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The impacts analysis of the technological shift in rice production to directly-seeded flooded rice on output supply and input demand in Lombok West Nusa Tenggara

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Abstract. The serious harvesting failure that occurred in the agricultural year 1979/1980 affected as many as 11.250 hectares. Since 1980/1981, this phenomenon inspired a technological shift in rice production to Directly-seeded flooded rice on rainfed land. Lombok, West Nusa Tenggara province achieved self-sufficiency of rice in 1984, a year before national self-sufficiency in 1985. This research aims to analyze the impact of directly-seeded flooded rice as a climate change adaptation strategy on output supply and input demand. Time series data from 2000 to 2015 was analyzed by employing Translog Profit Function and Seemingly Unrelated Regression. The results showed that Directly-seeded flooded rice as a climate change adaptation strategy has a positive impact on output supply and input demand. It indicated (1) elastic output supply subject to self-price change of rice and labor, yet inelastic to the price of seed, Urea fertilizer, TSP, and NPK fertilizer. (2) All demand inputs were inelastic subject to self-price except casual labor and herbicide, and elastic subject to output price. Herbicide and fertilizers are complementary inputs to the directly-seeded flooded rice, while herbicide and casual labor are substitution inputs. The output and inputs price changes faced by farmers have both positive as well as negative impacts on output supply and input demand. It means that inputs such as seed, fertilizers, pesticides, and energy such as petrol for hand tractors are the main physical inputs to Directly-seeded flooded rice. Those inputs were very strategic economic goods, meanings that when the price changes occurred, it disturbed supply directly and performance of rice farming, either the production side, profits, or price risk. It also has food security impacts in Lombok.

1. Introduction

Lombok society suffered from food insecurity almost every year in succession for six years during the seventies as a consequence of rice crop failure because of erratic rainfall patterns and short wet season of 3 to 4 months in a year. The serious harvesting failure that occurred in agricultural year 1979/1980 affected as many as 11.250 hectares of rice. The phenomenon inspired a technological shift to rice production system by Directly-seeded flooded rice (Gogorancah or Gora) on Rainfed Vertisols land since agricultural year 1980/1981.

Rainfed Vertisols is one of the most important rice fields in Lombok. It significantly contributes to rice and secondary crop productions for the region. The climate type in the Lombok is D_3 and D_4 with 3 to 4 months of wet season in a year [1]. Restriction of rice and secondary crop production is mostly due to a limit of water supply from rainfall [2,3]. On the other hand, water losses from evaporation are very high, particularly during hot days and even more severe during flooding.

The rice production system by Directly-seeded flooded rice succeeded in adapting to rain patterns in Southern Lombok. Through the system, earlier planting could be done by preparing the land in the dry season and dibbling the dry seeds soon after the first rains had fallen and a certain moisture level had been reached. Early sowing of dry rice seed allows the use of rainfall effectively and submergence when heavy rain occurs. During the submergence period, water is flooding with a depth of 15 to 25 cm from the soil surface. It allows water to be extensively evaporated, and a very little amount of water was conserved for secondary crops.

The directly-seeded flooded rice succeeded in increasing rice production indicated by the high productivity achievement of rice. The system owned the average harvesting yield of rice was 6.5 tons to 7.6 tons per hectare. The remarkable result of the rice production system brought West Nusa Tenggara (WNT) province in achieving self-sufficiency of rice in 1984. The success has also made WNT province owning identity name of Bumi Gora.

Those remarkable successes were lessons learned for massive campaigns to introduce directly-seeded flooded rice widely in South of Lombok. It was called Prosperity Effort Program. Alongside direct seedling, short maturing varieties such as IR 64 and IR 36, which had initially been developed for transplanting, were. This proved to be an ideal combination and allowed for soybean or green bean as a second crop after rice.

The Prosperity Effort Program of WNT province through the intensification program of Directly-seeded flooded rice started in 5 districts covered 28 sub-districts, 261 villages, and 26,200 hectares. The highest coverage was reached in the 1983/1984 season, with six districts, 44 sub-districts, and 294 villages, and a total of 51, 000 hectares. However, a stabilization to a slight decline (45.00 hectares) took place. The questions are to what extent the system can cope with the food insecurity in Lombok WNT, and to what extent is the impact of directly-seeded flooded rice on output supply and inputs demand.

