



Study of Modernization of Distillation Units and Applications of Nonlinear ROI Equity Model: A Case of Gayo Lues Patchouli Value Chain

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Abstract – The inequity of benefits among actors in the Indonesian patchouli value chain has been taking place for decades. This phenomenon has made distillers unable to guarantee the patchouli oil quality, one of the essential things in the global market. The objective of this study was to evaluate effects of modernization of distillation units and applications of a nonlinear return on investment (ROI) equity model to the financial performance of actors in the value chain to help the government together with the actors making the correct decisions and policies in the development of patchouli oil business. The study was done in the Gayo Lues District, Aceh, Indonesia. The findings indicate that the distillers get the least benefits (the lowest ROI) among actors in the Gayo Lues value chain. Moreover, modernization of the distillation units can increase the ROIs of the actors in the value chain. But, to observe how to establish equity among the actors, a nonlinear ROI equity model was developed. To make ROIs of the actors equal, outputs of the model recommend that the ideal patchouli oil share ratio between farmers and distillers is around 3.3 – 3.4: 1. Outputs of the model also suggest that both net gross and profits per kg of medium middlemen should be increased, while both net and gross profits per kg of large middlemen should be decreased.

Keywords: distillation units, Gayo Lues, nonlinear ROI equity model, patchouli oil, value chain

Introduction

Indonesia is well-known as a significant contributor to the world's patchouli oil requirement, exporting more than 2,000 tons per year (Directorate General of Estate Crops, 2017). The global patchouli oil market, like most of the global essential oils market, demands many things, and one of the most important things is quality assurance (Alighiri *et al.*, 2016; Sanganerina, 2015). However, several studies reported that many Indonesian patchouli oil producers, most of whom are small “poor” farmers and distillers, cannot meet the demands (Alighiri *et al.*, 2016; Rahmayanti *et al.*, 2018).

Besides, although the producers are key players to ensure the oil quality, they have the lowest control over the oil prices. Those who have the dominant control over the oil prices, especially at the local level, are middlemen (Suyono and Purwastuti, 2011), even though they have almost no contribution to the added value of the oil (Rahmayanti *et al.*, 2018). Therefore, the producers get the least benefits (inequity) from patchouli business or among actors in patchouli value chains (Hendrastuti *et al.*, 2012; Rahmayanti *et al.*, 2018). The unfairness makes production activities (patchouli cultivation and distillation) less attractive than marketing activities for investors. As a result, the “rich” investors are only interested in marketing sectors, as middlemen or buyers. The inequity also limits the ability of the producers to improve the qualities of their productions to meet the global market demands. Many producers have not yet been able to apply Good Agricultural Practice (GAP) in cultivation and Good Manufacturing Practice (GMP) in the distillation process (Hogervorst & Kerver, 2019; Rusli 2012).

The inequity has continued for decades in the patchouli value chain. Therefore, the government, together with the value chain actors, must pay more attention to this phenomenon in the development of the patchouli oil business. This study aims to evaluate the effects of the modernization of distillation units and applications of the ROI equity model to the financial performance of the actors in the value chain, especially to the distillers. We hope that this study can help the government together with the actors making the right policies and decisions in the development of the patchouli oil business. The nonlinear ROI equity model was developed using nonlinear programming with the leading indicator is that the ROIs of the actors are optimal (maximum and equal) in a stable price system.

Materials and Methods

Study location and data collections

The study was carried out in Gayo Lues District, Aceh Province, Indonesia, in early 2018. Like coffee, Gayo Lues has a long historical tie with patchouli production. Gayo Lues is known as one of the primary producers of patchouli oil with excellent quality in terms of aroma and levels of patchouli alcohol (PA). However, they are not the only parameters that define the quality of the oil. Another critical parameter is the color variant of the oil. For numerous reasons, most distillers in Gayo Lues still operate traditional “asphalt drums” distillation units (non-GMP), producing a low yield and dark variant oil. The dark variant oil indicates that the oil is contaminated with iron from the drums.

The data collected includes the marketing direction of patchouli oil, financial data of each actor, and monthly quantities supplied and local prices of patchouli oil. The data collections were carried out using about ten focus group discussions (FGDs) with 2 – 8 participants of farmers and distillers and in-depth interviews with 2 (two) medium-scale local middlemen and 3 (three) large-scale local middlemen.

Optimization of Gayo Lues patchouli value chain

Pre-optimized conditions of the actors in the value chain

This section will focus on collecting data on the standard (initial) conditions of the actors in the value chain, including a conventional (primary) marketing channel, actors involved, and their financial/ performance data, followed by calculation and tabulation of the data.

Technology optimization

The technology or physical optimization means the modernization of distillation units. So, here we discuss the replacement of traditional distillers with modern distillers into the value chains, their differences, and their effects on all actors in the value chain.

Mathematical model optimization

The mathematical model optimization is done by using a nonlinear ROI equity model. The model optimization is aimed to simulate how to make the actors in the value chains can financially obtain the equity, where the primary indicator is ROIs of the actors are equal and maximum in a stable price system. The brief steps to develop the nonlinear ROI equity model and optimization in the Gayo Lues patchouli value chain are as follows:

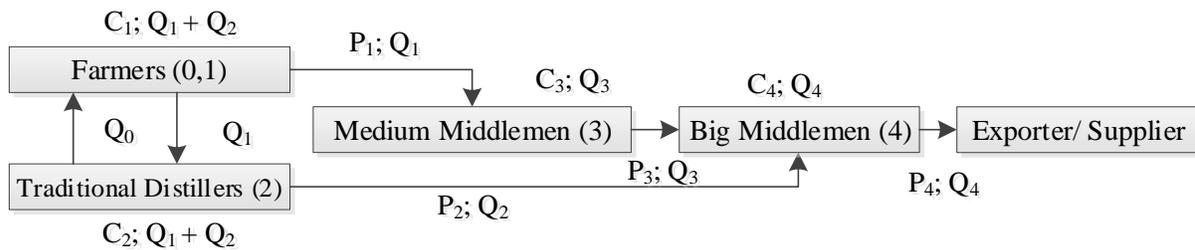
- a. Determine the decision variables
- b. Determine the objective function
- c. Determine the constraints
- d. Model execution, validation, and analysis

The model optimization is implemented to marketing channel I, where traditional distillers exist in the value chain; and to marketing channel II, where modern distillers replace the traditional distillers' position.

