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Measurement of Performance Efficiency of Kadatuan Koffie Suppliers Using Data Envelopment Analysis (DEA)

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Abstract

Higher market expectation towards coffee products both of its quantity and quality is one of several challenges currently faced by the coffee industry. Maintaining the coffee supply chain through a periodical evaluation of supply chain performance, therefore, is crucial. The research provided measurement of performance efficiency of Kadatuan Koffie company's suppliers using Data Envelopment Analysis (DEA). This measurement is required to know the supplier's level of performance efficiency as a consideration in conducting the company's raw material management. Management of supplier's activity is essential to maintain the flow of supply chain running smoothly. The data obtained in this research were interview results with farmers or suppliers of raw material or coffee beans for Kadatuan Koffie and the company's management. The data were processed using DEA by comparing output and input value. According to the measurement of performance efficiency towards seven suppliers of Kadatuan Koffie, three of them are categorized as efficient, namely the farmer in Cimaung, Cibodas and Dago that showed an efficiency value of 1.
Keywords: Data Envelopment Analysis, performance efficiency, supplier

INTRODUCTION

Today, coffee is turning to a strategic commodity both in the domestic and international markets. The trend of coffee industry development experienced an enhancement in the past ten years. It is indicated by several aspects, among others, the increase of businesspeople of the coffee industry, level of market demand, level of production and the increase of coffee export volume/level. Data of the Indonesian Central Bureau of Statistics (BPS) in 2018 showed that the business actors of the coffee industry increased since 2017 of about 12,770 industry players in micro, small and medium scale and 2,216 industry players on a large scale. Indonesia is the third-largest coffee producing country in the world with production level grows considerably as in 2016 by 4% and 0.6% in 2017. In the export aspect, Indonesian coffee has contributed significantly to the availability of world coffee. Additionally, the percentage of coffee export increased significantly to 77% in 2015, 72% in 2016 and 68% in 2017 of the total coffee produced. Another aspect which turns a positive indicator of coffee industry development is the global coffee demand that tends to increase year by year. The trend plays both as resistance and opportunity for coffee businesspeople, particularly in making a profit (Sub Directorate of Estate Crops Statistics, 2018).

The development of the business of coffee agro-industry that getting tighter must be seriously responded to in creating a strategy of development of business activity so that it is able to compete in the domestic and international market. The company, therefore, must have competitive predominance to other similar companies so as it can provide a product with good quality and excellent service to consumers. The predominance is not only made for the producer but also for every chain link of all business activities from suppliers to retailer/end seller that deals with consumers directly, both individual and retail.

Supply chains are formed of connected business activities among companies that are related to each other to distribute products to consumers. The activity flow of the supply chain is from the consumer's demand and ends at the consumer's satisfaction (Chopra & Meindl, 2004). The management of the supply chain is a series of approaches applied for connecting every single chain-link of the supply chain efficiently. The aim is so that the product provided for consumers having good quality and it is distributed by a precise amount, period and place in order that it satisfies consumers. Consequently, good management of supply chain flow is able to enhance the productivity of an industry and increase the quality of the product at once (Pujawan & Mahendrawathi, 2005).

Each link chain connected to a supply chain has an important role in achieving the goal of distributing products to consumers effectively and efficiently so that the expansive operating cost can be avoided. An effective and efficient supply chain can be created by conducting a sound supply chain management from downstream to the upstream sector. In this circumstance, there are several major players, namely the companies that have the same interest, they are, Supplier, Manufacturer, Distributor, Retail Outlet and Costumer (Djokopranoto & Indrajit, 2002).

One of the supply chain players is the supplier. It has a role to distribute raw materials required to produce the desired product of supply chain activity. The production activity can run well and smoothly only if it also obtains raw material from the supplier well (Mauidzoh & Zabidi, 2007). A company usually has several raw material suppliers. It aims to meet the company's needs and maintain raw material supply if one supplier cannot fulfill it. Management of raw material supply is one of the efforts to keep the flow of the supply chain run well till final consumers. Furthermore, a company should select a good supplier to maintain its supply chain (Heizer & Render, 2015).

