantity of vegetable sold by farmer to modern retailer must not exceed 100% as expressed in (12). Equation (13) expresses the quality improvement balance. Finally, the last equation is utilized to enforce non-negativity for all decision variables.

IV. Numerical Results and Analysis

In this computational study, the algorithm used to solve the MILP formulation was branch and bound method. We use IBM® ILOG® CPLEX Academic version solver to solve the MILP formulation [24].

The supply chain comprises three cooperative groups *j, j* = 1, 2, 3; 1 modern retailer *k, k* = 1; 1 vegetable *v, v* = 1; 1 consumer market *m, m = 1*; and 2 periods *t, t* = 1, 2. The numbers of farmers associated with the cooperative groups are 3, 2, and 4 respectively. The parameters values for (4) are a = 10.8159, b = 50, and c = 7. Initial quality of vegetable is 60%, *i.e.* currently all farmers can only sell 60% of their production to MR and the remaining is sold to traditional market.

TABLE I
QUANTITY AND SELLING PRICE FUNCTIONS

y	$f(y)$	$g(y)$
0-50%	0	0
50%-60%	60%	1.1
60%-70%	65%	1.2
70%-80%	70%	1.3
80%-90%	80%	1.4
90%-100%	100%	1.5

TABLE II
RISK FUNCTION

τ	$h(\tau)$
1-9	0.80
10	0.43
11	0.35
12	0.20
13	0.10
14	0.05

Table I represents the effect of quality to selling price of MR and quantity sold by farmers to MR. Table II presents risk function faced by modern retailer as a function of deterioration time. Suppose by doing quality improvement, vegetable will deteriorate after twelve days. Then the risk faced by modern retailer that it is unable to get gain from vegetable sold is 0.2.

There are two important results that can be discussed here, first the benefit of the effects of CSR to revenue of MR and customer, and second the effects of CSR to deterioration time of vegetables.

Benefit of CSR for modern retailer and farmer is depicted in Fig. 4. It can be seen that from CSR budget value 10-40 million the revenue of modern retailer increase as budget increase. The same applied to CSR budget above 40 millions. However the increase is not as sharp as the previous. Hence, there must be an optimal CSR budget that maximizes revenue. As for farmer, the increase is not as big as those of modern retailer. When CSR budget is 10-40 million IDR, all portion of CSR budget is allocated to quality improvement. Hence, there is only little increase to farmers revenue. For 40 million above, CSR budget is shared between quality improvement and farmers skill enhancement. This causes the "flat" increase in MR revenue.

In Fig. 5, we examine the effects of CSR budget to deterioration time of vegetable. As we expect, the deterioration time increases as the budget increases. This means that CSR budget not only increase modern retailer revenue but also lengthen deterioration time of vegetable. Thus lengthy deterioration time will reduce risk faced by MR. In a nutshell, ASC model succeds to describe two important effects of CSR activities, increasing farmers and MR revenue, and reducing risk faced by MR with making the deterioration time lengthy.

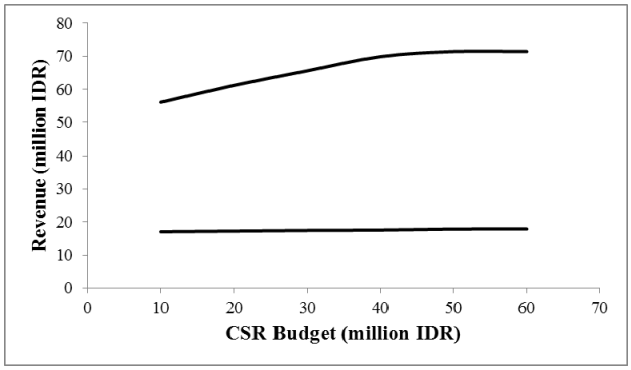

Fig. 4. Effects of CSR Budget to Revenue.

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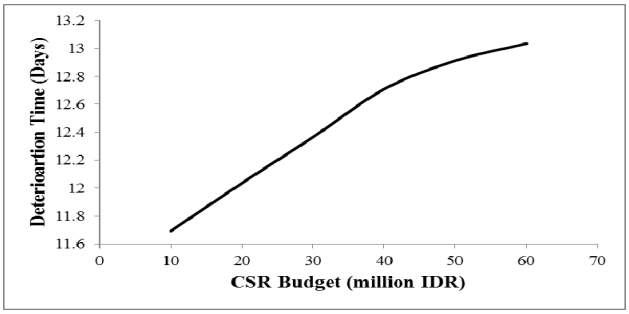

Fig. 5. Effects of CSR Budget to deterioration time.

V. Conclusion and Future Research

In this paper, we propose ASC model that consider CSR which empowering farmers to become qualified suppliers and improving vegetables quality. Multi-objective optimization programming was employed to determine the amount and timing of supply, level of farmers training skills, quality improvement target, and the CSR total cost. The results show that the proposed model can be used to determine which farmers to be awarded grant to improve the vegetables quality, which farmers must undertake the training, and what kind of training the farmers must undertake.

This paper has certain limitations that should be overcome in order to empower farmers in accessing capital and adopting new technology. This proposed model should be extended for enhance the capabilities of the farmers accessing market and adopting technology. However, further research is required to extend uncertainty factors such as price, demand, and supply.

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