2. Methods

This research was conducted in Lombok island WNT province, Indonesia. It is a quantitative and descriptive research that focuses on the impacts of Directly-Seeded Flooded Rice (Gogorancah) as a climate change adaptation strategy by using time series data of the year 2000 – 20015. The analysis focused on the rice supply and input demand through the farmers' response on output price changes, climate change, inputs price changes. The previous research used profit function that driven from production function to analyze the impact of technological change and price change on output supply and input demand.

The rational farmers always have a high willingness to maximize profit subject to a given state of technology and existing fixed and variable inputs. Assuming farmers maximize profits subject to those inputs by employing their own managerial skills to adapt to climate change. Following Christensen, Jogenson and Lau (1971), the translog profit function is used to analyze the data [4]. The translog profit function has been already widely used by previous researchers, such as Pitt (1983), Weaver (1983), Lopez (1984), Antle (1984), Eckstein (1985), Rahman (2003), Galawat and Yabe (2012), and Agustian (2012) [5–12]. The normalized restrict translog profit function for multi inputs and a single output, and the derived input demand functions, which can be expressed as share equations, is specified as below:

$$\ln \pi^* = \alpha_0 + \sum_{i=1}^{7} \alpha_i \ln P_i^* + ½ \sum_{i=1}^{7}\sum_{h=1}^{7} \gamma_{ih}\, lnP_i^* \ln P_h^* + \sum_{i=1}^{7}\sum_{k=1}^{2} \delta_{ik}\, lnP_i^* \ln Z_k + \sum_{k=1}^{2} \beta_k \ln Z_k$$
$$+ ½ \sum_{k=1}^{3}\sum_{j=1}^{3} \phi ln\, Z_k\, ln\, Z_j \text{ ------------------------ } (2.1)$$
$$S_i = -\frac{P_i^* X_i}{\pi^*} = \frac{\partial ln\pi^*}{\partial lnP_i^*}$$
$$S_i = \alpha_i + \sum_{h=i}^{n} \gamma_{ih}\ lnP_i^* + \sum_{k=1}^{m} \delta_{ik}\ lnZ_k \text{ ----------------------- } (2.2)$$

Where: π^*= normalized restricted profit drove as total revenue less total variable costs of variable inputs divided by the output price (P_y); P_i^* is the price of variable input $_i th$, normalized by the price of milled dry rice, namely P_1^* is the price of seed; P_2^* is the price of KNO3 fertilizer; P_3^* is the price of NPK- PONSKA fertilizer (a combination of 3 fertilizers: K, N and P special fertilizer for leaf) ; P_4^* is the price of TSP36 fertilizer; P_5^* is the price of pesticide; P_6^* is the wage of working day labor; P_7^* is the price of fuel for Hand tractors. Each price of variable input, P_1^* to P_7^* is divided the price of output, mill dried rice. Z_1 is the land rent per hectare; Z_2 is land width; Z3 is rainfall (ml).

These variables are defined as follow:

1. Restricted profit, π^*, used in the analysis can be defined as total revenues minus variable costs. The restricted profit normalized by output price, dry mill rice, is expressed as a function of the normalized variable input price and the quantities of fixed input.
2. Seeds input used per hectare was measured as Rupiah (Rp) price of seed per stem normalized by output price, mill dry rice. It is obtained by dividing the total expenditure of seed used per farm by total stems. It denotes as P_s^* indifferent function.
3. Three kinds of fertilizers, KNO3, NPK-Fertila fertilizer and TSP36 fertilizer. Each fertilizer used per hectare is measured as Rupiah (Rp) price of each fertilizer per kilogram normalized by the output price.
4. Pesticides input used per hectare is measured as Rupiah (Rp) price of pesticide per liter normalized by output price.
5. Labor input used in the analysis is casually hired labor comprised of child, female, and male labor. Child and female labor are converted into man-equivalents by treating two women equal to one man. The weighted average of daily money wage rate was calculated by dividing the total expenditure by the labor days employed per hectare. P_l^* in empirical function is the weighted average of money (Rp) wage of labor per day (working day) normalized by the output price.
6. Land rent is denoted by Z_1, and
7. Harvesting wide (Z_2),
8. Rainfall (Z3)