Results

Pre-optimized conditions of Gayo Lues patchouli value chain

The common (primary) marketing channel involving farmers, distillers, medium middlemen, and large middlemen in the Gayo Lues patchouli value chain is as presented in Figure 1, where Q is the quantity supplied (sales volume); C is the production/ marketing cost; P is the sales price of each actor. The majority of the distillers are still operating traditional distillers 35 kg “asphalt drum” distillation units. Small middlemen were not found operating in the Gayo Lues District - Aceh Province, although they were reported to operate in other districts in the province (Caritas Czech Republic, 2010). While patchouli farmers in many areas of Indonesia usually sell leaves to distillers (Directorate General of National Export Development, 2015; Nugraha *et al.*, 2019), patchouli farmers and distillers in Gayo Lues prefer to share the oil after distillation process based on agreed oil share ratio, usually at “farmer: distiller = 8.5%: 1.5%” share ratio, then sell the oil autonomously to middlemen.



Note: $P_1 < P_2 = P_3 < P_4$; $Q_1 = Q_3$; $Q_2 + Q_3 = Q_4$.

Figure. 1. Marketing channel I, the typical (initial) marketing channel of Gayo Lues patchouli oil

Table 1. The production/ sales frequencies, business capacities, annual incomes, and investment costs of the patchouli value chain actors participating in the initial marketing channel

Actors	Farmers	Traditional Distillers	Medium Middlemen	Large Middlemen
Productions/ sales frequencies	semiannually, 2 cropping seasons/ year	daily, 2 batches/ day, 24 working days/ month	weekly, 52 transaction frequencies/ year	monthly, 12 transaction frequencies/ year
Business capacities	0.7 ha/ farmer ¹⁾ , each farmer produces about 162 kg oil/ ha/ year ²⁾	35 kg dried leaves/ batch, each distiller produces about 1.4 kg oil/ day = 403.2 kg oil/ year	each middleman manages about 100 kg oil/ month = 1200 kg oil/ year	each middleman manages about 578.75 kg oil/ month = 6,945.00 kg oil/ year
Annual incomes (IDR)	76,572,171/ ha	34,841,299/ distiller	24,000,000/ middleman	555,600,000/ middleman
Total annual costs (IDR)	34,595,000/ ha	27,220,000/ distiller	18,204,854/ middleman	109,148,111/ middleman
Annual fixed costs (IDR)	3,520,000/ ha	700,000/ distiller	1,340,000/ middleman	16,590,000/ middleman
Annual variable costs (IDR)	31,075,000/ ha	26,520,000/ distiller	16,864,854/ middleman ³⁾	92,558,111/ middleman ⁴⁾

¹⁾The average plantation area of patchouli per farmer in Gayo Lues is about 0.7 ha (Ernawati *et al.*, 2018).

²⁾farmers hold about 137.70 kg oil/ ha at existing “8.5: 1.5” of share ratio between farmers and distillers

³⁾including IDR 1,283,261 total annual loan interest of the capital invested to purchase 100 kg oil/ month or 1,200 kg oil/ year (\approx IDR 1,069/ kg) and IDR 11,121,593 total annual loan interest of the capital invested to deliver credit to the farmers (\approx IDR 9,268/ kg) at 10% of discount factor

⁴⁾including IDR 33,340,611 total annual loan interest of the capital invested to purchase 578.75 kg oil/ month or 6,945 kg oil/ year (\approx IDR 4,801/ kg) at 10% of discount factor

Table 1 shows the production/ sales frequencies, business capacities, annual incomes, and investment costs of the value chain actors in the current marketing channel of Gayo Lues patchouli oil. Additionally, Table 2 presents pre-optimized financial data summary of the patchouli value chain actors in the marketing channel I, including average sales prices/ kg oil (P), total production/ marketing costs/ kg oil (TC), net profits (NP)/ kg oil, ROIs, existing patchouli oil share ratio between farmers and distillers, and average gross profits/ kg oil for both medium and large middlemen. Table 2 confirms that ROIs of the actors are unequal, where large middlemen have too high ROI, and distillers have too low ROI. The table also indicates that large middlemen have the highest ROI because they get too high gross profit margin (IDR 80,000 per kg), and distillers have the lowest ROI because they get too small oil share ratio (15%).

