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# Added-Value utility formulation in palm oil supply chain based on risk, investment and technology

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**Abstract:** In palm oil supply chain (POSC) the operational risk, investment and technology levels between the actors may not be proportionately rewarded by the same levels of added value. Each actor will attempt to obtain the highest reward. However, each actor must consider the level of added-value obtained by other actors so as to maintain the fair balance in the overall supply chain profitability. Otherwise any of the least profitable actor will withdraw itself from the supply chain and the supply chain will collapse. In this study the authors proposed a formula to calculate the utility function based added-value for each of the actors in the POSC. The utility function is a formula based on the risk, investment and technology levels of each of the POSC actors. Permutation of the three factors was used while seeking their combination that give the highest utility function added-value. To optimize the added-value distribution between the agents the concept of stakeholder dialogue was used. This research is important because the developed models offer a workable algorithm to seek optimum weight level of underlying factors while calculating utility added-value that satisfy the POSC as a whole. Agent-based modeling approach was used for this purpose to facilitate the negotiation between all actors to reach the balanced added-values. Netlogo software was used in developing the models. The proposed utility function model provided the means to find the weight values, while the optimization model proved to be practical to calculate the expected negotiated prices between all the actors. Application of the models to other types of commodity and different supply chain model will need some adjustments in the calculation.

**Keywords:** Added-Value, Palm Oil Supply Chain, Permutation, Agent Based Modeling, Netlogo Software

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## 1. Introduction

In a supply chain interdependent companies operate in sequence and cooperate in handling, improving and controlling the flows of goods, money and information. It begins with the supplier in the upstream and goes all the way downstream until the end consumers ([1, 2]). 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 the modification processes [3]. The value adding processes may be applied to the quality, costs, delivery activities, flexibilities in sending the products, and innovations [4].

### 1.1. Palm Oil Supply Chain

One of the most important supply chains in Indonesia is the palm oil supply chain (POSC). 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 [5]. This value came second only to oil export. Figure 1 shows the 6 actors in the POSC. The smallholder farmers sell their fresh fruit bunch (FFB) to CPO Factory through traders. CPO Factory converts 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. Although CPO can be converted into many types of popular consumer products, for simplicity in this study only frying oil refinery is discussed. The distributors subsequently sell them to the consumers. The farmers as a group supply the required FFB raw materials to the CPO factory through the traders. This is required to ensure the consistent quantitative operating levels along the POSC from the upstream to the downstream.

The business scale of each of the POSC actor is different from each other. The risks faced by each actor are different in type and level. The investment as well as the technology employed by each actor is also different in level. These three factors influence the capacity and the opportunity to create

added value in each of the actors. The sum of the added value created by each actor produces the total added value for overall supply chain.

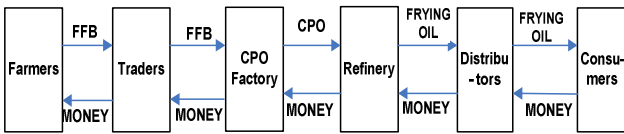


Figure 1. Palm oil supply chain actors

Due to the monopsonistic market conditions palm oil farmers bargaining power was low. [6] reported the sad conditions about small farmers suffering from low productivity compared to very high profit per hectare for the large estates, the low accessibility to financial and technical supports, and lacking in representation in the decision making processes. [7] described the low prices of FFB by the farmers despite their high risks.

The objective of this study is to design a utility added value model based on the level and weight of the risks, investment, and the technology faced or employed by the POSC actors. To achieve this objective some theories, methodologies, and an algorithm are utilized.

1.2. Theories Used in the Study

The first 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 [8]. [9] 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 [10]. Added value is the main motivation for the establishment and the growth of an enterprise. Without this no investor or 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 [11]. [12] 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 [1].