2.1. Procedure and technique of Estimation

The first step in the application of translog profit function is assuming the seeds, KNO3, NPK-Ponska, TSP36, pesticide, labor, and fuel as variable inputs. The price of each variable input in the Rupiah per unit (per stem of seed, per kilogram of fertilizer and pesticide, the wage of labor per working days 8 hours working a day).

Both equations (1) and (2) could be estimated jointly or separately using the Ordinary Least Squares method (OLS). If it is estimated separately would result in inefficient estimates because of cross equation restrictions, the presence of $\boldsymbol{\alpha_i}$ as well as $\boldsymbol{\alpha_{ih}}$ and $\boldsymbol{\alpha_i}$ $\boldsymbol{\delta_{ik}}$ In both equations would be ignored. The share equation for each variable input obtained by differentiating the normalized restricted translog profit function depicted by equation (1). The factor share equation presented by equation (2) was driven by the profit function (1). Therefore, the necessitates that the equations be jointly estimated for obtaining more consistent and efficient estimates.

Estimating both equations (1) and (2), the error terms for each equation are assumed to satisfy all classical assumptions but correlated across equations. The translog profit function, equation (1) and (2) can be estimated by using the Ordinary Least Square (OLS) and seemingly unrelated regression (SUR) method. However, using OLS estimation method is frequently correlated across equations so that that parameter estimates will become biased and inconsistent and inefficient estimates. The $\boldsymbol{S_i}$ and coefficients of the translog profit function are used to drive the output supply and input elasticities for variable inputs used in the analysis. These elasticities are functions of variable input price, variable input ratios, the level of fixed inputs, and the translog profit function parameter estimates.

2.2. *The elasticity of Output supply and Input Demand*

The output supply response and input demand subject to price change weres analyzed by calculating output supply input demand elasticity. The formula that used to Calculate elasticity follows the following equations

$$\eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*} \text{---} \quad (2.3)$$

By applying the same way, the cross elasticity of input demand (η_{ih}), input $i \neq h$ subject to input price hth could be obtained as follows

$$\eta_{ih} = -S_h^* - 1 - \frac{\gamma_{ih}}{S_i^*} \text{---} \quad (2.4)$$

The following formula is used to calculate the ith input demand elasticity (η_{ij}) subject to output price (P_y).

$$\eta_{iy} = \sum_{i=1}^{n} S_i^* + 1 + \sum_{h=1}^{n} \frac{\gamma_{ih}}{S_i^*} \text{ -------------} \quad (2.5)$$

The demand price elasticity of input ith (η_{ik}) is also driven subject to fixed input k^{th} (Z_k) such as the formula below.

$$\eta_{ik} = \sum_{i=1}^{n} \delta_{ik} \, lnP_i + \beta_K - \frac{\delta_{ik}}{S_i} \text{-------------} \quad (2.6)$$

The next, *output supply elasticity* subject to output price, price of variable input and *fixed factors* could be expressed as a linear function of the profit function.

Supply elasticity (ε_{vi}) subject to variable input price i^{th} *is* formulated *such* as the formulation below.

$$\varepsilon_{vi} = S_i^* - \sum_{h=1}^{n} \gamma_{hi} \Big/ \left(1 + \sum_{h=1}^{n} S_h^*\right) \text{-----------} \quad (2.7)$$

Furthermore, using the same way, the supply elasticity (ε_{vv}) is formulated subject to self-price.

$$\varepsilon_{vv} = \sum_{i=1}^{n} S_i^* + \sum_{i=1}^{n} \sum_{h=1}^{n} \gamma_{hi} / (1 + \sum_{h=1}^{n} S_h^*) \text{---------} \quad (2.8)$$

The last is supply elasticity (ε_{vk}) subject to fixed input (Z_k) such as below.

$$\varepsilon_{vk} = \sum_{i=1}^{n} \delta_{ik} \, lnP_i + \beta_k - \sum_{i=1}^{n} \delta_{ik} \Big/ \left(1 + \sum_{h=1}^{n} S_h^*\right) \text{------} (2.9)$$

Furthermore, simulating price change impact output supply, input price, a wage of labor, and profits. The policy of input allocation to develop directly-seeded flooded rice in Lombok WNT to improve the performance of the economy and food security and safe food safety.

