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A Model of Performance Based Contract Supply Chain Risk Management for Aquaculture Shrimp Agroindustry

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Abstract

The Shrimp Industry was to face the problem of scarcity of supply. It caused by a profit-sharing contract between farmers, collectors and agro-industry was never fair. This issue causing a contract between supply chain actors was unsustainable. The objective of this paper was to develop a model of performance based contract with revenue sharing approach in aquaculture shrimp agroindustry supply chain. We introduced a model of revenue sharing for each actor (farmers, collectors, industry) with price and quantity consideration. This paper localized a supply chain for two actor interaction and trade-off this localized supply chain with goal programming consideration. Revenue sharing for farmers in first localized supply chain is formulated based on revenue sharing in collectors. The addition of this revenue sharing called revenue sharing in supply chain 1. The revenue sharing addition for collectors and industry we called revenue sharing in supply chain 2.

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We trade-off of supply chain 1 and supply chain 2 with goal programming consideration to find a production quantity and revenue sharing for each actors. We find that the quantity in farmers is 0.2 kg/day or 200,000 shrimp fries for cultivation per day *(x_3)*, 2,117 kg/day in collectors *(x_2)* and 1,271 kg/day in industry *(x_1)*. The revenue sharing in supply chain 1 was 0.74 and supply chain and 0.70 in supply chain 2. Also, the needs of shrimp fries obtained based on the number of requests per year from the pond with the level of traditional technologies plus (x_4), semi-intensive (x_5) and intensive (x_6) (ratio of 6: 3: 1), each for 8,395,513 animals, 33,516,428 animals and 5,225,558 animals per year. We recommended this value for performance based contract supply chain risk management for aquaculture shrimp agroindustry.

***Keywords*:** performance based contract; revenue sharing; goal programming; shrimp industry.

1. Introduction

Shrimp agroindustry is a industry based on fisheries that has developed in Indonesia. Shrimp commodity or products have a high selling value that trading arround the world [1]. Currently, Indonesia is shrimp exporter country with main selling target is Japan, USA, Uni-Europe. The shrimp supply chain studied in this paper consists of a three main stake-holders, there are shrimp farmers, collectors and processor (shrimp industry).

The supply chain of shrimp industry was to face the problem that a contract beetween the actors unsustainable. This issue caused by a profit-sharing contract between farmers, collectors and agro-industry was never fair. The biggest profit received by industry, and the higher risk value in farmers. The higher value in farmers caused by a scarcity of supply. So, the supply chain need a model of revenue-sharing that solve a contract problem with fair revenue-sharing for each actor.

This paper solve a contract problem used a performance based contract approaches in a supply chain shrimp industry. The performance based contract analyzed by revenue sharing contract for two actors in supply chain (farmers-collectors and collectors-industry), which is we called supply chain 1 and supply chain 2. We formulated a total profit for each actors and trade-off it used goal programming approaches.

We formulated a revenue sharing contracts based on supply chain coordination with revenue sharing contracts [2, 3, 4]. We Formulated a revenue sharing contract from cost of good sold and share of revenue. The supply chain profit function generated from profit for each actors with share of revenue value consideration. We determined a share of profit in farmers-collectors coordination (supply chain 1) and collectors-industry (supply chain 2). We trade-off supply chain 1 and 2 using goal programming approaches to find a value of quantity and share of revenue for each stakeholder.

PBC procurement is supply chain contracts relating to the supplier's success in meeting or exceeding the minimum performance indicators set forth in the contract [5]. PBC-SCRM have the opportunity to apply to the agro-industry businesses shrimp, because of its potential to improve the competitiveness of agro-products shrimp. This approach focuses on two main business activities (core business) [6]. First, of orientation towards service orientation goods. Second, in the agro-industry shrimp, PBC was able to avoid the high risk and reducing costs in the procurement of raw materials. For customers, this approach can improve performance and decrease costs at an affordable price. Furthermore, [7] says that in the design and management of PBC needs to pay attention to performance, risk and rewards and punishment scheme.

The data used comes from the exploration of the shrimp industry, Sidoarjo, East Java, Indonesia, including the required amount of shrimp fries (for traditional plus ponds, semi-intensive ponds and intensive ponds), the cost of production, mass balance, the conversion of the total weight of shrimp fries in the pond, collecting up production of shrimp (shrimp headless). In the end of this paper we discussion about a total of quantity and share of revenue for each actors.

