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Analysis of the Effect of Temperature and Rainfall on Coffee Productivity in Indonesia using the Cobb-Douglas model for Determining Insurance Premiums

Saqila Novianti [1*],Riaman [2] , Sukono [3]

[1, *] *Mathematics Undergraduate Study Program, Faculty of Mathematics and Natural Sciences, Padjadjaran University , Jatinangor , Indonesia*

[3] *Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran , Jatinangor , Indonesia*

* *Corresponding author email: saqilanovianti9@gmail.com*

Abstract

Coffee is one of Indonesia's foreign exchange earners and plays an important role in the development of the plantation industry. Indonesia is a coffee bean producing country ranked 4th in the world after Brazil, Vietnam, and Colombia. The agricultural sector in Indonesia has risks and uncertainties including a decrease in production yields which results result in a decrease in farmers income. The risk of loss in coffee is caused by temperature and rainfall. Efforts that can be made to reduce losses are through risk transfer through agricultural insurance. The purpose of this study to analyze the effect of temperature and rainfall on coffee productivity in Indonesia and determine the insurance premium. This research uses data on coffee productivity, temperature, and rainfall from 1980-2019. The relationship between coffee productivity as a dependent variable while temperature and rainfall as an independent variable was used the Cobb-Douglas method. The results that will be obtained from this study indicate the temperature and rainfall affect coffee productivity in Indonesia, and obtain insurance issued by the farmers to the insurance companies. The results obtained from the data analysis show that temperature and rainfall have an effect on coffee productivity in Indonesia. The results of productivity predictions are used as the basis for determining the price of insurance premiums issued bye insurance companies.

Keywords: Productivity, Temperature, Rainfall, Cobb-Douglas, Premium.

1. Introduction

In Indonesia exports production coffee beans by 67% and the remaining 33% for needs domestically. Coffee is one commodity producer source Indonesia's foreign exchange, so that hold role important in development industry plantation. Sector agriculture in Indonesia have risk of them, namely drop results production, which causes drop income to farmers. one risk loss to coffee caused by change climate. Change climate be marked among other things by increasing temperature, diversity rainfall, and rising incident climate extreme. According to Solomon, *et al.* (2007), condition this causing drop productivity plant, that is more temperature high, erosion land because rainfall high, degradation land consequence increase intensity rainfall, and duration drought.

In Article 7 paragraph 2 part “g” of Law no. 19 of 2013 in Indonesia mentioned that one of the protection strategies farmers is introduce insurance Agriculture to the farmers. Insurance is something shape control risk where one party divert possible risk happen in the future. Existence insurance plantation the aim is that the farmers permanent could fulfil needs his life although no have income from results production. Insurance obliged for party insured to party guarantor for pay premium in the form of cash payment in total certain, at once or periodic.

On research this discussed about influence temperature and rainfall to coffee productivity in Indonesia with use Cobb-Douglas method and got quantity premium insurance plantation.

2. Literature Review

Coffee

Coffee is one type plant plantations that have been cultivated for a long time and have Mark pretty economical high. The advantages of coffee in Indonesia own special taste because influenced by the region where the coffee is grown. According to data from Association Indonesian Coffee Exporters (AEKI), 67% of coffee production is exported and the remaining 33% needs domestically.

Production in Indonesia is very dominated from plantation coffee people with an average contribution of 99.996% during period 2010-2020. While coffee from plantation big only 0.004%. Coffee is plants that can growing on the plains low and plain high. Height for growing coffee is 500-2.000 masl. There is two The types of coffee that are most widely grown in Indonesia are Robusta and Arabica.

Productivity

According to Sumanth (1984), productivity is ratio Among results achieved with whole source power used. Productivity no same with production, but performance quality, production, and results that constitute component from effort productivity. Something combination from productivity is something combination from effectiveness and efficiency.

According to Gasperz (2000), productivity looking at from two side at a time that is input and output. The input used is large land and output used, namely production.

Coffee Temperature and Rainfall

Temperature optimum air for coffee growth ranges between 24-30 ℃. according to Setyawan (2009), speed reaction affected by temperature, usually more tall temperature so reaction more fast, at optimum temperature, system enzyme working good and stable in long time. At temperature more cold, system permanent stable but no function, while at temperature tall system enzyme experience damage.

Not only temperature just but coffee productivity affects to rainfall, amount rainfall nor distribution rainfall along year is very important in coffee growth and production. according to Soenaryo (1975), distribution rainfall will determine intensity and quality formation interest, value it worked flowering and success formation fruit as well as formation fruit next. Optimum rainfall for coffee plants reach 2000-3000 mm.year $^{-1}$ with month dry 3-4 months, will be but on time that still there is enough rain, at least still there is rain about 80 mm per the month or with frequency 2-3 times.