Added value formula is written as follows [13]:

$$\Pi = TR - TC \tag{1}$$

$$TR = P * Q \tag{2}$$

$$TC = TFC + TVC \tag{3}$$

where

$\Pi$  = profit = added value

TR = total revenue

P = price per unit

Q = quantity sold

TC = total cost

TFC = total fixed cost

TVC = total variable cost

The second 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 [14]. During negotiation stages there are additional factors that need to be considered [15]. They are : the level of dependence perceived by each negotiator (both customers and suppliers were measured); the cooperative orientation of each negotiator (both customers and suppliers are 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 concept. Basically the method is a structured discussions between the representatives of business partners or companies [16].

The third theory discussed in this study is the utility formulation to describe added value calculation. The selling prices are negotiated between the actors until each actor reaches a satisfactory value, which is ruled by the levels of optimum added value utility. The concept about the utility function is that all of the tangible and intangible outputs of various business processes, represent inputs into the intrinsic satisfactions, or else they represent goods and services that add to the stock of wealth available for the production of future satisfactions of the actor [17]. With satisfaction the author is referring to the optimization of the added value obtained from the business negotiation in the POSC. In this research the utility function is written in an exponential format.

2. Methods

In line with the objective, this study is organized into several parts as follows: (1) identification of the actors, with relevant risk, investment and technology factors in the POSC, (2) formulation of the added values in the POSC, (3) formulation of the negotiation behavior in the POSC, (4) formulation of permutation and iterative algorithm using the three factors, and (5) development of the solution models using Agent Based approach and Netlogo software.

2.1. Identification of POSC Actors, Risk, Investment and Technology Levels

All information and data needed for this study are obtained and identified from recent literatures and by interviewing relevant managers in the palm oil industries. Risk, investment and technology levels for each actor are obtained from replies to questionnaires, as well as from secondary

resources. Most quantitative results are taken from the author’s previous study in the POSC [18]. Calculation of input material quantities, investment and maintenance costs follow modified Hayami Method. The technology levels are defined as the combination of their sophistication, operation personnel costs, and maintenance costs. Each are given a weight factor, and later normalized to obtain a global score.

**2.2. Formulation of added value for the POSC**

Following [19] 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 and the technology employed, the higher the added value. The level of risk, investment, and technology will never be zero. Nowadays for any real business there are always risk faced by the industry, need for investment, and some technology, although with some differences in their level. An exponential utility function is the best representation of this logic. This assumption is written as a functional exponential utility formula for added value shown in (4).

$$AV = f(\text{investment, risk, technology}) = \alpha e^{(w1i*x1i+w2i*x2i+w3i*x3i)} \alpha \tag{4}$$

where :

- AV = Utility based added value
- $\alpha$  = variable coefficient
- w1i = risk weight level for i-th POSC actor
- x1i = risk score for i-th POSC actor
- w2i = investment weight level for i-th POSC actor
- x2i = investment score for i-th POSC actor
- w3i = technology weight level for i-th POSC actor
- x3i = technology score for i-th POSC actor

i = 1, 2, 3, 4, 5, 6 the actors of the POSC, namely the group of farmers, traders, CPO factory, Frying oil refinery, distributors and the consumers, respectively.

Subject to the constraints:

$$0 < w1i, w2i, w3i < 1 \tag{5}$$

$$w1i + w2i + w3i = 1 \tag{6}$$

The total sum of weights should be equal to 1, while the weight levels for risk, investment and technology are defined to be less than 1. The value for  $\alpha$  from previous research was selected at 2.0 as this value provides sufficient visibility of the graph movement.

In this study, the scores are obtained from the field. It is the values of the weight level that we need to find that give the optimum AV.

**2.3. Identification of Negotiation Behavior**

In agroindustry supply chain the business 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

products [20]. Figure 2 shows a flowchart how the negotiation process is conducted between farmers and traders. This diagram represent 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. Initially the selling price is set, and the gains of both negotiating parties are calculated. The price is increased or lowered, until the gains are acceptable by both negotiating partners. The process is continued between two consecutive actors along the POSC.