2. Research method

2.1 Model of Revenue Sharing Contracts

Total revenue sharing contracts generated from share of revenue, cost of supply chain and cost of a actors (collectors in supply chain 1 and industry in supply chain 2).

$$w_n = \phi_n C_n - c_{n+1} \tag{1}$$

w_n : set of revenue sharing contract in supply chain n

ϕ_{n+1} : share of revenue in actor n+1

C_n : cost of good sold in supply chain n

c_{n+1} : cost of good sold in actor n+1

2.2 The Supply Chain Profit Function

The supply chain profit generated from total revenue in actor n + total revenue in actor n+1, or in other hand the supply chain profit is a deviation between revenue with cost and revenue sharing contract for q quantity [8]. Supply chain profit formula defined as

$$\prod\nolimits_{n(q,p)} = \pi_{n(p,q)} + \pi_{n+1(p,q)} = R_{n(q,p)} - (C_n - w_n)q_n \tag{2}$$

$\prod_n$: the supply chain profit in supply chain

π_n : the supply chain profit for actor n in supply chain n

π_{n+1} : the supply chain profit for actor n+1 in supply chain n+1

R_n : total revenue in supply chain n

C_n : cost of good sold in supply chain n

w_n : revenue sharing contract in supply chain n

q_n : quantity of good sold in supply chain n

p : price product

Revenue R_n generated from difference between expected wholesale price with expected total revenue sharing contract. The formula of revenue (R_n) is

$$R_n = (p - w)S_{(q,p)} \tag{3}$$

hence $S(q,p)$ is expected quantity of good sold, derived from stochastic or deterministic. We assume that the expected quantity of good sold equals with cost of good sold (q). While, π_n and π_{n+1} is a total profit in supply chain n for actor n and n+1. The profit function for each actor in supply chain n defined as

$$\pi_{n+1(q,p)} = \phi_n \prod\nolimits_{n(q,p)} \tag{4}$$

$$\pi_{n(q,p)} = (1 - \phi_n) \prod\nolimits_{n(q,p)} \tag{5}$$

2.3 Goal Programming

Goal programming is a method dealing with multiple objective decision making problems. In this paper we used a weight method approach [9] to find a satisfied goal. Weight method find a single objective function is formed as the weighted sum of the functions representing the goals of the problem. The goal programming formulation is

$$Minimasi = \sum_{i=1}^{n} P_i d_i^- - P_i d_i^+ \tag{6}$$

Subject to

Goal constraints:

$$\sum a x_n + d_n^- - d_n^+ = b \tag{7}$$

Resources constraint:

$$\sum a x_n \geq b \ \ atau \ \sum a x_n \leq b \tag{8}$$

where: $x_1, x_2, \ldots x_n \geq 0$

The goal constraint is to define a share of revenue and total product between farmers-collectors and collectors-industry. The constraint for the resources is raw materials, yield and time for shrimp processed. The goal formulated for find a target revenue sharing and target minimum product with these constraints in shrimps industry

3. RESULT AND DISCUSSION

3.1 Model of Revenue Sharing Contract in Aquaculture Shrimp Agroindustry

The model of revenue sharing contract in aquaculture shrimp agroindustry developed from an interaction between two actors. Interaction between farmers and collectors we called supply chain 1 and collectors and industry called supply chain 2. The formulation of revenue sharing contract based on formula 1 for each supply chain defined as

$$w_1 = \phi_1 C_1 - c_2 \tag{9}$$

$$w_2 = \phi_2 C_2 - c_3 \tag{10}$$

where

w_1 : revenue sharing contract in supply chain 1

w_2 : revenue sharing contract in supply chain 2

ϕ_1 : share of revenue in collectors

ϕ_2 : share of revenue in industry

C_1 : cost of good sold in supply chain 1

C_2 : cost of good sold in supply chain 2

c_2 : cost of good sold in collectors

c_3 : cost of good sold in industry

C = cost actor $_n$ + cost actor $_{n+1}$ in supply chain n and $\phi \in \{0,1\}$ or $0 \leq \phi \leq 1$. Share of revenue in farmers was 1- ϕ_1 (Share of revenue in collectors) and share of revenue in collectors in supply chain 2 was 1- ϕ_2 (Share of revenue in industry, ϕ_2).

