Agent Based Modeling for Investment and Operational Risk Considerations in Palm Oil Supply Chain

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Abstract — **In palm oil supply chain (POSC) the investment and operational risk levels between the actors may not be proportionately rewarded by the same levels of added value. However, each actor will attempt to obtain the highest reward. In this study the authors designed a model to simulate the interaction and negotiation behaviors of the actors, and to facilitate optimum distribution of the added value, while considering the successive investment and operational risk levels. Agent-based modeling approach was used for this purpose as it provided the best means to identify and study the supply chain actors (or agents) behaviors. Netlogo software was used to develop the program. This study is important because the model can facilitate further development of various formula to calculate the fair distribution of added value among the actors, therefore ensure the supply chain sustainability. The result of this study indicated that the negotiation between all actors in POSC need to consider overall supply chain sustainability while conducting pairwise negotiation, otherwise the supply chain continuity may be endangered.**

Keywords – Investment Level, Operational Risks Level, Business Negotiation, Agent Based Modeling, Netlogo Software.

1. Introduction

A supply chain is a chain of interdependent companies operating in sequence and cooperate in handling, improving and controlling the flows of goods, money and information beginning with the supplier in the upstream to the downstream until the end consumers (Preckel *et al.*, [20]; van der Vorst, [25]). The principal roles of the supply chain is to add value to the products by moving them from one to another location, or to perform modification processes (Janvier-James, [14]).

The value adding processes may be applied to the quality, costs, delivery activities, flexibilities in sending the products, and innovations (Trienekens, [24]). One of the most important supply chains in Indonesia is the palm oil supply chain. Figure 1 shows how important palm oil is (PKPN, [18]). Export of palm oil and its derivatives has always been increasing. In 2010 the export value was USD 15,6 billions, which has shown an increase of 34,6 % compared to 2009. The export tax was US$ 2,8 billion (PKPN,[18]). This value came second only to oil export.

Due to the monopsonistic conditions palm oil farmer bargaining power was low. CAO [5] reported the sad conditions about small farmers suffering of low productivity compared to very high profit per hectare for the large estates, the low accessability to financial and technical supports, and lacking in representation in the decision making processes.

Mulyana [17] described the low prices of FFB by the farmers despite their high risks. Departing from the unfavorable conditions above we need to identify what are the risks faced by the palm oil supply chain actors and their impacts to each of them.

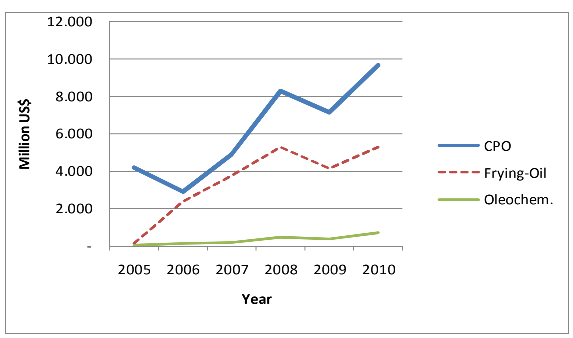

Figure 1. Indonesian palm oil products exports (PKPN, [18])

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The objective of this study is to design a model to simulate the interactive and negotiation behaviors of the palm oil supply chain actors, and to facilitate optimum distribution of the added value for each actor, while considering the successive investment and operational risk levels. the scope of this study is the palm oil supply chain beginning with farmer groups, traders, CPO factory, Frying Oil factory (refinery), and the frying oil distributor. To achieve this objective some theories, methodologies, and models are utilized.

The first theory that will be utilized in this study is the theory about risk and risk management. Holton [12] defined risks as the exposure to the probability of uncertain event. Risks may also be defined as the uncertainty of the achievements by a company (Kaplan and Garrick, [15]). Risk management involved the control of the potential risks by identifying, measuring and controlling the related risk potentials (IRM, [13]). Risks must be controlled otherwise problems may happen in the supply of raw materials which may cause financial loss to the company (Zsidisin, et al.,[27]).