Plantation Insurance

according to Nurmanaf, et al. (2007), by general, goal insurance plantation is for stabilize income farmer through subtraction level loss consequence lost results, push farmer adopt technology farming for more productive and efficient, and reduce risks faced institution credit as well as Upgrade access farmer to institution that.

Quantity Premium

according to Pasaribu (2014), amount premium insurance estimated range between 2,5% to 3,5% of applied coverage based on cost production in accordance type the commodity. Collaborating parties will stage meeting and taking decision together about quantity ethnic group premium in one season plant or in something period certain.

Analysis Correlation

Correlation is number showing direction and strength connection Among two variable by together or more with variable other. According to Lind et al. (2008), analysis correlation is bunch technique for measure connection Among two variable, idea base from analysis is report connection Among two variable.

Correlation Among variable not independent and variable free could calculated use correlation pearson.

$$r_{xy} = \frac{n\sum_{i=1}^{n} x_i y_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sqrt{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}\sqrt{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2}} \tag{1}$$

with,

r_{xy} : correlation Among variable not independent on variable free
y_i : value variable not free i; $i = 1,2,\dots,n$
x_i : value variable free i; $i = 1,2,\dots,n$
n : number of data.

Analysis Multiple Linear Regression

Analysis multiple linear regression is expansion from a simple linear regression model used for overcome analysis regression involving connection between two or more. Variable that counts next grouped Becomes variable not independent (Y) and variable free (X).

Common models from equality multiple linear regression could formed.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon_i \quad (2)$$

Multiple linear regression model on could appraised Becomes a sample that can be formed.

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \cdots + \hat{\beta}_k X_k \quad (3)$$

with,
Y : variable not free
$\hat{Y}$: estimate of$Y$
$\beta_0, \beta_1, \beta_2, \dots, \beta_k$: regression parameters
$\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2, \dots, \hat{\beta}_k$: estimated regression parameter
$X_1, X_2, \dots, X_k$: variable free
ε : *error*, $e_i \overset{iid}{\sim} N(0, \sigma^2)$

Ordinary Least Square

According to Sembiring (1995), equation the best regression is regression that has a total error minimum standard. Estimation of regression parameters used in the study this is use method square smallest or normal called *Ordinary Least Square* (OLS). Estimator generated by method squared the smallest this expected is BLUE (Best Linear Unbiased Estimator).

Square estimator the smallest from $\hat{\boldsymbol{\beta}}$ as following:

$$\hat{\boldsymbol{\beta}} = \left(\mathbf{X}^{\mathbf{T}}\mathbf{X}\right)^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{Y} \quad (4)$$

With,
$\hat{\boldsymbol{\beta}}$: matrix sized $m \times 1$of the parameters to be estimated;m is many variable free to use.
$\mathbf{X}$: matrix with variable free .
$\mathbf{X}^{\mathbf{T}}$: t*ranspose* matrix **X**.
$\mathbf{Y}$: matrix with variable bound

F test

F test used for look is variable free capable by thorough together explain Act in demand variable tied. The F test test is compare $F_{count}$with F_{table} on $\alpha = 0.05$ (Suharyadi and Purwanto, 2009).

$$F = \frac{\frac{R^2}{n-1}}{\frac{1-R^2}{n-k}} \quad (5)$$

Hypothesis used in F test testing is:
H_0: no there is variable free to contribute to variable not free.
H_a: yes influence variable free to contribute to variable not free.

Criteria F test testing with compare compare $F_{count}$with F_{table}, as follows:
a. $F_{count} < F_{table}$
That is, the variable free no own influence by simultaneous to variable not free.
b. $F_{count} > F_{table}$

That is, the variable free own influence by simultaneous to variable not free.

Criteria F test testing with compare probability (significance) with $\alpha = 0{,}05$, as follows:

a. Probability (significance) > 0.05 (α); H_0accepted and $H_a$rejected.

It means variable free no own influence by simultaneous to variable not free.

b. Probability (significance) < 0.05 (α); H_0rejected andH_a accepted.

That is, the variable free own influence by simultaneous to variable not free.

***t* test**

Ordinary t test used for test is by partial, variable free have significant influence or no significant to variable tied. Test through t test is with compare $\mathrm{t_{hitung}}$with $\mathrm{t_{tabel}}$ on $\propto = 0{,}05$ (Suharyadi and Purwanto, 2009).

$$t_{count} = \frac{\hat{\beta}_i}{S(\hat{\beta}_i)} \tag{6}$$

Hypothesis used in testing t test is:

H_0 : the independent variable has no effect on the dependent variable.

H_a : the independent variable has an effect on the dependent variable.

Criteria t test test with compare $\mathrm{t_{hitung}}$with $\mathrm{t_{tabel}}$, as following:

a. $t_{count} > t_{table}$

That is, there is partial influence among variable free to variable not free.

b. $t_{count} < t_{table}$

That means, no there is partial influence among variable free to variable not free.