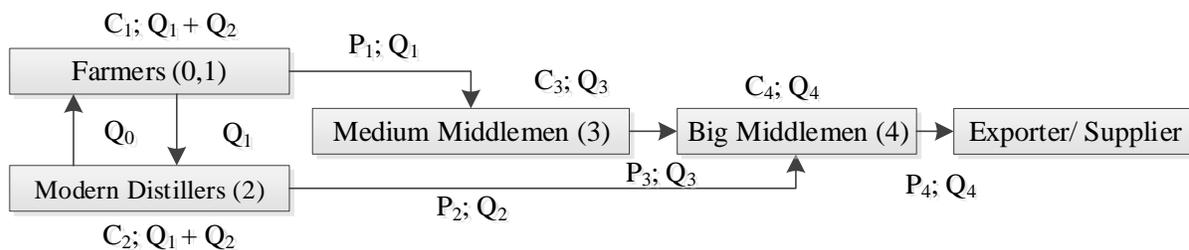
Table 2. Pre-optimized financial data summary of the patchouli value chain actors in marketing channel I

Actors	Farmers	Traditional distillers	Medium middlemen	Large middlemen
Sales price per kg (IDR/kg)	556,079.67	576,079.67	576,079.67	656,079.67
Total cost per kg oil produced (IDR/kg)	213,549.38	67,509.92	-	-
Total cost per kg oil owned/ purchased (IDR/kg)	251,234.57	450,066.14	15,170.71	15,716.07
Net profit per kg (IDR/kg)	304,845.11	126,013.54	4,829.29	64,283.93
ROI	121.3%	28.0%	31.8%	409.0%
Oil share ratio (farmers: distillers = 85%: 15%)	5.67	1	-	-
Gross profit per kg (IDR/ kg)	-	-	20,000.00	80,000.00

Optimization of Gayo Lues patchouli value chain

Technology optimization

The actors who play the most important role in improving the quality of post-harvest patchouli oil are the distillers. Thus, one of the simplest ways to improve the quality is to optimize the distillation unit technologically or modernize the distillation unit, so that the marketing channel will be as shown in Figure 2. The modernization is believed will significantly improve the patchouli oil quality because this type of distillation unit produces a higher PA level of light variant patchouli oil instead of a lower PA level of dark variant patchouli oil. Additionally, the physical optimization is likely to benefit the producers (farmers and distillers) because buyers (exporters/ suppliers) are willing to pay IDR 30,000 higher for the light variant patchouli oil than the dark one.



Note: $P_1 < P_2 = P_3 < P_4$; $Q_1 = Q_3$; $Q_2 + Q_3 = Q_4$.

Figure. 2. Marketing channel II, the marketing channel after technology optimization

We noted some essential differences between traditional and modern distillation units, as presented in Table 3. The data were collected from the only current distillation unit operating in Rebebe Village, Gayo Lues, which was built by JIKA OISCA under the USAID IFACS project in 2013. The unit also introduced a 4: 1 oil share ratio between farmers and distillers instead of the 8.5: 1.5 ratio. Furthermore, some data calculated after the technology optimization compared to those presented in Tables 1 and 2 (pre-optimization) are as shown in Tables 4 and 5. The most important result of technology optimization is that all ROIs of the actors increase due to the changes in sales prices, costs, and net profits.

Table 3. The differences between traditional and modern distillation units

Parameters	Traditional distillation	Modern distillation ¹⁾
Operating capacities	35 kg dried leaves/ batch	200 kg dried leaves/ batch
Total batches/ day	2 batches/ day	2 – 3 (2.5) batches/ day
Regular working hours ²⁾	4 – 6 hours/ batch	3 – 4 hours/ batch
Biomass consumption per oil produced (IDR/ kg)	67,509.92	60,460.86
% of patchouli oil yield	2%	2.2%
PA level	±30	±35
Iron content	Iron-contaminated	Iron-free

¹⁾Even though this is a hydro-electric distillation unit, it also uses biomass as an alternative energy source, so we use biomass for a fair comparison.

²⁾Optimal working hours are 8 - 12 hours/ batch for traditional distillation and 6-8 hours/ batch for modern distillation.

Table 4. The production/ sales frequencies, business capacities, annual incomes, and investment costs of the patchouli value chain actors participating in the marketing channel post-technology optimization

Actors	Farmers	Modern distillers	Medium middlemen	Large middlemen
Productions/ sales frequencies	semiannually, 2 cropping seasons/ year	daily, 2 batches/ day, 24 working days/ month	weekly, 52 transaction frequencies/ year	monthly, 12 transaction frequencies/ year
Business capacities	0.7 ha/ farmer ¹⁾ , each farmer produces about 178,2 kg oil/ ha/ year ²⁾	200 kg dried leaves/ batch, each distiller produces about 11.0 kg oil/ day = 3168.0 kg oil/ year	each middleman manages about 100 kg oil/ month = 1200 kg oil/ year	each middleman manages about 578.75 kg oil/ month = 6,945.00 kg oil/ year
Annual incomes (IDR)	82,838,718 / ha	384,012,081/ distiller	30,000,000/ middleman	694,500,000/ middleman
Total annual costs (IDR)	34,595,000/ ha	198,440,000/ distiller	18,762,547/ middleman	110,884,361/ middleman
Annual fixed costs (IDR)	3,520,000/ ha	61,640,000/ distiller	1,340,000/ middleman	16,590,000/ middleman
Annual variable costs (IDR)	31,075,000/ ha	136,800,000/ distiller	17,422,547/ middleman ³⁾	94,294,361/ middleman ⁴⁾

¹⁾ The average plantation area of patchouli per farmer in Gayo Lues is about 0.7 ha (Ernawati *et al.*, 2018).

²⁾farmers hold about 142.56 kg oil/ ha at existing “4: 1” of share ratio between farmers and distillers

³⁾including IDR 1,340,953 total annual loan interest of the capital invested to purchase 100 kg oil/ month or 1,200 kg oil/ year (≈ IDR 1,117/ kg) and IDR 11,621,593 total annual loan interest of the capital invested to deliver credit to the farmers (≈ IDR 9,685/ kg) at 10% of discount factor

⁴⁾including IDR 35,076,861 total annual loan interest of the capital invested to purchase 578.75 kg oil/ month or 6,945 kg oil/ year (≈ IDR 5,051/ kg) at 10% of discount factor

Model optimization

The model optimization was done using a nonlinear ROI equity model. This model aims to optimize the summary of financial data of the patchouli value chain actors, before (marketing channel I) and after the technology optimization (marketing channel II). The optimization will focus on how to make the ROIs are equal and maximum in a stable price system. The detail steps to develop the model are as follows:

The decision variables

The decision variables of the model are sales prices of farmers (P_1); distillers (P_2); and middlemen ($P_{3,4, \dots, m}$).