The measurement of supply chain performance is crucial to do in order to be able to control and supervise the supply chain and to communicate the organization's goal in every chain link of the supply chain. It is also essential to know the position of the organization towards competitors and to determine improvement to create a competitive predominance. It is required to measure the efficiency level of the supply chain member's performance. Additionally, it can also be important information in determining the policy of the supplier's performance improvement. The research regarding method and model of measurement of performance of supply chain management has been widely developed viz., SCOR method, Balanced Scorecard method, Activity Based Costing, Multi-criteria Analysis, Life Cycle Analysis, and Data Envelopment Analysis (Slamet, Marimin, Arkeman, & Udin, 2011).

Data Envelopment Analysis (DEA) is a linear program-based technique to measure the efficiency of an organization called Decision Making Units (DMU) in utilizing available resources to obtain certain output (Tanjung & Devi, 2013). DEA, moreover, is a multifactor analytical method to measure the efficiency and effectiveness of a homogenous Decision-Making Unit (DMU) group (Prasetyo, 2008). It is in agreement with Marimin & Slamet (2010) that stated the DEA works by the phase of unit identification that will be evaluated. Research of the Decision-Making Unit (DMU) needs a lot of suppliers and consequently, it is suitable for evaluating a unit of a group of business entities (CV. Tri Anom Agrektur). As a concern of the research, the DMU will measure the efficiency of the supplier unit in CV. Tri Anom Agrotektur with seven suppliers scattered around West Java. The comparison of the coffee supply chain performance of the supplier level will describe which suppliers having a better performance. The DEA model used in the calculation is CCR (Constant Return to Scale). CCR is a compatible model for a system with a lot of entities of DMU (Sari, Nurmalina, & Setiawan, 2014). Measurement of efficiency level using DEA method has three advantages; it is able to determine relative efficiency value to ease comparing each DMU, to measure entire output and input value of each DMU, and it does not need a parametric specification of a functional form (Aramyan, Ondersteijn, Kooten, & Lansink, 2006).

CV. Tri Anom Agrotektur is one of the coffee agro-industrial companies located in Bandung Regency, which houses the Kadatuan Koffie trademark. Kadatuan Koffie has started its coffee agro-industrial business activities since 2013 by providing coaching to coffee farmers in Mekar Sari village. The company has been conducting coffee plantation business by managing the company's plantations and fostering farmers in West Java to get coffee supply. The coffee supply of Kadatuan Koffie is obtained from suppliers of several regions in West Java, such as Pangalengan, Cibodas, Manglayang, Lemah Sugih, Cikajang, Bukit Tunggul, and Dago.

The relationship that exists between the company and the farmers is not bound to one another in any form. This condition could make the company losing the supply of coffee if there are farmers who do not provide their crops to the company. Companies must choose suitable suppliers to maintain their supply chains (Heizer & Render, 2015). Therefore, the company needs to identify the farmer groups/suppliers of coffee to determine the farmers who need to be attached through partnerships to become a permanent supplier of the company to maintain the company's raw material supply.

According to the description, measuring the performance efficiency of suppliers at Kadatuan Koffie is the aim of this study. This study used the Data Envelopment Analysis (DEA) method to determine the efficiency of suppliers' performance that has and has not been efficient. The results of the efficiency measurement of supplier performance can be used as consideration for companies in determining policies for their suppliers.

METHODS

The research on the measurement of supplier performance efficiency was conducted at the Kadatuan Koffie located in Mekar Sari Village, Cimaung District, Bandung Regency. The respondents of this study were seven suppliers of Kadatuan Koffie located in Pangalengan, Cibodas, Manglayang, Lemah Sugih, Cikajang, Bukit Tunggul, and Dago as well as the Koffie Kadatuan management. Data collection in this study was obtained by conducting interviews with respondents. The data collected were in quantitative form and processed using Data Envelopment Analysis (DEA).

DEA method is one of the linear programming techniques used to measure the performance of the decision-making unit (DMU). This method aims to measure the relative efficiency of each DMU to produce maximum output based on the existing inputs. DEA is able to determine the efficiency value of a unit towards a frontier formed from efficient DMUs with 1 value and it is called the efficiency frontier. The DMUs that have not been efficient yet will be below the efficiency limit value of 1.