Criteria t test test with compare probability (significance) with $\alpha = 0{,}05$ the following:

a. Probability (significance)$>$ 0.05 (α); H_0accepted and $H_a$rejected.

That means, no there is partial influence among variable free to variable not free.

b. Probability (significance)$<$ 0.05 (α); H_0rejected and $H_a$accepted.

That is, there is partial influence among variable free to variable not free.

Normality Test

Normality test for test in the regression model is variable the bully (residual) has normal distribution or no (Ghozali, 2018:161). One for detect is the residual normally distributed or whether or not that is with using the *Kolmogorov – Smirnov* test.

$$D = max_x |F_n(x) - F_0(x)|; x \in \mathbb{R} \tag{7}$$

Kolmogorov test – *smirnov* with use level significance $\propto = 0{,}05$ based on the decision making, namely:

a. Test – *Smirnov* Sign $\propto = 0.05$ > Significance Score; H_0received

That is, the data is normally distributed.

b. Test – *Smirnov* Sign $\propto = 0.05$ < Significance Score; H_0 rejected

That is, the data is not normally distributed.

Koefieisen Determination (R^2)

Coefficient determination normal called with coefficient correlation . According to Gujarat (2010), the coefficient determination (R^2 is usual amount used for measure strength connection Among variable free with variable not free. Coefficient determination (R^2) has *range* from 0 to 1. The coefficient of determination can be defined as follows.

$$R^2 = \frac{\sum_{i=1}^{n}\left(\hat{Y}_i - \bar{Y}\right)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \tag{8}$$

Function Cobb-Douglas Productivity

Function Cobb-Douglas production often called as function production exponential. Function Cobb-Douglas production is function involving two or more variable, that is variable not independent (Y) and independent variable (X). On function production, the Cobb-Douglas function is something function production that looks at influence *inpu*t used and use desired *outpu*t. Solution connection Among X and Yusually by regression, where variation from Y will influenced variation from X. Thus So, the rules on the regression line also apply in solution Cobb-Douglas function (Soekartawi, 2003).

Formulation function Cobb-Douglas production.

$$Y = a_0 {X_{1i}}^{\beta 1} {X_{2i}}^{\beta 2} e^{\varepsilon_i} \quad (9)$$

with ,

Y : *outpu*t

a_0 : constant

X_{1i} : temperature

X_{2i} : rainfall

$\beta_1$and β_2 : Cobb-Douglas production function model parameters

e : base of neutral logarithm

ε_i : *error*

For make it easy estimating to the above equation, equation the expanded by general. The data should transformed to in shape natural logarithm (ln) first first to be linear because shape original equality function Cobb-Douglas production is nonlinear (Favour, 2017).

Following transformed form in shape natural logarithm (ln)

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \varepsilon_i \quad (10)$$

Determination premium

Determination premium insurance plantation based on index temperature and rainfall with got expectations and variance use function natural logarithm (ln) Cobb-Douglas.

- **Expectations**

Expectation or average with use function Cobb-Douglas natural logarithm (ln).

$$\mu_G = \beta_0 + \beta_1 \mu_1 + \beta_2 \mu_2 \quad (11)$$

- Variance

Variance with use function Cobb-Douglas natural logarithm (ln).

$$\sigma_G^2 = \beta_1 \sigma_1^2 + \beta_2 \sigma_2^2 + 2\beta_1 \beta_2 \sigma_{12} + \sigma_{\varepsilon_i}^2 \quad (12)$$

Next according to Djuric (2013), the model used in calculation premium insurance based on three principle as following :

a. Premium pure

$$\Pi_G = E[G] \text{ X IDR} \quad (13)$$

b. Premium with *Loading* Factor

$$\Pi_G = \big((1+\theta)E[G]\big) \text{ X IDR} \quad (14)$$

with $\theta = 2.5\%$ and 3.5%

c. Premium Standard Deviation

$$\Pi_G = (E[G] + \theta\sqrt{Var[G]}) \text{ X IDR} \quad (15)$$

with $\theta = 2.5\%$ and 3.5%

3. Materials and Methods

3.1. Materials

In research, object used is secondary data about coffee productivity, temperature, and rainfall in Indonesia. The data could obtained from the official website of the Ministry of Agriculture Directorate General of Plantations and the Meteorology, Climatology, and Geophysics Agency (BMKG). Data used is data from 1980-2019 .

4. Results and Discussion

Based on results research, obtained the equation model using IBM SPSS statistics 25 software for coffee productivity with temperature and bulk rain in Indonesia.