The objective function

It is assumed that each actor eagers to obtain an ideal (maximum) ROI, which is symbolized as M (Big M). Furthermore, the Δ ROI variable was set, which is the difference between the Big M and the ROI of each

actor. Thus, to obtain a maximum value of ROI for each actor, the objective function is to minimize the total value of ΔROI : $\text{Min. } \sum_{j=1}^m \Delta ROI_j = \sum_{j=1}^m M - ROI_j$ (1)

Where M is ideal (maximum) ROI for each actor; ROI_j is ROI of actor-j.

Table 5. Financial data summary of the patchouli value chain actors in marketing channel II after the technology optimization

<i>Actors</i>	<i>Farmers</i>	<i>Modern distillers</i>	<i>Medium middlemen</i>	<i>Large middlemen</i>
<i>Sales price per kg (IDR/ kg)</i>	581,079.67	606,079.67	606,079.67	706,079.67
<i>Total cost per kg oil produced (IDR/ kg)</i>	194,135.80	60,460.86	-	-
<i>Total cost per kg oil owned/ purchased (IDR/ kg)</i>	242,669.75	302,304.29	15,635.46	15,966.07
<i>Net profit per kg (IDR/ kg)</i>	338,409.92	303,775.38	9,364.54	84,033.93
<i>ROI</i>	139.5%	100.5%	59.9%	526.3%
<i>Oil share ratio (farmers: distillers = 80%: 20%)</i>	4	1	-	-
<i>Gross profit per kg (IDR/ kg)</i>	-	-	25,000.00	100,000.00

The constraints

Various constraints of the model are as follows:

1. Profitability constraint. For each actor of the value chain, total revenue is larger than total cost: $TR_j > TC_j$ (2)

Where TR_j is the total revenue of actor-j; TC_j is the total cost of actor-j

2. Price stability constraint. This constraint is vital because the tendency of local patchouli oil prices set by large middlemen is usually very volatile (Directorate General of National Export Development, 2015; Rahmayanti *et al.*, 2019). The prices significantly affect patchouli oil supplies because the farmers' production highly depends on last seen (monthly) local prices of the patchouli oil. Thus, to maintain the stability of the oil supply, the monthly sales price of each actor ($P_{bm-1} = P_t$) who sells the oil directly to large middlemen (P_{bm}) must be $P_{t \text{ lower stability}} < P_{bm-1} < P_{t \text{ upper stability}}$... (3)

Where $P_{t \text{ lower stability}}$ is the lowest constraint of the sales price of patchouli oil; P_{bm-1} is the local sales price of oils sold to large middlemen (P_{bm}); $P_{t \text{ upper stability}}$ is the highest constraint of the sales price of patchouli oil.

In this case, we first determined that the local price of (dark) patchouli oil (P_{bm-1}) must be higher than the minimum price expected by the producers ($P_{t \text{ lower stability}}$), which is IDR 500,000. This value was obtained through in-depth interviews with representatives of farmers and distillers.

Furthermore, the quantities supplied by many agricultural commodities, including patchouli oil, are mainly influenced by prices in previous periods (Dufresne and Vázquez-Abad, 2013). If P_{bm-1} is set to be higher than $P_{t \text{ lower stability}}$, the quantity supplied may increase in the next period, which may trigger the decrease in the price. The decrease in the price may lead to the quantity supplied falls in the next period because the producers decrease their productions. The drop in quantity supplied will cause price rises, and so on. This cycle will repeat itself following the Cobweb Model Theorem proposed by Ezekiel (1938) that “the market must dynamically go towards the point each time quantity and price move away from the stable equilibrium point.” Although high prices must technically be good news for the producers, high fluctuation of the price is very risky, as the producers and middlemen can lose their investments if price falls (Asibey *et al.*, 2019; Huka *et al.*, 2014). Thus, to control the quantity supplied fluctuation as well as to reduce the price fluctuation, the value of $P_{t \text{ upper stability}}$ should be precisely determined. Because in one year, there is one planting period for two harvest periods, so to maintain actual quantity supplied/ demanded at the equilibrium point (market clearing), the monthly sales price of patchouli oil in this year ($P_{bm-1} = P_t$) must be the same as average monthly sales price of patchouli oil in last year (P_{t-1}). However, it is well known that agricultural commodity prices are never constant for years because the productions are heavily affected by various uncontrollable factors, i.e., natural conditions (Boussard, 2005), and our target is to decrease the fluctuation instead. Thus, to avoid bigger fluctuation, we set the average monthly local price of patchouli oil this year to be lower than the average price of patchouli oil last year, so that

$$P_{bm-1} = P_t < P_{t-1} = P_{t \text{ upper stability}} = \frac{\sum_i P_{t-1i} \cdot Q_{t-1i}}{Q_{t-1i}} \dots\dots\dots (4)$$

Where P_{t-1} is last year's monthly sales prices, Q_{t-1} is the previous year's monthly quantity supplied.