3.2 The Supply Chain Profit Function

The supply chain profit function formulated for each actors (farmers, collectors and industry). The supply chain profit localized for 2 actor interaction. There are farmers-collectors (Supply Chain 1) and collectors-industry (Supply Chain 2). The profit function for each stakeholder generated from model 2. There are

$$\pi_{1(q,p)} = (1-\phi_1)\prod_{1(q,p)} \quad (11)$$

$$\pi_{2(q,p)} = \phi_1\prod_{1(q,p)} \quad (12)$$

$$\pi_{3(q,p)} = (1-\phi_2)\prod_{n(q,p)} \quad (13)$$

$$\pi_{4(q,p)} = \phi_2\prod_{n(q,p)} \quad (14)$$

$$\prod_{1(q,p)} = \pi_{1(p,q)} + \pi_{2(p,q)} = R_{1(q,p)} - (C_1 - w_1)q_1 \quad (15)$$

$$\prod_{2(q,p)} = \pi_{3(p,q)} + \pi_{4(p,q)} = R_{2(q,p)} - (C_2 - w_2)q_2 \quad (16)$$

where

$\prod_1$: the supply chain profit in supply chain 1

$\prod_2$: the supply chain profit in supply chain 2

π_1 : the supply chain profit for farmers in supply chain 1

π_2 : the supply chain profit for collectors n in supply chain 1

π_3 : the supply chain profit for farmers in supply chain 2

π_4 : the supply chain profit for industry in supply chain 2

R_1 : total revenue in supply chain 1

R_2 : total revenue in supply chain 2

C_1 : cost of good sold in supply chain 1

C_2 : cost of good sold in supply chain 2

w_1 : revenue sharing contract in supply chain 1

w_2 : revenue sharing contract in supply chain 2

q_1 : quantity of good sold in supply chain 1

q_2 : quantity of good sold in supply chain 2

$$w_1 = \phi_1 c_1 - c_{collectors} \quad (18)$$

$$w_2 = \phi_2 c_2 - c_{industry} \quad (19)$$

w_1 : set of revenue sharing contract in supply chain 1

w_2 : set of revenue sharing contract in supply chain 2

ϕ_1 : share of revenue in collectors

ϕ_2 : share of revenue in industry

c_1 : cost of good sold in supply chain 1

c_2 : cost of good sold in supply chain 2

$c_{collectors}$: cost of good sold in collectors

$c_{industry}$: cost of good sold in industry

3.3 Share of revenue trade-off used goal programming approached

The trade-off of revenue sharing need to find a satisfied revenue in whole supply chain. The trade-off generated from revenue sharing in supply chain 1 and supply chain 2 (Figure 1).

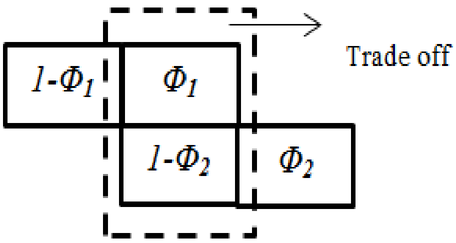

Figure 1: Trade-off share of revenue supply chain actors

We formulated a goal programming to find a satisfied goal for quantity of good sold and share of revenue. The resources a constraint in the supply chain is raw materials requirement for each actors and yield in processing. The goal constraint in the supply chain is total profit and share of revenue.

We will take the example of shrimp industry who are located in the Sidoarjo-East Java province. We defined are raw materials requirement for each actors in the supply chain. Farmers need 100,000 shrimp fries for each aquaculture pond per 0.5 year. The farmers have 331 pond and the shrimp fries weight is 10^{-6} kg per animals [11]. When it harvested the shrimp fries weight increased 16.9 x 10^{-3} kg per animals with success rate 0.56. So the farmers need 0.2 kg shrimp fries per day and harvest it for 2,087 kg. Hence, the factor conversion of the shrimp fries is comparison between a requirement shrimp fries per day with total harvest from it. So, the factor conversion of shrimp harvest per shrimp fries cultivated per day is 1,043,500 animals. The collectors need minimum raw material as much as 2,095 kg per day, and the industries need as much as 2,160 raw material per day. So the formulation is

$x_1 \geq 2{,}160$

$$x_1 + d_1^- - d_1^+ = 2{,}160 \tag{20}$$

$x_2 \geq 2{,}095$

$$x_2 + d_2^- - d_2^+ = 2{,}095 \tag{21}$$

$1{,}043{,}500x_3 \geq 2{,}095$

$$1{,}043{,}500x_3 + d_9^- - d_9^+ = 2{,}095 \tag{22}$$

for

$x_1 =$ total raw material requirement for industries (kg/day)

$x_2 =$ total raw material requirement for collectors (kg/day)

$x_3 =$ total shrimp fries requirement for farmers (kg/day)

The yield of shrimp processing in industry was 0.65 for minimum output product was 1,404. In the collectors, the shrimp weight increased because a amount of water adsorbed by shrimp. The conversion factor was 1.03. The collectors need 0.0034 hours for processing for each kg raw materials with target processing time maximum 7.2 hours. So the formulation for this constraint is