DEA method is relative by comparing output and input factors in each DMU. The model used is as follows:

$$Ef = \frac{\sum_{r}^{s} UrYr0}{\sum_{i}^{m} ViXi0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Description:
Ef : Efficiency of supply chain
m : Number of Input
s : Number of Output
Ur : Weight attached output-r
Vi : Weight attached input -i
Xi0 : Quantity input-i used by DMUo
Yr0 : Quantity output-r used by DMUo
Criteria of supply chain mentioned as follow:
If Ef = 1, implies efficient supply chain
If Ef < 1, implies the supply chain is not yet efficient (Charnes, Cooper, & Rhodes, 1978)

In this method, measurements of the supplier/farmer-level use output values: the selling price of coffee beans and the number of coffee beans sold to the company, while the input value: outside the coffee plantation area and the number of farmers. In this study, measurements of supplier performance efficiency were performed using Deap 2.1 software developed by the Coelli Team (University of Queensland, Australia). The results of the calculation of the level of efficiency of Kadatuan Koffie suppliers are explained descripttively to be easily understood.

RESULTS AND DISCUSSION

Supply Chain Identification

Identifying the supply chain in the company is the initial step taken before conducting an evaluation. This process is performed through direct data collection in the field and then mapping the occurred supply chain conditions. The flow of the supply chain that occurs in the CV. Kadatuan Koffie is described as follows (Figure 1).

Three types of flows that exist in the supply chain of coffee commodities, namely: the flow of goods, the flow of information, and financial flows. The flow of goods in the coffee supply chain is started by farmers who are members of farmer groups as suppliers of the primary raw materials in the form of cherry beans or green beans. Moreover, it also flows from suppliers of supporting raw materials (packaging) to the company. The flow of goods from companies in the form of processed coffee products flows from the company to several types of consumers, both directly and indirectly. The direct way mentioned is to distribute directly to foreign cafes, restaurants and consumers, and the indirect way through exporters until the goods reach final consumers in foreign countries. Information flow occurs in two-way communication between the company and all suppliers and consumers. The information that flows from suppliers to compa-

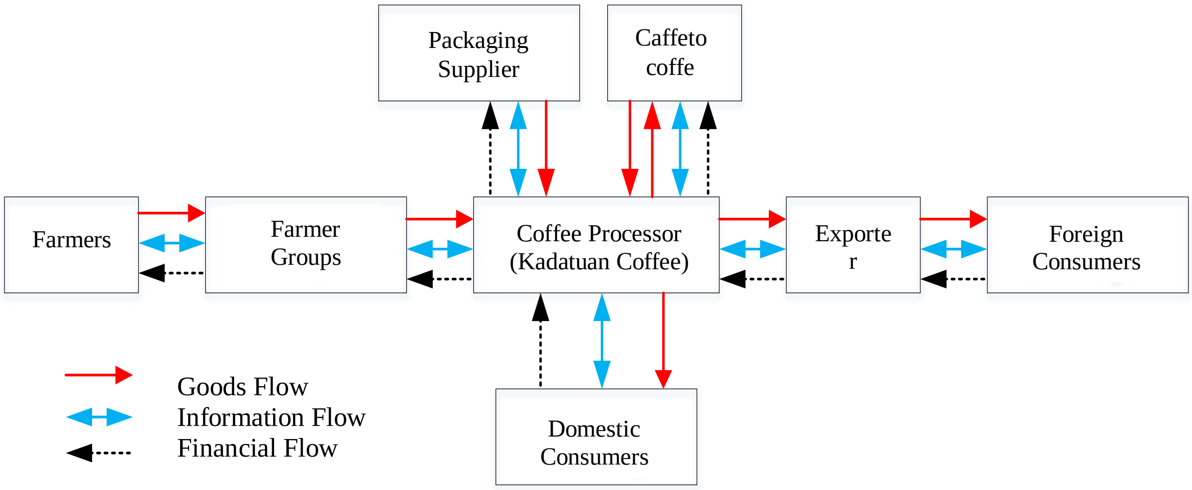

Figure 1. Supply Chain Flow

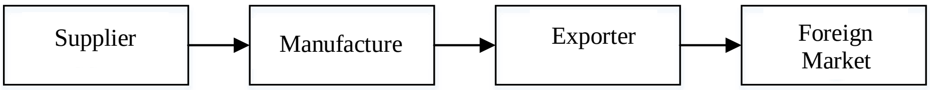

Figure 2. Structure of Supply Chain 1

Figure 3. Structure of Supply Chain 2

nies are regarding production quantities, selling prices, quality of raw materials, as well as the mechanism of transportation of goods.

On the other hand, the flow of information that flows from the company to suppliers is the need for goods in terms of quality and quantity, purchase price, and other agreements offered by the company. The flow of information is from companies to consumers in the form of selling prices, availability of offers, and quality of goods. The flow of information from consumers to companies is regarding the price of sale, the need for goods both in its quality and quantity, transportation mechanisms, and other agreements. The third flow is the flow of finance. It is a one-way form, from consumers to farmers, farmers to companies, and companies to suppliers.