Now we need to find the negotiated selling prices between two consecutive POSC actors which are acceptable to both parties, i.e. both are happy as the utility function reaches optimum value. This is achieved when the weight level of risk, investment and technology are adjusted in trial-and-error iterative fashion between both parties and the value of the utility function is calculated. The process is described in the next paragraph.

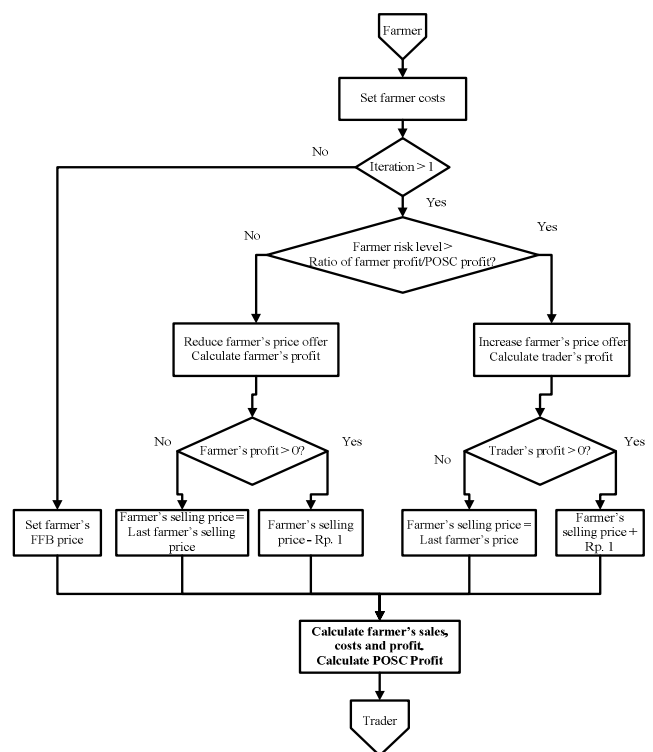


Figure 2. Business negotiation process diagram between the farmer and the trader.

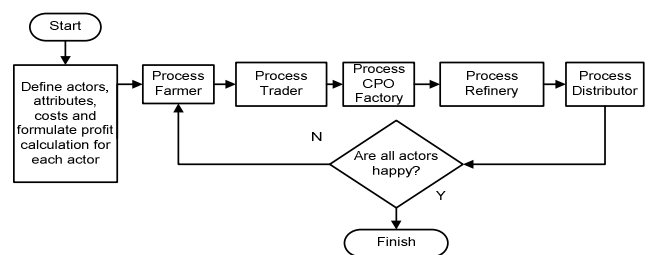


Figure 3. Overall negotiation process in the POSC.

Bear in mind that the model is controlled to maintain a satisfactory level of overall POSC profitability as shown in

Figure 3. The negotiation process will only stop when individual actor has reached satisfactory added value utility level, therefore the overall POSC profitability is sustained. The overall processes are then translated into Netlogo software program.

#### 2.4. Formulation of Permutation and Iterative Algorithm

While we have 3 factors to consider i.e. the weight levels of risks, investments and technology for all five of the supply chain actors, we use mathematical permutation to seek the combinations of the factors which will provide the highest added value of the POSC business. We start with assigning the lowest possible value for one factor (0.001) and increase this value step-by-step by 0.001 until it to reach the highest value of 0.998. For the second factor we started with the lowest value of 0.001, keep it at this level, while to the third factor we assign the highest value of 0.998 because have already assigned the initial value of 0.001 and 0.001 for the first two factors, and that the sum must be equal to one.

Using the Netlogo modelling language we work out an

iteration in the following fashion. A represents the values for risk factor; B represents the values for investment factor, and C represents the values for technology factor. ABC means we started the values of risk factor from 0.001. The value (= A) is incremented with 0.001 gradually until it reaches 0.998. The value for investment (= B) is kept constant at 0.001. The technology factor, the third (= C) was started at 0.998, decreased by 0.001 until it reaches 0.001. Next, the value A is increased to 0.002, B stays at 0.001 and C starts at 0.997. The process is then repeated. This is repeated until A starts at 0.998, B at 0.001 and C at 0.001.