Table 6 shows the monthly local price and quantity supplied of dark patchouli oil managed by three large middlemen using samples in the study area from January 2016 to December 2017, before the patchouli oil production fell drastically at the beginning of 2018. Based on the data, we analyze the main reason for the drop of patchouli oil production is that despite the monthly prices in 2016 fluctuate and tend to decrease. However, they were still larger than IDR 500.000/kg, and the total amount of local quantity supplied is about 20,835 kg, with the average monthly local price of IDR 576,079.67. In 2017, the monthly prices were expected to increase (rebound). However, due to the increase of quantity supplied of the oil to a total amount of 22,545 kg, the monthly prices continued to fall, below IDR 500.000/kg, which made the drop of the quantity supplied drastically in 2018. Therefore, we consider that the data of the monthly sales prices of patchouli oil used to calculate the $P_{t \text{ upper stability}}$ constraint is only the data in 2016 when the monthly prices set were still larger than IDR 500.000/kg.

Table 6. Monthly local prices and quantities supplied of (dark) patchouli oil managed by three large middlemen (samples)

2016			2017		
Month	Quantity supplied (kg)	Price (,000 IDR/kg)	Month	Quantity supplied (kg)	Price (,000 IDR/kg)
1	1,490	630	1	1,788	500
2	1,611	630	2	1,796	500
3	1,727	630	3	1,826	480
4	1,890	580	4	1,889	450
5	1,613	620	5	1,895	450
6	1,727	580	6	1,913	400
7	1,873	570	7	1,910	400
8	1,823	570	8	1,906	400
9	1,825	550	9	1,890	400
10	1,811	550	10	1,971	380
11	1,743	500	11	1,923	380
12	1,702	520	12	1,838	400

3. Quantity supplied constraint. Based on the marketing direction, if there are some actors selling patchouli oil to actor n , the restriction can be formulated as: $\sum_{j=1}^{n-1} Q_j = Q_n$ (5)

Where Q_i is the quantity of oil supplied by actor/s j ; Q_n is the quantity of oil purchased by actor n .

4. Equivalent ROI constraint. The equality among patchouli value chain actors can be formulated as follows: $ROI_1 = ROI_2 = \dots = ROI_i$ (6)

Based on the market direction in Figures 1, 2, 3, and 4, the equations of ROIs for all actors can be described as follows:

a. Farmers.

Total revenue (TR) of farmers from the sales of Q_1 oil is $TR_1 = P_1 \cdot Q_1$ (7)

The total cost (TC) of farmers to produce $Q_1 + Q_2$ oil is $TC_1 = C_1 \cdot (Q_1 + Q_2)$ (8)

Thus, the ROI of farmers is $ROI_1 = \frac{P_1 \cdot Q_1 - C_1 \cdot (Q_1 + Q_2)}{C_1 \cdot (Q_1 + Q_2)} = \frac{P_1 \cdot Q_1}{C_1 \cdot (Q_1 + Q_2)} - 1$ (9)

b. Distillers

TR of distillers from the sales of Q_2 oil is $TR_2 = P_2 \cdot Q_2$ (10)

TC of distillers to produce $Q_1 + Q_2$ oil is $TC_2 = C_2 \cdot (Q_1 + Q_2)$ (11)

Thus, the ROI of distillers is $ROI_2 = \frac{P_2 \cdot Q_2 - C_2 \cdot (Q_1 + Q_2)}{C_2 \cdot (Q_1 + Q_2)} = \frac{P_2 \cdot Q_2}{C_2 \cdot (Q_1 + Q_2)} - 1$ (12)

c. Medium middlemen

TR of the middlemen from the sales of $Q_3 = Q_1$ oil is $TR_3 = P_3 \cdot Q_3 - P_1 \cdot Q_1 = (P_3 - P_1) \cdot Q_3$ (13)

TC of the middlemen to purchase $Q_1 = Q_3$ oil is $TC_3 = C_3 \cdot Q_3 = (C_{3a} + C_{3b} + C_{3c}) \cdot Q_3 = C_{3a} \cdot Q_3 + P_1 \cdot Q_1 \cdot \frac{i_3}{n_3} + C_{31L} \cdot Q_1 \cdot \frac{i_3}{n_{31L}} = (C_{3a} + P_1 \cdot \frac{i_3}{n_3} + C_{31L} \cdot \frac{i_3}{n_{31L}}) \cdot Q_3 \dots\dots\dots (14)$

Where C_{3a} is marketing cost/ kg without loan interest cost of the capital invested in purchasing oil from farmers and in delivering loans to farmers; $C_{3b} = P_1 \cdot \frac{i_3}{n_3}$ Is loan interest cost of the capital invested in purchasing per kg oil from farmers in n_3 frequencies of transactions/ year; $C_{3c} = C_{31L} \cdot \frac{i_3}{n_{31L}}$ Is loan interest cost of the capital invested in delivering loans to farmers producing a kg oil/ year. Amount of the loan given (C_{31L}) is assumed about 1/3 sales price/ kg oil of farmers (P_1); thus the value will change dynamically following the equation $C_{31L} = \frac{i_3}{3} \cdot P_1$; i_3 is a discount factor, and n_{31L} is the number of total frequencies of loans delivered annually, which is based on whole numbers of planting period/ year. It is important to note that in this study, the interest costs of the invested money are considered as parts of investment costs, but not the amount of the invested capital.