Supply Chain Structure

Supply chain structure formed based on the type of company's consumers describes as follows:

(a) Structure of Supply Chain 1 (Figure 2)

This supply chain structure consists of suppliers, processors, exporters and consumers of foreign markets. In this structure, the goods flowed are green bean products. Suppliers or farmer groups will supply coffee beans to processors to then be processed into green beans. Then the green bean will be directly marketed to exporters for overseas sales. The exporter will take green beans directly in the company's main warehouse.

(b) Structure of Supply Chain 2 (Figure 3)

In this structure, the processor will process the coffee beans into a downstream roasted coffee product. Café consumers choose roasted coffee products that have not been ground because they usually do independent grinding when the customers buy their brewed coffee drinks.

(c) Structure of Supply Chain 3 (Figure 4)

In this structure, coffee processing companies sell coffee products that have been ground to resellers and then proceed to the final consumer. The company will deliver it according to the reseller's order. Products will be sent by courier, which the reseller will bear the shipping cost.

(d) Structure of Supply Chain 4 (Figure 5)

The last supply chain structure is a structure that reaches the final consumer directly. The company also markets through various media for direct sales to final consumers. Final consumers can make purchases through corporate's social media and online buying in a marketplace on the internet.

Supplier's Performance Measurement

Measurement of supplier or farmer performance is carried out towards seven farmers in several regions in West Java, such as Pangalengan, Cibodas, Manglayang, Lemah Sugih, Cikajang, Bukit Tunggul, and Dago. This performance measurement aims to identify which suppliers are already efficient and not. This performance measurement provides information for companies in which suppliers are efficient so that they can be permanent suppliers to maintain the supply of coffee beans for the company. Besides, the company can also provide coaching to farmers who have not been efficient so that the level of efficiency increases and can help to increase the coffee supply for the company. The input and output values of each DMU are presented in Table 1.

Measurement of supplier performance using the DEA method is performed based on a comparison of predetermined output and input values. The input variables used are the land area and the number of members, while the output variables used are the number of coffee beans sold to the company and the selling price of coffee beans per kilogram. The value of each variable for each DMU is shown in Table 1. The results of the calculation of supplier efficiency levels can be seen in Table 2.

Figure 4. Structure of Supply Chain 3

Figure 5. Structure of Supply Chain 4

Table 1. The values of input and output variable of the supplier's performance measurement

DMU	Farmer's Region	Input		Output	
		Land Area (Ha)	Number of Member	Number of Coffee Bean (Kg)	Selling Price (IDR/Kg)
1	Cimaung (Pangalengan)	6,5	26	87,000	9,000
2	Cibodas (Lembang)	8	30	103,000	10,000
3	Manglayang	10	35	77,000	9,000
4	Lemah Sugih (Majalengka)	9	30	77,000	9,000
5	Cikajang (Garut)	15	40	103,000	9,000
6	Bukit Tunggul (Lembang)	7,5	20	51,500	9,000
7	Dago	1,5	6	15,000	9,000

Table 2. Result of efficiency level and reference set measurement

DMU	Farmer's Region	Efficiency	Reference Set	
1	Cimaung (Pangalengan)	1.000		
2	Cibodas (Lembang)	1.000		
3	Manglayang	0.650	DMU 2 (1.105)	DMU7 (0.311)
4	Lemah Sugih (Majalengka)	0.759	DMU 2 (0.947)	DMU7 (0.266)
5	Cikajang (Garut)	0.750	DMU 2 (1.333)	
6	Bukit Tunggul (Lembang)	0.793	DMU 2 (0.533)	DMU7 (0.668)
7	Dago	1.000		
	Mean	**0.850**		

Table 3. Output slack value of each DMU

DMU	Farmer's Region	Output Slack	
		O1	**O2**
1	Cimaung (Pangalengan)	0.000	0.000
2	Cibodas (Lembang)	0.000	0.000
3	Manglayang	0.000	0.000
4	Lemah Sugih (Majalengka)	0.000	0.000
5	Cikajang (Garut)	0.000	1333.333
6	Bukit Tunggul (Lembang)	0.000	0.000
7	Dago	0.000	0.000
	Mean	**0**	**190.476**