3. Results

The mill dried rice as the output supply elasticity and input demand elasticities were derived from the translog profit function. The required input demand and output supply elasticities are determined by combining the estimates of translog profit function and $\boldsymbol{S_i}$ function with the variable input ratios, variable prices, and the total cost of fixed inputs. The own-price elasticity of mill dried rice is 1.766, and the elasticities of all inputs demand are greater than unity, implying active price-responsiveness of rice growers. Therefore, the price change is greatly considered for government and private corporate policy.

The elasticity of output supply includes rice supply elasticity subject to self-price and input price. The estimation result shows that the value of rice supply elasticity subject to self-price was positive and significantly different at 5%. The characteristic of output supply was elastic that indicated by the coefficient of elasticity as much as 1.766. The elastic output supply indicated a high response of farmers on price change of rice. The price change of rice plays an important role in determining the further development policy of rice production. While, the elasticity coefficient of output supply subject to inputs prices, such as seeds, KNO3, NPK, TSP36, and fuel was a negative sign with the value respectively -0.344, -0.349, -0.254, -0.929, -1.542. It is interpreted that the increasing of inputs price as much as 1% causes the decreasing of output supply respectively as much as 0.344, 0.349, 0.254, 0.929, and 1.542 percent.

Table 1. Drive Elasticity Estimate of output supply and Demand for variable input for mill dried rice in Lombok West Nusa Tenggara.

Variables	Output	Seeds	KNO_3	NPK	TSP36	Pesticide	Labor	Fuel
Output Price	1.766 (2.331)	1.654* (1.585)	1.727 (0.510)	1.768 (0.189)	1.554* (1.878)	1.581 (0.288)	1.633* (1.460)	1.543* (1.447)
Seed price	-0.3435* (-1.496)	-0.616* (-1.680)	-0.289** (-1.801)	1.668 (0.180)	-0.122* (-2.102)	-0.151 (-0.81)	-0.120*** (-3.460)	-0.120*** (-3.370)
KNO3 price	-0.349 (-0.510)	-0.281** (-1.794)	-0.553 (-1.121)	-0.264 (-0.512)	-0.134 (-0.940)	-0.086* (-1.463)	-0.099* (-1.60)	-0.059*** (-2.990)
NPK price	-0.2538 (-0.189)	-0.040 (-0.502)	-0.154* (-1.524)	-0.501* (-1.514)	-0.52** (-1.868)	-0.640 (-1.242)	-1.276*** (-2.980)	-1.276*** (-2.981)
TSP36 price	-0.929* (-1.778)	-0.640** (-2.103)	-0.632 (-0.940)	-0.184 (-0.770)	-1.146** (-1.808)	-0.715** (-2.990)	-0.963* (-1.780)	-0.925* (-1.681)
Pesticide price	1.198** (2.197)	-1.292** (-2.330)	-1.35** (-2.322)	-0.729* (-1.468)	-1.052 (-1.051)	-1.378*** (-2.980)	1.421** (1.218)	1.430 (1.209)
Labor wage	1.648** (2.188)	-1.699** (-2.090)	-1.587** (-2.225)	-1.447** (-1.860)	-1.353 (-1.273)	-1.656*** (-2.361)	-1.452*** (-2.971)	- 0.676 (-1.035)
Fuel price	-1.542** (2.282)	-0.523 (-1.212)	-0.421 (-1.320)	-0.241 (-1.321)	-0.132 (-1.241)	0.210 (1.214)	-1.472*** (-2.870)	-1.652** (-2.765)
Land Rent	0.998* (1.361)	0.906* (1.378)	0.916*8 (1.366)	1.023* (5.219)	0.743 (1.065)	0.890 (1.469)	0.669 (1.035)	1.025* (4.216)
Harvesting wide	1.313* (1.545)	1.479* 1.370)	1.554* (1.930)	0.864* (1.496)	1.169 (0.044)	1.562* (1.464)	1.240 (1.187)	1.482* (1.386)
Rain Fall	1.987* (1.365)	1.483* (1.360)	1.574* (1.440)	1.560* (1.466)	1.560* (1.466)	1.623* (1.432)	1.231 (1.197)	1.493* (1.540)