Thus, the ROI of medium middlemen is $ROI_3 = \frac{(P_3 - P_1) \cdot Q_3 - (C_{3a} + P_1 \cdot \frac{i_3}{n_3} + C_{31L} \cdot \frac{i_3}{n_{31L}}) \cdot Q_3}{(C_{3a} + P_1 \cdot \frac{i_3}{n_3} + C_{31L} \cdot \frac{i_3}{n_{31L}}) \cdot Q_3} = \frac{P_3 - P_1}{C_{3a} + P_1 \cdot \frac{i_3}{n_3} + \frac{P_1}{3} \cdot \frac{i_3}{n_{31L}}} - 1 \dots\dots\dots (15)$

d. Large Middlemen

TR of the middlemen from the sale of $Q_4 = Q_2 + Q_3$ oil is $TR_4 = P_4 \cdot Q_4 - P_2 \cdot Q_2 - P_3 \cdot Q_3$. Since $P_2 = P_3$, then $TR_4 = (P_4 - P_3) \cdot Q_4 \dots\dots\dots (16)$

TC of the middlemen to purchase $Q_2 + Q_3 = Q_4$ oil is $TC_4 = C_4 \cdot Q_4 = C_{4a} \cdot Q_{4a} + (P_2 \cdot Q_2 + P_3 \cdot Q_3) \cdot \frac{i_4}{n_4} = (C_{4a} + P_2 \cdot \frac{i_4}{n_4}) \cdot Q_4 \dots\dots\dots (17)$

Where C_{4a} is marketing cost/ kg without loan interest cost of the capital invested in purchasing the oil; and $P_2 \cdot \frac{i_4}{n_4}$ Is annual loan interest cost of capital invested in purchasing a kg of oil from distillers and medium middlemen in n_4 transaction frequencies/ year; i_4 is a discount factor.

Thus, the ROI of large middlemen is $ROI_4 = \frac{(P_4 - P_3) \cdot Q_4 - (C_{4a} + P_2 \cdot \frac{i_4}{n_4}) \cdot Q_4}{(C_{4a} + P_2 \cdot \frac{i_4}{n_4}) \cdot Q_4} = \frac{P_4 - P_3}{C_{4a} + P_2 \cdot \frac{i_4}{n_4}} - 1 \dots\dots\dots (18)$

ROIs of farmers and distillers, as shown in equations 9 and 12, depending on the oil share ratio between them. The ideal patchouli oil share ratio (η) can be obtained from an optimum state, when $ROI_1 = ROI_2 \Leftrightarrow \frac{P_1 \cdot Q_1}{C_1 \cdot (Q_1 + Q_2)} - 1 = \frac{P_2 \cdot Q_2}{C_2 \cdot (Q_1 + Q_2)} - 1 \Leftrightarrow \frac{P_1 \cdot Q_1}{C_1} = \frac{P_2 \cdot Q_2}{C_2} \Leftrightarrow \eta = \frac{Q_1}{Q_2} = \frac{C_1 \cdot P_2}{C_2 \cdot P_1} \dots\dots\dots (19)$

From equation 22, the oil share for farmers can also be written as $\frac{Q_1}{Q_1 + Q_2} = \frac{C_1 \cdot P_2}{C_1 \cdot P_2 + C_2 \cdot P_1} \dots\dots\dots (20)$

And the oil share for distillers is $\frac{Q_2}{Q_1 + Q_2} = \frac{C_2 \cdot P_1}{C_1 \cdot P_2 + C_2 \cdot P_1} \dots\dots\dots (21)$

At an optimum state ($ROI_1 = ROI_2$), by substituting equations 20 and 21 into equations 9 and 12, then the equations 9 and 12 can also be written as $ROI_1 = ROI_2 \Leftrightarrow \frac{2 \cdot P_1 \cdot P_2}{C_1 \cdot P_2 + C_2 \cdot P_1} - 1 \dots\dots\dots (22)$

e. General price constraints.

- $P_1 < P_2 = P_3 < P_4 \dots\dots\dots (23)$

- $P_1, P_2, P_3, P_4 > 0 \dots\dots\dots (24)$

The model for each marketing channel requires the following input data: $C_1, C_2, C_{3a}, n_3, n_{31L}, C_{4a}, i_3, i_4, n_4, P_t$ lower stability, and P_t upper stability. Where C_1 is production cost/ kg oil of farmers; C_2 is production cost/ kg oil of distillers; C_{3a} is marketing cost/ kg oil of medium middlemen without loan interest costs of invested capital to purchase oil and to deliver loans to farmers; i_3 is a discount factor of medium middlemen; n_3 is total frequencies of transactions between medium middlemen and large middlemen per year; n_{31L} is total frequencies of loan

delivered by medium middlemen to farmers annually, based on numbers of planting periods/ year; C_{4a} is marketing cost/ kg oil of large middlemen without loan interest cost of invested capital to purchase the oil; i_4 is a discount factor of large middlemen; n_4 is total frequencies of transactions between large middlemen and buyers per year; $P_{t \text{ lower stability}}$ is lower price stability constraint, and $P_{t \text{ upper stability}}$ is upper price stability constraint. The executed model will produce optimum values of Z and sales prices of farmers (P_1), distillers (P_2), medium middlemen (P_3), and large middlemen (P_4). Then, the ideal oil share ratio between farmers and distillers can be calculated using equations 19, 20, and 21.

Model execution and validation

Based on the data presented in Tables 1, 2, 4, and 5, we secured input data of the model to optimize the marketing channel I and II, as shown in Table 7. It is important to note that for marketing channel I, the $P_{t \text{ lower stability}}$ (IDR 500,000.00) was based on the minimum price of dark variant patchouli oil expected by the producers. In contrast, the $P_{t \text{ upper stability}}$ was based on the average monthly local price of dark variant patchouli oil in 2016 (IDR 576,079.67). Since the sales price of light variant oil is about IDR 30,000/ kg more expensive than the sales price of dark variant oil, then for marketing channel II, the $P_{t \text{ lower stability}}$ must be about IDR 530,000.00, and the $P_{t \text{ upper stability}}$ must be about IDR 606,079.67.