Table 1: Parameter Estimation Results of Multiple Linear Regression Model

Coefficient	Estimate	Std. Error	t value	Pr (>|t|)
(constant)	-37.558	4.648	-8.081	0.000
$\ln X_1$	11.433	1.403	8.148	0.000
$\ln X_2$	-0.182	0.088	-2.083	0.044
Residual Standard Error	0.10211			
Multiple R-Squared	0.664			
Adjusted R-Squared	0.646			
F- *Statistics*	36.579			
P-Value	0.000			

Based on Table 1, obtained as following.

$$\ln Y = -37.558 + 11.433 \ln X_{1i} + 0.182 \ln X_{2i} + \varepsilon_i$$

$$Y = 4.8839\, X_{1i}{}^{-11.433} X_{2i}{}^{0.182}$$

Based on results study showing that by Partial temperature and bulk rain give influence to results coffee productivity in Indonesia. This thing in accordance with test of F results of 36.578. Temperature and bulk rain showing that by simultaneous give influence to results coffee productivity in Indonesia, p this in accordance with a test t of 0.000 where Mark this more small from level significance of 0.05, it means temperature have influence against results coffee productivity. Likewise with variable bulk rain that has more p-value small from Mark level significance which is 0.044.

Table 2: Kolmogorov – Smirnov One Sample Test Results

		Unstandardized Residual
N		40
Normal Parameters [a,b]	mean	0.0000000
	Std. Deviation	0.09945964
Most Extreme Differences	Absolute	0.063
	Positive	0.63
	negative	-0.57
Test Statistics		0.063
asymp . Sig. (2-tailed)		0.200

Normality results with use *standardized residual* is known that probability coefficient tolerance more than 0.05, 0.200 more big of 0.05. This thing concluded the data normally distributed. Based on Table 1, can seen coefficient determination give influence variable free against variable not free by 66.4%.

Premium is one element urgent in insurance because is obligation mandatory tree filled with dependents to guarantor, based on results function Cobb-Douglas productivity gained Mark expectations and variance as following.

- Expected Value

$$E[G] = E[c] + \beta_1 \mathrm{E}[Z_1] + \beta_2 \mathrm{E}[Z_2]$$
$$= -37.558 + 11.433(3.2845) - 0.182(4.320828)$$
$$= -0.79563$$

So, $E[Y]$=$e^{E[G]} \approx 0.45129$

From the results above, we get expectations for premium is 0.45129.

- Variance Value

$$\sigma_G^2 = \beta_1 \sigma_1^2 + \beta_2 \sigma_2^2 + 2\beta_1\beta_2\sigma_{12} + \sigma_{\varepsilon_i}^2$$
$$= (-11.433 \times 0.000136) + (0.182 \times 0.035) + \left(2(-2.08391)(-0{,}0013782)\right) + 0.10211$$
$$= 0.09786$$

so that,$\sigma_Y^2 = e^{\sigma_G^2} \approx 1.10281$

Obtained results variance for premium is 1.10281.

Furthermore, if assumed Mark coverage IDR 50,000,000.00 ton/ hectare in the contract period, then based on calculation refer to equations (13), (14), and (15) are obtained Mark premium insurance coffee plantation is like given in Table 3.

Table 3. Premium Value Coffee Plantation Insurance

No	Premium Model	Results	
1	$\Pi_Y = E[Y] \times$ IDR 50,000,000 ton/ha	$\Pi_G =$ IDR 22,564,783.81 ton/ha/year	
2	$\Pi_Y = (1+\theta)E[Y]$ ×IDR 50,000,000 ton/ha	$\theta_1 = 2{,}5\%$ $\Pi_G =$ IDR 23,128,903.41 ton/ha/year	$\theta_2 = 3{,}5\%$ $\Pi_G =$ IDR 23,354,551.24 ton/ha/year
3	$\Pi_Y = E[Y] + \theta\sqrt{Var[Y]}$ ×IDR 50,000,000 ton ha	$\theta_1 = 2{,}5\%$ $\Pi_G =$ IDR 23,943,291.45 ton/ha/year	$\theta_2 = 3{,}5\%$ $\Pi_G =$ IDR 24,494,694.51 ton/ha/year

4. Conclusion

Based on results analysis could concluded that estimation of temperature and bulk parameters rain consecutive is $\hat{\beta}_1$by 11.433 and $\hat{\beta}_2$by -0.182. Besides it can explained that connection variable free (temperature and bulk rain) with variable not free (coffee productivity) has Mark determination to $R^2$by 66.4%. From result function Cobb-Douglas production is also available results premium insurance, premium insurance the consists of:

a. Premium pure, amounting to IDR 22.564.783,81 ton/ha/year.
b. Premium with *loading* factor, equal to IDR 23,128,903.41 ton/ha/year with θ =2.5% and IDR 23,354,551.24 ton/ha/year with θ =3,5%.
c. Premium Standard Deviation, equal to IDR 23,943,291.45 ton/ha/year with θ =2.5% and IDR 24,494,694.51 ton/ha/year with θ =3.5%.

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