This procedure is repeated for the other 5 permutation namely ACB, BAC, BCA, CAB and CBA with the corresponding changes in each iteration. Table 1 shows the iteration steps for the permutation. We regard each iteration as the realization of one negotiation cycle between the POSC actors. In one negotiation cycle we adjust the levels of weight risk, investment and technology and calculate the related value of the utility function.

Table 1. Iteration steps

		1st	2nd	3rd	4th	5th	6th	7th	End value
<i>Iteration for ABC</i>									
Risk	A	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998
Investment	B	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Technology	C	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
<i>Iteration for ACB</i>									
Risk	A	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998
Investment	B	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
Technology	C	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
<i>Iteration for BAC</i>									
Risk	A	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Investment	B	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998
Technology	C	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
<i>Iteration for BCA</i>									
Risk	A	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
Investment	B	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998
Technology	C	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
<i>Iteration for CAB</i>									
Risk	A	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Investment	B	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
Technology	C	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998
<i>Iteration for CBA</i>									
Risk	A	0.998	0.997	0.996	0.995	0.994	0.993	0.992	0.001
Investment	B	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Technology	C	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.998

#### 2.5. Development of Netlogo Agent Based Modeling

Agent-based modeling approach is used for this purpose as it provided the best means to identify and study the supply chain actors (or agents) business and decision making behaviors. The agent-based approach facilitates the interaction between all the POSC actors with the characteristics of autonomy, social interaction, reactive and pro-active behaviours [21].

Netlogo open-source programming software is used to develop the agent-based program due to its vast modeling facilities, easy availability, and continuous development by the diverse user communities. The programming language is

flexible and facilitate appropriate algorithm coding. It also has the facility to write the numerical calculation output in an excel-like format [22].

Two Netlogo models were developed, i.e. Utility model and the Optimization model. The Utility model is used to obtain the weight levels of risk, investment and technology that give the optimum utility or added value. For each permutation described in paragraph 2.4, say ABC, the Utility model calculates the utility based added value for a combination of score and weight level of risk, investment and technology for all 5 POSC actors. While the weight levels are being changed in the iteration, a plot is printed in the output. The result for the complete iteration is a repetitive

exponential graph as shown in Figure 4 and Figure 5.

To obtain the optimum level in trial-and-error iterative fashion we plot the graph of one permutation, say ABC, and plot another permutation, say ACB, side by side, and find where the two graphs intersect. At this intersection we consider that the risk, investment, and technology level meet the optimum utility added value for all 5 POSC actors.

These weight levels then are entered into the Netlogo Optimization model to find the selling prices and the individual added values for each of the POSC actors. In this Optimization model, the selling prices undergo the iterative negotiation process again to achieve the most acceptable added value level, following the logic shown in Figure 2. The Optimization model is written to facilitate the calculation following the process described in paragraph 2.4.

### 3. Results and Discussion

#### 3.1. The actors in the POSC

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. However, the CPO factory is supplied 50% of its FFB requirement from its own palm oil estate. The respective operating maintenance costs, yields, and added values were calculated using these capacity and respective amount of FFB needs, to obtain corresponding value-added or utility values.

#### 3.2. Investment, Risk and Technology Levels

The scores of risk, investment and technology levels for each actor in the POSC, i.e.  $x_{1i}$ ,  $x_{2i}$  and  $x_{3i}$ , were obtained from the interviews with the selected respondents in previous research [18]. Identified risks are shown in Table 2. The data is processed using Fuzzy Analytical Hierarchy Processing (FAHP) to give the final scores shown on the first row of Table 3. The investment levels were identified from each of the financial reports, further processed using modified Hayami method [18] and normalized to result in the scores shown on Tabel 3. The technology levels were defined as the combination of their values, sophistication, and maintenance costs. Each were given a weight factors, and later normalized to obtain a global score.