The second theory is about added value. Added value may be defined as the incremental value to a commodity as it undergoes processing in the production stream. (Coltrain et al.,[6]). Hines [11] defined added value as the "difference between output value and the input costs". Added value concept is the increase in the value due to the growth of the value as functional input is affected to the commodity. Functional input is the treatment and services that causes increments in the utility and the value of the commodity (Harjanto, [8]). Added value is the main motivation for the establishment and the growth of an enterprise. Without this no investor or a businessman is willing to invest in or nurture a business. This kind of motive is the strongest one that push a person or an organization to get involved in supply chain (Li and Yuanyuan, [16]). Bunte [4] mentioned that the unfair cost and benefit distribution along an agroindustry supply chain will endanger its survival, as it hampers the efforts to modernize the agriculture and subsequently it will hamper the growth of the industry. The motives for the investor or the businessman to engage in any enterprise including the agroindustry is the fair and just arrangement of risk and benefit (Preckel et al., [20]).

Added value formula is written as follows (Salvatore, [21]):

$$\Pi = TR - TC \quad \text{(1)}$$

$$TR = P * Q \quad \text{(2)}$$

$$TC = TFC + TVC \quad \text{(3)}$$

where

Π	=	profit
TR	=	total revenue
P	=	price per unit
Q	=	quantity sold
TC	=	total cost
TFC	=	total fixed cost
TVC	=	total variable cost

The third theory is about negotiation behavior between POSC actors. Actors will need to interact very closely to obtain either raw materials or sell their products. They need to do this at the most efficient and economical manners to maintain their continuous financial objectives. They have to consider supply chain factors such as inbound lead times & associated variability, supply chain risk, protection of supply & logistics costs as well as risk & inventory costs (Goel, et al, [7]). During negotiation stages there are additional factors that need to be considered (Atkin and Rinehart, [1]). They were : the level of dependence perceived by each negotiator (both customers and suppliers were measured); the cooperative orientation of each negotiator (both customers and suppliers were measured); the cooperative orientation of each negotiator; the level of coercion implemented in the negotiation; and the level of contract formality implemented in the negotiation. In this study, the negotiation will consider the concept of fairness as introduced by stakeholder dialogue (Palazzo, [19]).

The last theory discussed in this study is the Agent-based modeling approach and Netlogo software. Agent-based modeling was used for this purpose as it provided the best means to identify and study the supply chain actors (or agents) behaviors. To facilitate fair distribution of rewards for the supply chain actors a concept of added value utility based on investment and risk level was introduced. To optimize the added value distribution between the agents the concept of stakeholder dialogue was used. The selling prices were negotiated between the actors until each actor reached a satisfactory value, which was ruled by the levels of optimum added value utility. Many situations and subsystems can be viewed as being characterized by the presence of a number of autonomous entities whose behaviors (actions and interactions) determine (in a non-trivial way) the evolution of the overall system. Agent-based models are particularly suited to tackle these situations and they support the study and analysis of topics like decentralized decision making, local-global interactions, self-organization, emergence and effects of heterogeneity in the simulated system (Bandini, et al. [3]). Netlogo open-source programming software was used to develop the program due to its vast modeling facilities, easy availability, and continuous development by the diverse user communities. NetLogo is written in Java. Java was chosen because both the core language and the GUI libraries are cross-platform, and because modern Java virtual machines have used JIT (just in time) compiler technology to achieve relatively high performance (Tisue and Wilensky [23]).

2. Methods

In line with the objective, this study is organized into several parts as follows: (1) identification of the actors in the palm oil supply chain (POSC), (2) identification of investment and risk levels of the palm oil supply chain (POSC) actors, (3) formulation of the added values in the POSC, (4) identification of the negotiation behavior in the POSC, and (5) using agent based approach with the development of the Netlogo simulation model to facilitate the negotiation behavior. To optimize the added value distribution between the agents, the concept of stakeholder dialogue was used. The selling prices were negotiated between the actors until each actor reached a satisfactory value, which was ruled by the levels of optimum added value utility. To facilitate fair distribution of rewards for the supply chain actors a concept of added value utility based on investment and risk level was introduced.