Table 7. Input data of the model

Parameters	Marketing Channel I	Marketing Channel II
C_1	IDR 213.549,38/ kg	IDR 194,135.80/ kg
C_2	IDR 67.509,92/ kg	IDR 60,460.86/ kg
C_{3a}	IDR 4.833,33/ kg	IDR 4.833,33/ kg
i_3	10%	10%
n_3	52 (weekly transactions of sales)	52 (weekly transactions of sales)
n_{3IL}	$n_{3IL} = 2$ (planting periods/ year)	$n_{3IL} = 2$ (planting periods/ year)
C_{4a}	IDR 10.915,41/ kg	IDR 10.915,41/ kg
i_4	10%	10%
n_4	12 (monthly transactions of sales)	12 (monthly transactions of sales)
$P_{t \text{ lower stability}}$	IDR 500,000.00	IDR 530,000.00
$P_{t \text{ upper stability}}$	IDR 576,079.67	IDR 606,079.67

Thus, the final models for both marketing channels as follows:

- Marketing channel I: objective function, $\text{Min } Z = f(P) = M + 4 - \left(\frac{2.P_1.P_2}{213549.38.P_2 + 67509.92.P_1} + \frac{P_3 - P_1}{4333.33 + 0.0186.P_1} + \frac{P_4 - P_3}{10915.41 + 0.00833.P_2} \right)$; subject to: (1) *linear inequalities*: $1.0186.P_1 - P_3 \leq -4833.34$ and $1.00833.P_3 - P_4 \leq -10915.42$; (2) *linear equalities*: $P_2 - P_3 = 0$; (3) *lower bounds*: $P_1 = 246883.56$, $P_2 = 500,000.00$, $P_3 = 500,000.00$, and $P_4 = 515082.07$; and *upper bounds*: $P_1 = 560820.83$, $P_2 = 576,079.674$, $P_3 = 576,079.674$, and $P_4 = \text{Inf}$; (4) *nonlinear constraints*: $-P_1.P_2 + 67509.92.P_1 + 213549.38.P_2 + 0.01 \leq 0$; $0.0186.P_1^2.P_2 + 67509.92.P_1^2 + 218382.72.P_1.P_2 - 67509.92.P_1.P_3 - 213549.38.P_2.P_3 = 0$; and $0.00833.P_1.P_2^2 + 10915.41.P_1.P_2 + 67509.92.P_1.P_3 - 67509.92.P_1.P_4 + 213549.38.P_2.P_3 - 213549.38.P_2.P_4 = 0$; (5) *start point*: [246883.57; 500000.01; 500000.01; 515082.08].
- Marketing channel II: objective function, $\text{Min } Z = f(P) = M + 4 - \left(\frac{2.P_1.P_2}{194135.80.P_2 + 60460.86.P_1} + \frac{P_3 - P_1}{4333.33 + 0.0186.P_1} + \frac{P_4 - P_3}{10915.41 + 0.00833.P_2} \right)$; subject to: (1) *linear inequalities*: $1.0186.P_1 - P_3 \leq -4833.34$ and $1.00833.P_3 - P_4 \leq -10915.42$; (2) *linear equalities*: $P_2 - P_3 = 0$; (3) *lower bounds*: $P_1 = 219133.96$, $P_2 = 530,000.00$, $P_3 = 530,000.00$, and $P_4 = 545332.07$; and *upper bounds*: $P_1 = 590273.31$, $P_2 = 606079.67$, $P_3 = 606079.67$, and $P_4 = \text{Inf}$; (4) *nonlinear constraints*: $-P_1.P_2 + 60460.86.P_1 + 194135.80.P_2 + 0.01 \leq 0$; $0.0186.P_1^2.P_2 + 60460.86.P_1^2 + 198969.14.P_1.P_2 - 60460.86.P_1.P_3 - 194135.80.P_2.P_3 = 0$; and $0.00833.P_1.P_2^2 + 10915.41.P_1.P_2 + 60460.86.P_1.P_3 - 60460.86.P_1.P_4 + 194135.80.P_2.P_3 - 194135.80.P_2.P_4 = 0$; (5) *start point*: [219133.98; 530000.01; 530000.01; 545332.08].

The models were solved by using the FMINCON function in MATLAB software package together with the Microsoft Excel software package. Outputs of the models are as shown in Tables 8 and 9. Furthermore, to validate the models, the essential thing to observe is that the ROIs of the optimized model must be the same, as shown in Tables 8 and 9. Moreover, the (local) sales prices of both distillers and medium middlemen should be as close as possible to the value of $P_{t \text{ upper stability}}$ to maximize the (equal) ROIs.

Table 8. Financial data summary of the value chain actors in marketing channel I after the model optimization

Actors	Farmers	Traditional Distillers	Medium middlemen	Large middlemen
Sales price per kg (IDR/kg)	546,548.67	576,079.66	576,079.66	607,018.40
Total cost per kg oil produced (IDR/kg)	213,549.38	67,509.92	-	-
Total cost per kg oil owned/ purchased (IDR/kg)	277,598.61	292,597.76	14,993.53	15,716.07
Net profit per kg (IDR/kg)	268,950.06	283,481.91	14,537.46	15,222.66
ROI	96.9%	96.9%	96.9%	96.9%
Oil share ratio (farmers: distillers)	3.334	1	-	-
Gross profit per kg (IDR/ kg)	-	-	29,530.99	30,938.73

The data in Table 8, compared to those in Table 2, indicate that after the model optimization of marketing channel I, ROIs of the actors have been the same. ROI of the distillers is increased due to the increase in their oil share ratio to the farmers. ROI of the medium middlemen is also increased due to the rise in both net and gross profits per kg oil. Furthermore, if we compare the data presented in Table 9 to those in Table 5, the outputs of the model recommend that to make the ROIs are equal, oil share ratio for distillers should be increased. In contrast, the oil share ratio for farmers should be decreased. Additionally, the outputs also recommend that both net gross and profits per kg of medium middlemen should be increased, while both net and gross profits per kg of large middlemen should be decreased.