Table 2. Identified risks and their final scores

Risk Type	Supply Chain Actor						Score
	Farmer	Trader	CPO Fct	Refinery	Distributor	Consumer	
Price	0.119	0.145	0.045	0.076	0.137	0.221	0.108
Supply	0.082	0.198	0.208	0.197	0.146	0.087	0.152
Transportation	0.037	0.074	0.035	0.043	0.141	0.087	0.058
Information	0.050	0.062	0.044	0.046	0.049	0.057	0.050
Policy	0.037	0.040	0.034	0.031	0.048	0.057	0.039
Market	0.041	0.154	0.081	0.082	0.166	0.081	0.121
Warehousing	0.140	0.057	0.032	0.054	0.066	0.075	0.045
Production	0.100	0.037	0.138	0.156	0.037	0.060	0.098
Environment	0.072	0.025	0.060	0.054	0.031	0.061	0.054
Quality	0.166	0.065	0.138	0.156	0.066	0.129	0.129
Partnership	0.093	0.116	0.067	0.046	0.090	0.051	0.081
Technology	0.059	0.028	0.118	0.078	0.023	0.033	0.064

Table 3. POSC actors risk, investment and technology levels

Variable	Farmer	Trader	CPO Factory	Refinery	Distributor
Risk	0.355	0.124	0.224	0.193	0.103
Investment	0.01	0.028	1.313	1.953	0.04
Technology	0.104	0.224	2.07	0.822	0.316

The Netlogo negotiation process model shows output graphs as depicted in Figure 4, 5 and 6. They show the movement of the utility added value figures following the changes of each iteration as described in paragraph 2.5. The 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.

#### 3.3. Calculation of Maximum Utility Formula

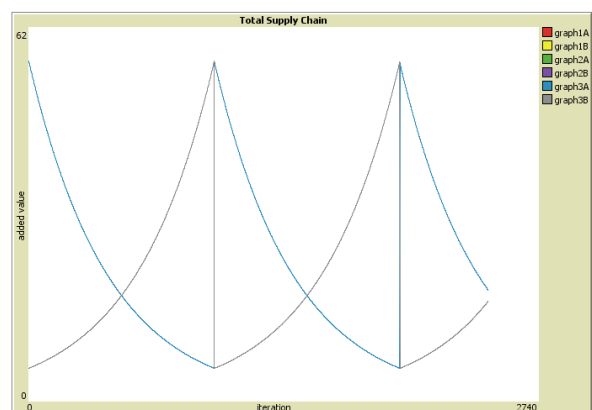


Figure 4. The Netlogo output after the negotiation cycle.

The Utility function described in paragraph 2.2. will look for the optimal values for the variation values for the risk, investment, and technology.

Figures 4, 5 and 6 show the output “world model” in Netlogo showing the actors added value for each incremental iteration. Figure 4 shows the initial condition after running the iteration twice as the realization of stakeholder dialogue procedure. Figure 5 show the result after 5 cycles of the iteration, while Figure 6 shows the final condition after the permutation iteration was completed. The highest optimum values following the process described in paragraph 2.4 are shown in Table 4. The table shows that the farmers and traders added values are increased by the end of the negotiation cycle.

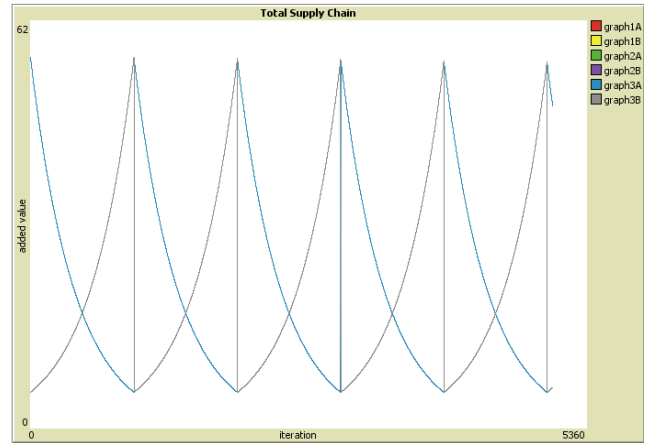


Figure 5. The Netlogo output after the negotiation cycle.