2.1 Identification of POSC actors, investment and risk levels

All information and data needed for this study were obtained and identified from recent literatures and by interviewing relevant managers in the palm oil industries. Investment and risk levels for each actor were obtained from replies to questionnaires sent to the relevant industry managers which were processed using fuzzy Analytical Hierarchical Process (FAHP). The quantitative results were taken from the authors previous study in the POSC (Hidayat, et al, [9]).

Later in this study the author designed a model to simulate the interactive and negotiation behaviors of the POSC actors, directed to facilitate optimum distribution of the added value for each actor, while considering the successive investment and operational risk levels.

2.2 Formulation of added-value for the POSC

The calculation for added-value for each actor were performed using the modified Hayami method (Hidayat, et al, [10]). Table 1 describes the generic model of modified Hayami method. The added values are shown at row 11 for each actor. The modified Hayami method was used to calculate the investment levels for each actor in the POSC.

Table 1. Modified Hayami method to calculate added value

No	Variables	Unit	Value
Palm Oil Supply Chain Interaction			
1	Raw Material Price	Rp/kg	(1)
2	Product Selling Price	Rp/kg	(2)
3	Total Added Value per kg	Rp/kg	(3) = (2 last actor) - (1)
I. Output, Input, and Prices			
4	a. Output (Sales volumes)	kg	(4a)
	b. Output (Sales values)	Rp	(4b)
5	Total costs of main raw material	Rp	(5)
6	Number of direct labor	MD	(6)
7	Conversion Factor		(7) = (4b) / (5)
8	Direct labor cost coefficient	Rp/MD	(8) = (4b) / (6)
9	Direct labor cost	Rp	(9)
II. Income and Added Value			
10	a. Other Input costs (Production)	Rp	(10a)
	b. Other Input costs (Operational)	Rp	(10b)
11	a. Added Value	Rp	(11a) = (4b) - (5+10a+10b)
	b. Added Value Ratio	%	(11b) = (11a) / (4b)
III. Reward for the Production Owner			
12	Margin	Rp	(12) = (4b) - 5
	a. Contribution from other input	%	(12a) = (10a+10b)/(12)*100%
	b. Company profit	%	(12b) = (11a)/(12) * 100%

Note : MD = mandays

From the initial interviews with the experts and analysing the data it was found that the added value (AV) was dictated by two variables, namely the risk and the investment levels of each POSC actor. Following Suharjito [22] by common sense it was assumed that if the risk is higher then the added value should be higher. Likewise, the higher the investment level, the higher the added value. An exponential function is the best representation of this logic. This assumption is written as a functional exponential formula for added value shown in (4).

$$AV = f\text{ (investment, risk)} = \alpha e^{(w_{1i}x_{1i} + w_{2i}x_{2i})} \quad \alpha\text{....}(4)$$

where:

AV = Added Value
α = variable coefficient
w_{1i} = risk level for i-th POSC actor
x_{1i} = risk score for i-th POSC actor
w_{2i} = investment level for i-th POSC actor
x_{2i} = investment score for i-th POSC actor
i = 1, 2, 3, 4, 5, 6 the actors in the POSC

subject to the constraints:

$0 < x_{1i}, x_{2i} < 1$ ……………………………(5)
$0 < w_{1i}, w_{2i} < 1$……………………………(6)
$w_{1i} + w_{2i} = 1$ ……………………………(7)

2.3 Identification of negotiation behavior

The negotiation process were based on the Stakeholder Dialogue method. Basically the method is a structured discussions between the representatives of business partners or companies (Palazzo, [19]). In the agroindustry supply chain the method aims at maintaining supply continuity and improve the raw materials quality while balancing the financial interests for each actor. The farmers want to get the highest price for their crops, but the traders and factories demand the lowest cost for quality product (Awal, [2]). Figure 2 shows a flowchart how the negotiation process is conducted between farmers and traders. This diagram represented the application of stakeholder dialogue approach by checking if the profit obtained by each POSC actor is higher than the expected gain, and if the gain is higher than the overall POSC gain. The process is iterated between two consecutive actors in the POSC.