Table 4. Input slack value of each DMU

DMU	Farmer's Region	Input Slack	
		I1	**I2**
1	Cimaung (Pangalengan)	0.000	0.000
2	Cibodas (Lembang)	0.000	0.000
3	Manglayang	0.698	0.000
4	Lemah Sugih (Majalengka)	1.027	0.000
5	Cikajang (Garut)	4.333	0.000
6	Bukit Tunggul (Lembang)	2.234	0.000
7	Dago	0.000	0.000
	Mean	**1.184**	0

Based on the measurement results using Deap 2.1 software shows that there are three DMU or farmer units that have a value of 1, which means that the performance of these farmers is efficient. The efficient farmers are Cimaung, Cibodas and Dago farmers. Moreover, there are also inefficient farmers, namely Manglayang farmers with an efficiency value of 65%, Lemah Sugih farmers with an efficiency value of 75%, Cikajang with a value of 75%, and Bukit Tunggul with a value of 79%.

The inefficient DMU has a reference set value that shows that it is obtained based on the frontier created by the efficient DMU. The reference set value shows the reference for DMU that is not yet efficient to increase the output value to be efficient. The DEA calculation results also indicate the existence of slack inputs and outputs as a reference to increase the DMU efficiency values that have not reached the value of 1 yet, as presented in Table 3.

Output slack is defined as the amount of output that can be added so that an inefficient DMU is able to be an efficient DMU. Variable Output 1 (O1) is the number of coffee beans sold to companies and Output 2 (O2) is the selling price of the coffee. The DEA calculation results show that Cikajang DMU needs to increase the selling price of coffee beans to the company by 1333.333%.

Slack input is defined as the amount of input that can be reduced so that an inefficient DMU can be an efficient DMU. Variable Input 1 (I1) is the area of coffee plantations and Input 2 (I2) is the number of farmers. According to the calculation results of DEA, DMU, which has not been efficient, can reduce the area of its plantations. Manglayang DMU can increase its efficiency value by reducing the plantation area by 45%, Lemah Sugih DMU by 77%, Cikajang DMU by 325%, and Bukit Tunggul DMU by 177% (Table 4).

In Table 5, the Deap 2.1 software calculation results show the output values and output targets that need to achieve by each DMU. The target output can be achieved by increasing the value of the input variable. Based on Table 5 it can be seen that DMU 3 needs to increase the value of O1 and O2 variables by 53.80%. DMU 4 needs to increase the value of the O1 and O2 variables by 31.8%. DMU 5 needs to increase the value of the variables O1 and O2 respectively by 33.33% and 48.14%. DMU 6 needs to increase the value of O1 and O2 variables by 26.06%.

Table 6 shows the value of the input variable for each DMU. DMU which is not yet efficient needs to improve its performance efficiency by reducing the value of its input variables. DMU 3 needs to reduce the value of variable I1 by 7%. DMU 4 needs to reduce the value of variable I1 by 12.22%. DMU 5 and 6 need to reduce the value of variable, respectively, I1 by 29.33% and 30.67%.

Measurement of the performance efficiency of coffee beans suppliers is intended to determine suppliers who are efficient or not, so Kadatuan Koffie can make policies in regulating the supply of its raw materials, coffee beans. Suppliers or DMU that have not been efficient can improve their performance efficiency by reducing the input used and increasing the output produced. Kadatuan Koffie can provide coaching to its suppliers based on the efficiency made by each factor, both input and output factors.

Table 7 shows the area of farmer groups sorted by the land area used as coffee plantations, while Table 8 shows the regions of farmer groups sorted by the highest number of coffee beans harvested by each region. The table shows the

Table 5. Actual value and target of output variable

DMU	Output Value		Output Target		Ratio %	
	O1	O2	O1	O2	O1	O2
1	87,000	9,000	87,000	9,000	0.00%	0.00%
2	103,000	10,000	103,000	10,000	0.00%	0.00%
3	77,000	9,000	118,426	13,842	53.80%	53.80%
4	77,000	9,000	101,508	11,864	31.83%	31.82%
5	103,000	9,000	137,333	13,333	33.33%	48.14%
6	51,500	9,000	64,923	11,345	26.06%	26.06%
7	15,000	9,000	15,000	9,000	0.00%	0.00%