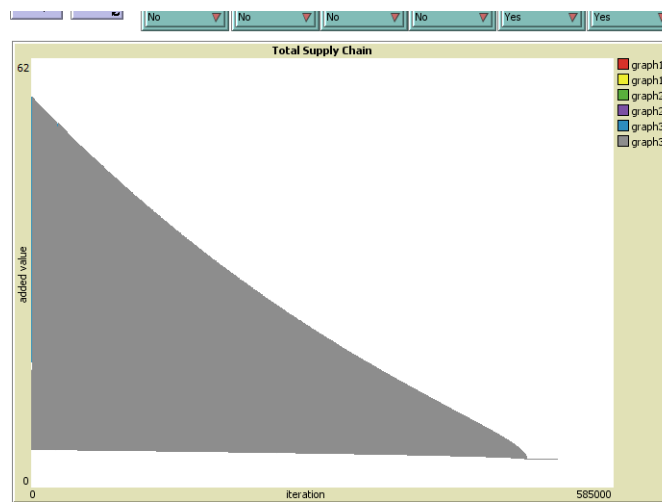


Figure 6. The Netlogo output after the negotiation cycle.

Table 4 shows the highest crosspoint between two utility graphs while running the Utility Netlogo Model. Permutations CAB and CBA provided the result.

Table 4. Added value for each iteration

Iteration	CAB Permutation				CBA Permutation			
	W1	W2	W3	Utility	W1	W2	W3	Utility
1	1	998	1	56.382	998	1	1	5.442
2	2	997	1	56.250	997	2	1	5.455
3	3	996	1	56.118	996	3	1	5.468
4	4	995	1	55.987	995	4	1	5.481
5	5	994	1	55.856	994	5	1	5.494
6	6	993	1	55.725	993	6	1	5.506
7	7	992	1	55.594	992	7	1	5.519
8	8	991	1	55.464	991	8	1	5.532
9	9	990	1	55.334	990	9	1	5.545
10	10	989	1	55.205	989	10	1	5.558
11	11	988	1	55.075	988	11	1	5.571
12	12	987	1	54.946	987	12	1	5.584
496	496	503	1	17.661	503	496	1	17.374
497	497	502	1	17.620	502	497	1	17.415
498	498	501	1	17.579	501	498	1	17.455
499	499	500	1	17.538	500	499	1	17.496
500	500	499	1	17.496	499	500	1	17.538
501	501	498	1	17.455	498	501	1	17.579
502	502	497	1	17.415	497	502	1	17.620
503	503	496	1	17.374	496	503	1	17.661
504	504	495	1	17.333	495	504	1	17.703

The highest utility added value was 17.538, obtained for iteration 499, with risk weight factor  $w_1 = 499$ , investment weight factor  $w_2 = 500$  and technology weight factor  $w_3 = 1$ . These weight factors apply to all 5 POSC actors.

**3.4. Calculation of Maximum Selling Prices**

The weight factor values from paragraph 3.3. were then entered into the Optimization Netlogo Model to obtain the individual product prices and added values for the respective

weight levels. Figure 7 shows the “world output” of the Netlogo model after the negotiation cycle was completed at iteration 720 where the iteration was stopped. The weight levels for the risk, investment and the technology are shown at the top. The selling prices changes in each iteration are shown. The figure shows the calculated “should be” prices and the relevant achieved added value (in ratio format) at every iteration of price changes.