Figure 3 shows how the overall negotiation process to ensure that all POSC actors are happy with the outcome of the negotiation. The overall processes were then translated into Netlogo software program.

2.4 Agent-based and Netlogo modeling

Agent-based modeling approach was used for this purpose as it provided the best means to identify and study the supply chain actors (or agents) behaviors. The agent-based approach facilitates the interaction between all the POSC actors with the characteristics of autonomy, social interaction, reactive and pro-active behavior (Wooldridge and Jennings, [26]).

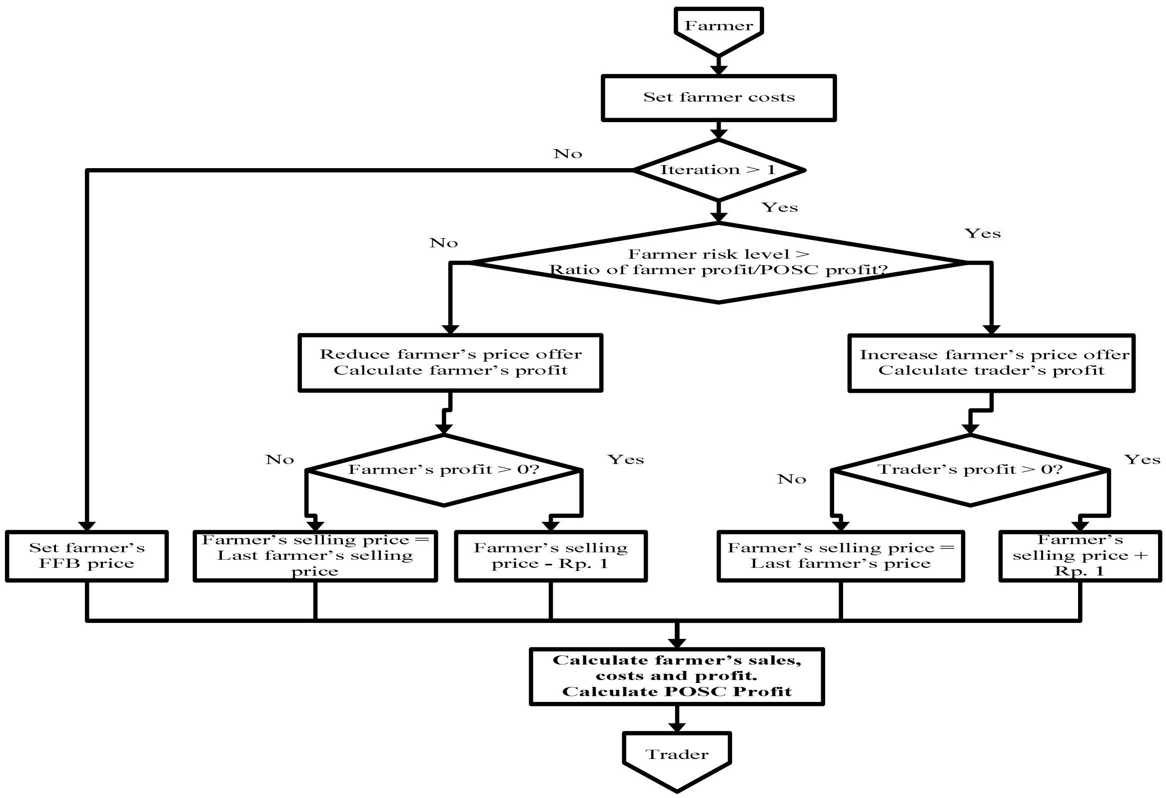

Figure 2. Business negotiation process diagram between the farmer and the trader.