$0.65x_1 \geq 1{,}404$

$$0.65x_1 + d_3^- - d_3^+ = 1{,}404 \tag{23}$$

$1.03x_2 \geq 2{,}160$

$$1.03x_2 + d_4^- - d_4^+ = 2{,}160 \tag{24}$$

$0.0034x_2 \leq 7.2$

$$0.0034x_2 + d_{10}^- - d_{10}^+ = 7.2 \quad (25)$$

The goal constraint developed based on revenue sharing in supply chain 1 and supply chain 2. Based on exercise the model with verious revenue sharing value, we targeted the total profit for industry was Rp 55,620,000 (Rupiah, Indonesian Currency). We target profit for industry as much as 60.59%. we find that factor conversion for target these value is Rp 28,750. Target profit for collectors is 9.53 with total profit as much as 7,992,000. The factor conversion of the collectors is 3.775. So the formulation of goal profit is

$28{,}750x_1 \geq 55{,}620{,}000$

$$28{,}750x_1 + d_5^- - d_5^+ = 55{,}620{,}000 \quad (26)$$

$3{,}775x_2 \geq 7{,}992{,}000$

$$3{,}775x_2 + d_6^- - d_6^+ = 7{,}992{,}000 \quad (27)$$

The revenue sharing contract formulation for goal programming generated from (9) and (10). formulation find from total cost in supply chain 1 Rp 46,578 with minimum total sharing is Rp 13,973 and supply chain 2 Rp 49,852 with total sharing Rp 29,911. Hence

$46{,}578\emptyset_1 \geq 13{,}973$

$$46{,}578\phi_1 + d_{12}^- - d_{12}^+ = 13{,}.973 \quad (28)$$

$49{,}852\emptyset_2 \geq 29{,}911$

$$49{,}852\phi_2 + d_{13}^- - d_{13}^+ = 29{,}911 \quad (29)$$

And total profit for each supply chain for trade off generated from (15) and (16) for target total revenue in supply chain 1 is Rp 25,142,400 and the second supply chain is Rp 13,770,000 with expected revenue in supply chain 1 is Rp 83,808,000 and in supply chain 2 is Rp 91,800,000 and cost of each product in supply chain 1 is Rp 17,580 and supply chain 2 is Rp 39,726.96. Hence the formulation is

$25{,}142{,}400 \leq 83{,}808{,}000\emptyset_1 - 17{,}580{,}41x_2$

$$25{,}142{,}400 = 83{,}808{,}000\emptyset_1 - 17{,}580{,}41x_2 + d_{14}^- - d_{14}^+ \quad (30)$$

$13{,}770.000 \leq 91{,}800{,}000\emptyset_2 - 39{,}726.96x_1$

$$13{,}770{,}000 = 91{,}800{,}000\emptyset_2 - 39{,}726.96x_1 + d_{15}^- - d_{15}^+ \qquad (31)$$

So a satisfied goal target for each formulation (constraints) for each resources, target profit and revenue sharing in shrimp industry supply chain concluded with quantity of raw material. We used a linear program solver [10], in farmers is 0.2 kg/day or 200,000 shrimp fries for cultivation *(x_3)*, 2,117 kg/day in collectors *(x_2)* and 1,271 kg/day in industry *(x_1)*. The trade-off of supply chain 1 and 2 concluded that share of revenue in supply chain 1 was 0.74 (ϕ_1) and 0.70 (ϕ_2) in supply chain 2.

3.4 Shrimp fries need to ponds traditional plus, semi intensive and intensive

Based on observations of one of the shrimp industry, was obtained raw material requirements based on the number of requests per year amounted to 628,500 kg. To meet the demand, shrimp farmers supplied from Sidoarjo and from outside the area. Generally shrimp farmers in Sidoarjo commercialize traditional plus pond and only a fraction seek semi-intensive pond, while from outside the area dominated by semi-intensive and intensive pond. These farmers in producing shrimp based technology is divided into traditional plus, semi-intensive and intensive pond with a ratio of 6 : 3 : 1 in order to obtain the equation.