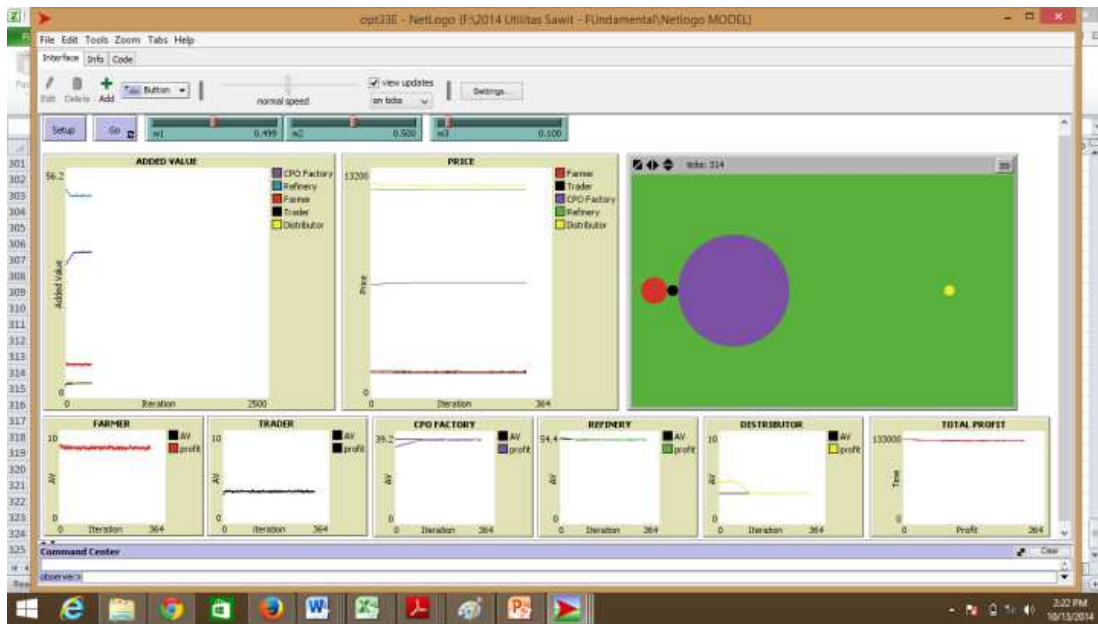


Figure 7. The Netlogo output after the negotiation cycle.

The result of running Optimization Netlogo Model using these weight levels is shown in Table 5. The table shows the gradual increase in the main products being sold along the POSC. Selling prices before the models were run appears on the first row, while the selling prices after the models were run (= “the should be prices”) appear on the second row. The selling prices show increases for the farmers, traders and

CPO factory, but decreases for the refinery and the distributors. The total supply chain gain is reduced from 11,211 Rp/kg to 10,722 Rp/kg. The highest profit is obtained by the refinery, CPO factory, group of farmers, traders, and the distributor respectively. Although the selling price is decreased, the refinery still gain the highest profit.

Table 5. The corresponding prices and profit ranks

		Farmer	Trader	CPO Factory	Refinery	Distributor
Price (before)	Rp/kg	1,209	1,423	1,162	12,000	12,420
Price (after)	Rp/kg	1,397	1,500	6,753	11,889	12,119
Incr/Decr		16%	5%	481%	-1%	-2%
Profit rank		3	4	2	1	5
Change		188	77	5,592	(111)	(301)

**3. Conclusion**

This study has managed to provide a utility added value calculation computer model to obtain the maximum total added value and for each of the POSC actors. The utility model was a function of the risk, investment and technology levels of each actor. The algorithm used to obtain maximum value of the utility added value was based on the mathematical permutation of the risk, investment and

technology factors, while changing the and weight levels in iteration. While the factual figures might be different considerably between the actors, we need to normalize their figures to come up with feasible results. The business levels among the POSC actors must be maintained to have fair flow of materials as well as money. 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.

Many of the figures and values of the model were taken from different sources and they might not represent the real life values. The model still need to be tested to have a valid value in real life.

The model may be extended to be used for other commodity and different supply chain model with some adjustments in the profitability calculation formula. The model may also be extended to cover the most upstream of the POSC namely the palm oil seed industry. The secondary downstream industry may also include other products such as margarine, soap, vitamin E and many other palm oil based products.

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