Table 6. Actual value and target of the input variable

DMU	Input Value		Input Target		Ratio %	
	I1	I2	I1	I2	I1	I2
1	6,5	26	6.5	26	0.00%	0.00%
2	8	30	8.0	30	0.00%	0.00%
3	10	35	9.3	35	-7.00%	0.00%
4	9	30	7.9	30	-12.22%	0.00%
5	15	40	10.6	40	-29.33%	0.00%
6	7,5	20	5.2	20	-30.67%	0.00%
7	1,5	6	1.5	6	0.00%	0.00%

Table 7. Input factor of measurement of Kadatuan Koffie supplier’s level of performance efficiency

No	Farmer Group’s Region	Ownership Status	DEA Value	Land Area (Ha)	Number of Member
1	Cikajang (garut)	Perhutani	0.750	15	40
2	Manglayang	Perhutani	0.650	10	35
3	Lemah Sugih (majalengka)	Perhutani	0.759	9	30
4	Cibodas (lembang)	Private	1.000	8	30
5	Bukit Tunggul (lembang)	Perhutani	0.793	7.5	20
6	Cimaung (pangalengan)	Private	1.000	6.5	26
7	Dago	Private	1.000	1.5	6

Description: Perhutani (State Forest Enterprise of Indonesia)

Table 8. Output factor of measurement of Kadatuan Koffie supplier’s level of performance efficiency

No	Farmer Group’s Region	DEA Value	Land Ownership Status	Amount of Wet Coffee (Kg)	Price (IDR/Kg)
1	Cibodas (lembang)	1.000	Private	103,000	10,000
2	Cikajang (garut)	0.750	Perhutani	103,000	9,000
3	Cimaung (pangalengan)	1.000	Private	87,000	9,000
4	Manglayang	0.650	Perhutani	77,000	9,000
5	lemah sugih (majalengka)	0.759	Perhutani	77,000	9,000
6	Bukit Tunggul (lembang)	0.793	Perhutani	51,500	9,000
7	Dago	1.000	Private	15,000	9,000

problem of plantation land productivity where the area with ownership status by Perhutani does not get a DEA value of 1 that implies inefficiency, while there are some lands with Perhutani ownership status that have a wider land area compared to areas with private ownership status. These phenomena can occur due to different levels of awareness of each farmer in these areas. Land ownership status is one of the factors of agricultural land productivity (Koirala, Mishra, & Mohanty, 2016).

Farmers with private land of ownership status have more awareness in cultivating coffee plants, from coffee beans planting to picking. Farmers with private land ownership carry out planting using planting patterns that have been provided in coaching by the government and the private sector that the ratio of harvested coffee of the land area used is greater than planting without a pattern. Farmers who cultivate on Perhutani's land also have problems in planting patterns because they do not have the authority to do land clearing without large trees. During the treatment of coffee plants, farmers with private land status have more awareness in taking care of coffee plants such as fertilizing, cutting unproductive stems, and also protecting plants from pests and diseases. Moreover, farmers of Perhutani's land usually have relatively further distances because they have to enter the forest first.

This phenomenon can also be caused by external factors that cannot be controlled, such as weather and climate change. The difference between climate and weather that occur in each region of Kadatuan Koffie suppliers can cause differences in the ratio of the amount of harvested product based on the area of land used. The climate and weather changes can cause the change of temperature, so it impacts on pests and diseases attack (Widayat, Anhar, & Baihaqi, 2015). The difference in temperature, location of planting, and crop cultivation care also influences the productivity of coffee beans yields.

CONCLUSION

Based on the results of measurements of the supplier’s performance efficiency, there are three suppliers/farmers who already have efficient performance, namely farmers in Cimaung, Cibodas, and Dago. However, there are four inefficient suppliers, namely farmers in Bukit Tunggul, Lemah Sugih, Manglayang, and Cikajang. It is due to the status of land ownership which the supplier of inefficient plantation land is owned by Perhutani so that the land is planted with coffee plants optimally and the care of the coffee plant is neglected; it causes the impact of the coffee plant productivity. This result can be used by companies in managing the supply of raw materials. Moreover, the company can submit contracts/ partnerships to suppliers who have been efficient in maintaining the supply of raw materials. Further research is required to measure the efficiency of sales performance to consumers so that the most efficient supply chain structure can be seen from upstream to downstream in the coffee supply chain flow. Input and output variables used in measuring performance using the Data Envelopment Analysis (DEA) method can be varied with other variables such as transportation costs, delivery distance from farmer to the warehouse, delivery time, percentage of material quality and others.

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