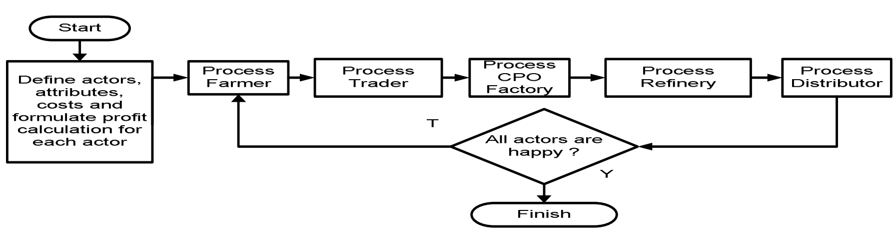

Figure 3. Overall negotiation process in the POSC.

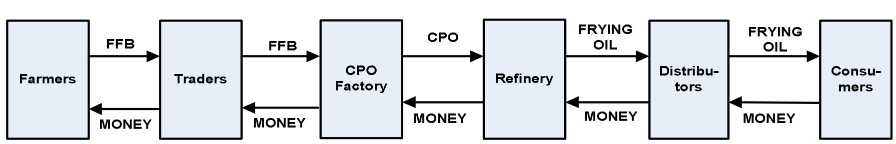

Figure 4. Palm oil supply chain actors

Each of the actors is free to make it's own decisions in the business interaction without having to submit to other actor orders. Each actor will react to the business situation, and may also put forward it's own wish or goals.

3. Results and Discussion

3.1 The actors in the POSC

Investment and risk levels for each actor were obtained from replies to questionnaires sent to the relevant industry managers which were processed using fuzzy Analytical Hierarchical Process (FAHP). The quantitative results were taken from the authors previous study in the POSC (Hidayat, *et al*, [9]). Figure 4 depicts the 5 actors in the palm oil supply chain for this study namely the farmers group, the traders group, the CPO factory, the refinery (frying-oil factory) and the distributors. The consumers were not considered in the quantitative analysis of the study.

In palm oil supply chain the smallholder farmers sell their fresh fruit bunch (FFB) to Palm Oil Mills through traders. Palm Oil Mills convert the FFB into crude palm oil (CPO). CPO is sold to the refinery, who converts CPO into frying oil and sends the product to the distributors. The distributors subsequently sell them to the consumers. The farmers as a group supplied the required FFB raw materials to the CPO factory through the traders. This was required to ensure the consistent quantitative operating levels along the POSC from teh upstream to the downstream.

3.2 Investment and risk level

The values of risk and investment levels for each actor in the POSC were obtained from the interviews with the selected respondents and are shown in Table 2. The data were taken from previous research by the author (Hidayat, et al, [9]).

The CPO factory in the study has a processing capacity of 30 tons of FFB per hour. To operate for a year (working 300 days per year and 20 hours per day) the factory needed 180.000.000 kg of FFB). This amount of FFB is produced by a palm oil estate of 3.032 hectares. Assuming that one farmer owns 2 hectares, then 1.516 farmers are involved in producing the required FFB.

Table 2. POSC actors risk and investment levels

	Unit	Farmers	Traders	CPO Factory	Refinery	Distributor
Input price	Rp/kg	1,209	1423.008	1161.5	6500	12215
Selling price (now)	Rp/kg	1,423	1,500	6,500	12,000	12,420
Risk level		0.355	0.124	0.224	0.193	0.103
Investment level		30	85	3938	5858	89

At the farmer FFB selling price of Rp 1.423/kg, CPO selling rice of Rp 6.500/kg, frying-oil of Rp 12.000/kg, stearin Rp 5.000/kg and PFAD Rp 2.500/kg, the comparison of added value obtained by the POSC actors is Farmers : Traders : CPO factory : Refinery : Distributor = 4,27 %:1,54% : 51,11% : 40,02% : 3,06%. The highest added value is obtained by the refinery at Rp 53.778.500.888. The farmers (as a group) obtained Rp 44.029.700.759 for a year. From this figure we obtained a monthly added value per farmer at Rp 2.420.003 per month. These are the initial data to be entered into the negotiation process using the agent-based Netlogo model.