Table 9. Financial data summary of the value chain actors in marketing channel II after the model optimization

Actors	Farmers	Modern Distillers	Medium middlemen	Large middlemen
Sales price per kg (IDR/kg)	570,942.28	606,079.65	606,079.65	642,379.39
Total cost per kg oil produced (IDR/kg)	194,135.80	60,460.86	-	-
Total cost per kg oil owned/ purchased (IDR/kg)	251,091.45	266,544.32	15,447.00	15,966.07
Net profit per kg (IDR/kg)	319,850.83	339,535.34	19,690.37	20,333.66
ROI	127.4%	127.4%	127.4%	127.4%
Oil share ratio (farmers: distillers)	3.409	1	-	-
Gross profit per kg (IDR/ kg)	-	-	35,137.38	36,299.73

Discussion

Modernization of distillation units in Gayo Lues

Quality of the Gayo Lues patchouli oil has not been improved so much compared to what we observed in 2010 – 2012, before first modern distillation units funded by Aceh Economic Development Financing Facility (Aceh – EDFFF) project started operating in 2012 (World Bank, 2012). The operations of the modern distillation units temporarily improved the quality of Gayo Lues patchouli oil, producing iron-free oil (light variant oil), one of the vital quality indicators. However, all the distillation units with capacities of 100 – 300 kg dried leaves have stopped operating now. We assume that the lowest ROI and small patchouli oil share ratio earned by distillers (farmers: distillers = 85%: 15%), have contributed to the situation. Most distillers are now re-operating small traditional distillation units with capacities of 35 kg, which are much cheaper, and modernization is not always

more reasonable in the situation (Hogervorst & Kerver, 2019). In fact, many distillers are also farmers, since only being a distiller is the most unfavorable role in the value chain.

The modern distillation unit with a 200 kg dried leaves/ batch operating capacity located in Rebebe Village - Gayo Lues is the only current unit that has been serving since 2013. However, its capacity is too small compared to the total capacity of traditional distillation units in Gayo Lues. The findings of the study are the modernization of the distillation unit and the application of “farmers: distillers = 80%: 20%” oil share ratio have made the distillers receive a better ROI in the value chains. However, at these stages, the equity among the actors is not yet fully guaranteed.

Equity in Gayo Lues value chain

As aforementioned, modernization of the distillation unit can increase the ROI of the actors in the patchouli value chain, but it does not guarantee equity among the actors. Therefore, this study also developed a nonlinear ROI equity model to ensure that the distillers, as well as the other actors, receive an equity, including fair sales prices of patchouli oil, reasonable (net/ gross) profit margins, and ideal oil share ratio between the producers (farmers and distillers), and the most important thing is equal and ideal ROIs.

Margin and profit margin are the popular financial indicators usually used to measure equity among actors in value chains (Muchfirocin *et al.*, 2015; Odongo & Etany, 2018). Nevertheless, these indicators are arguably more applicable to similar business models. In fact, the actors in the patchouli value chain have different business models, where farmers and distillers are more as producers, and middlemen are more like distributors. Therefore, an alternative indicator to measure equity in the patchouli value chain is preferable, which can guarantee that the result is fair and impartial, to reflect better attraction of each business. We chose ROI or net-profit-to-cost ratio, which is one of the financial indicators widely used as a quantitative decision support tool (Zamfir *et al.*, 2016; Matthews, 2011). The main advantage of ROI, besides its simplicity and versatility, is that the ROI can compare businesses with different business models. There is also a limitation of the ROI, especially when we compare businesses/ projects with different time frames. However, we could eliminate the weakness in the model by comparing the businesses with the same (adjusted) time frame of ROI.

The transformations of equity of ROI values in the Gayo Lues value chain, before and post-modernization, and after the model optimizations are as shown in Table 10. Distillers and medium middlemen gain the most advantages from the complete transformations. However, since there is no added-value activity carried out by both middlemen, the most important findings that may significantly affect the improvement of Gayo Lues patchouli oil quality from outputs of the model are the modernization of the distillation units and application of ideal patchouli oil share ratio between farmers and distillers to be around 3.3 – 3.4: 1. Mathematically, the considerably better oil share ratio can help the distillers increasing their ROI value, as shown by the outputs of the model, as presented in Table 10, as well as help them enhancing the oil quality.

Table 10. Transformations of the equity of ROIs in the Gayo Lues value chain

Actors	Initial ROI	Post-modernization ROI	Initial ROI + Equity Model	Post-modernization+ Equity Model ROI
Farmers	121.3%	139.5%	96.9%	127.4%
Distillers	28.0%	100.5%	96.9%	127.4%
Medium middlemen	31.8%	59.9%	96.9%	127.4%
Large middlemen	409.0%	526.3%	96.9%	127.4%

Conclusion

Modernization of the distillation unit in Gayo Lues has positive effects on financial performance indicators of all actors in the Gayo Lues value chain. However, equity among actors is not established. The application of “farmers: distillers = 80%: 20%” oil share ratio has further contributions to the distillers to receive a better ROI in the value chains.

The applications of an ROI equity model can guarantee ROIs all of the actors are equal and maximal in a stable price system. Distillers and medium middlemen gain the most advantages from the complete transformations, which are much higher ROIs than those in pre-optimized conditions. The research finding

suggests that the ideal patchouli oil share ratio between farmers and distillers is around 3.3 – 3.4: 1. Additionally, the outputs of the ROI equity model also recommend that both net gross and profits per kg of medium middlemen should be increased. In contrast, both net and gross profits per kg of large middlemen should be decreased.

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