$$6x_4 + 3x_5 + x_6 \le 628{,}500 \qquad (33)$$

Formulation of goal programming to obtain the optimal goal (satisfied) for a margin of cultivation. Constraints in the supply chain goal is to target the expected profit of each technology and the selling price assuming the same quality. Constraints on resources is the number of requests, the price of shrimp fries, survival rate and yield. Target benefits expected to be obtained from the difference between the proceeds of demand by 628,500 kg multiplied by the selling price of Rp 70,000 per kg with a pond operating costs. Here is the equation for constraint purposes:

$$70{,}000x_4 + d_1^- - d_1^+ = 2{,}514{,}000{,}000 \qquad (34)$$

$$70{,}000x_5 + d_2^- - d_2^+ = 2{,}514{,}000{,}000 \qquad (35)$$

$$70{,}000x_6 + d_3^- - d_3^+ = 2{,}514{,}000{,}000 \qquad (36)$$

$$70{,}000x_4 + 70{,}000x_5 + 70{,}000x_3 + d_4^- - d_4^+ = 25{,}140{,}000{,}000 \qquad (37)$$

In the maintenance of the level of shrimp survival rate vary between the level of technology used. Survival rate for intensive pond is 90% of the number of shrimp fries stocked or 1.11 multiplied by the number of products with size crop size of 66.6 animals per kg obtained shrimp fries number 1,500,000 animals, in a similar way to traditional plus and semi-intensive pond obtained the number of shrimp fries stocked 600,000 animals and 150,000 animals with a survival rate of 80% and 74%, so the equation:

$$1.11x_6 \ge 1{,}500{,}000 \qquad (38)$$

$$1.25x_5 \geq 600{,}000 \quad (39)$$

$$1.34x_4 \geq 150{,}000 \quad (40)$$

Shrimp fries prices for traditional technologies plus is Rp 40 per animals, for a semi-intensive technology is Rp 35 per animals and for intensive technology is Rp 25 per animals. The big difference in the price of shrimp fries is more due to the number (quantity) of purchase. More and more shrimp fries are bought an average price per animals is lower when compared to the purchase of fewer. In order to obtain costs for shrimp fries as follows.

$$40 * 1.34x_4 \leq 6{,}000{,}000 \quad (41)$$

$$35 * 1.25x_5 \leq 21{,}000{,}000 \quad (42)$$

$$25 * 1.11x_6 \leq 37{,}500{,}000 \quad (43)$$

The selling price of shrimp harvest, assumed the same quality is Rp 70,000 per kg, in order to obtain a sales target of Rp 43,995 billion, so the equation.

$$70{,}000x_4 + 70{,}000x_5 + 70{,}000x_6 \geq 43{,}995{,}000{,}000 \quad (44)$$

Volume production of the pond is affected by the productivity of each pattern of cultivation used. Results of the analysis showed productivity in the field patterns of traditional plus productivity levels ranging from 350 to 400 kg/ha. The pattern of semi-intensive shrimp farming has a productivity level in the range of 2000 kg/ha, this range refers to research conducted [11] with the stocking of seedlings 25 head/m^2. Productivity intensive pattern refers to a study conducted by [12], with 50 animals shrimp fries stocking/m^2 capable of producing 5,000-6,000 kg/ha. Yields obtained for each pond with traditional technologies plus level, semi-intensive and intensive are as follows.

$$x_4 \leq 112{,}100 \quad (45)$$

$$x_5 \leq 480{,}100 \quad (46)$$

$$x_6 \leq 1{,}348{,}650 \quad (47)$$

where

x_4 = Number of juveniles required for traditional technologies plus (animals)
x_5 = Number of juveniles required for semi-intensive technology (animals)
x_6 = Number of juveniles needed to technology-intensive (animals)

Based on the results if the data using linear solver program [10], obtained the shrimp fries need for traditional plus pond 8,395,513 animals/year, for a semi-intensive pond 33,516,428 animals/year and for intensive pond

5,225,558 animals/year. Supplies of shrimp fries for aquaculture farmers (traditional plus, semi-intensive and intensive) is a response to meet the demand for shrimp from consumers of 628,500 kg/year.

4. Conclusion

The model of performance based contract supply chain risk management produce fair distribution of incomes (share of revenue) of 0.74 for the perpetrators of the collector and the supply chain 1 and 0.7 for industry players in the supply chain 2. Then, the model also resulted in agreement targets the supply (demand) for each offender supply chain that perpetrators farmers need shrimp fries batch of 200,000 animals/day for cultivation or 0.2 kg/day (x_3), the offender collector requires raw materials amounted to 2,117 kg/day (x_2) and the needs of industrial production (shrimp headless) of 1,271 kg/day (x_1). Also, the needs of shrimp fries obtained based on the number of requests per year from the pond with the level of traditional technologies plus (x_4), semi-intensive (x_5) and intensive (x_6) (ratio of 6: 3: 1), each for 8,395,513 animals, 33,516,428 animals and 5,225,558 animals per year.

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