The Netlogo negotiation process model shows an output graph as depicted in Figure 5. It shows the movement of the optimum selling prices of each product supplied from the most upstream all the way down to the most downstream actor in the POSC. Vertical axis represent the movement of the added value (in percentage of maximum value) for each actor until the optimum stable selling price for each product is obtained. It is obvious that the selling prices for the refinery and the distributor are decreasing, while the selling prices of CPO factory, farmers and the traders are increasing following the relevant added values. Bear in mind that the model is controlled to maintain a satisfactory level of overall POSC profitability as shown in Figure 3.

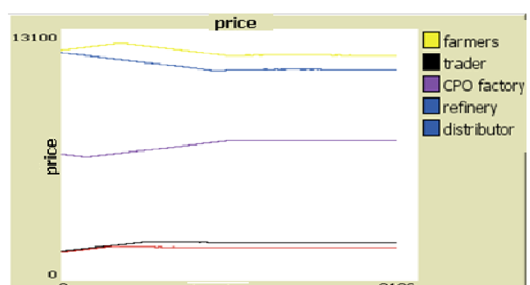

Figure 5. The selling prices between the POSC actors

Figures 6 and 7 show the output "world model" in Netlogo showing the actors added value for each incremental iteration. The size of the circles indicate the comparison of the added value for each actor.

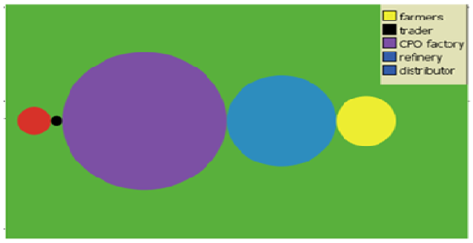

Figure 6. The Netlogo output prior to the negotiation process.

Figure 6 shows the initial condition prior to running the *stakeholder dialogue* procedure while Figure 7 shows the final condition after the optimum profit or added value has been obtained by each POSC actor. The optimum values are shown in Table 3. The table shows that the farmers and traders added values are increased by the end of the negotiation process.

Figure 7. The Netlogo output after the negotiation process.

Table 3 shows that after the negotiation, the farmer group, the trader and the CPO factory received higher selling prices of their product, while refinery and the distributor received lower selling prices ("should be") than before the negotiation.

Table 3. Result of added value balancing simulation

	Unit	Farmer	Trader	CPO Factory	Refinery	Distributor
Input Price	Rp/kg	1,209	1,423	1,162	6,500	12,215
Product Selling Price (now)	Rp/kg	1,423	1,500	6,500	12,000	12,420
Risk Level		0.355	0.124	0.224	0.193	0.103
Investment Level		30	85	3,938	5,858	89
Optimum Utility Value		2.984	2.301	3.608	4.192	2.233
Selling Price (should be)	Rp/kg	1,620	1,942	7,274	11,136	11,973
Profit (rupiah)	Rp/kg	178	138	897	1,377	735
Profit (%)	%	11	7	12	12	6

The model identifying and evaluating the risk level of POSC actors showed that the farmers obtained the highest level 0,335) followed by CPO factory with (0,224), refinery (0,193), traders (0,124), and distributors (0,103). This was obtained as the result of the interviews with experts and the practitioners in the real POSC.

4. Conclusions

This study has managed to provide an agent-based computer model to obtain the fair balance in the added value for each of the POSC actors. The fairness was based on the risk and investment levels of each actor. The balancing process was initiated by optimizing the added value utility of each actor, while considering the overall POSC business continuity. The study indicated that the negotiation between all actors in POSC need to consider overall supply chain sustainability while conducting pairwise negotiation. Otherwise overall sustainability of the supply chain may be endangered.

The model may be extended to consider not only the risk and investment levels of each actor but also other factors such as technology level, and competitiveness of the commodity. The model may also be used to simulate another type of commodity but definitely with appropriate adaptation or changes.

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