Note :
***) significant different by α = 1%
**) significant different by α = 5%
*) significant different by α = 10%

The characteristic of inputs demand, such as seeds, KNO3, NPK, and TSP36 was inelastic. While the characteristic of inputs demand, especially pesticide, labor, fuel, harvesting wide were elastic that indicated by the coefficient of elasticity were greater than one.

The price change of seed and TSP36 was significantly different at 10 percent toward rice supply in Lombok. The value of output elasticity subject to input price was relatively small and inelastic. It indicated that the low impact of the subsidized policy of inputs, fertilizer, and seed on farmers' behavior for inputs allocation. The farmers allocate seed and fertilizer as much as they need to maximize physical output and profits.

The elasticity of rice supply subject to the price of pesticide, labor wages, and fuel were positive but greater than one and significant difference at 5%. It indicated that when the price of pesticide, fuel, and labor wages increase as much as 1% so that the rice supply will increase respectively as much as 1.198, 1.648, and 1.542 percent. Weeds are the main biological stress, and excessive growth is a well-known problem in directly-seeded flooded rice. Therefore, the farmers make weeding and herbicides application for controlling weeds. The farmers do weeding twice; the first weeding is before the inundation of land, and the second weeding is done after flooding or after a heavy re-infestation of weeds. Consequently, directly-seeded flooded rice needs high costs for weeding and herbicides.

The value of supply elasticity respects to the price of all variable inputs, such as seed, KNO3, NPK, TSP36 a fuel was negative sign meant that a one percent increase for each variable input would decrease output respectively as much as 0.344, 0.349, 0.254; 0.929, 1.542 percent. It implies that using all those variable inputs are not effective in increasing output. Fuel and was significantly different at 10%. While the elasticity of output respect to pesticide, labor wage, harvesting wide, and rainfall were more than unity and elastic. The land rent, harvesting wide and rainfall have a positive effect on the output supply.

The price of seed and TSP 36 fertilizer is significant at 10% to output supply. The elasticities values seed and TSP36 are -0.3435 and -0.929 means that a one percent increase of seed and TSP36 fertilizer leads to a decrease in the supply of mill dried rice as much as 0.3435 and 0.929 percent. It implies that the rising price of seed and TSP36 will affect rice farming because the price of both inputs tends to be getting expensive. There are also three important variable inputs on Directly-seeded flooded rice are pesticide, labor, fuel, land, and rainfall. The elasticities of those inputs are greater than unity, and their price significantly different at 5% and 10% degree to output supply. Labor, fuel, and herbicide are also the main physical input for the farm.

The own-price elasticity of each input is depicted in table 1. For example, the own-price elasticity of seed demand is -0.616 means that a 1 percent increase (decrease) in seed price leads to a decrease (increase) the demand for seed - 0.616 percent. Further, the elasticity of output supply for seed price is -0.3435, with means that if seed price per stem increase (decrease) by 10 percent, dried leaf of tobacco supply is likely to increase (decrease) by 3.435 percent.

The cross-price elasticities of variable inputs of seed and all variable inputs are negative with indicating the complementarity relationship between them, except NPK, the substitute relationship because of the cross-price elasticity is positive. This is the same case as the other variable inputs relationship. The cross-elasticities of almost all variable inputs depicted in table 1 are complementary among them, except seed and NPK, pesticide, and fuel. It means those variable inputs are the main variable inputs on directly-seeded flooded rice.

The elasticity of output to land rent and stove building is positive, but less than unitary (inelastic), while respect to marketing cost is positive and greater than unitary and elastic. For example, one percent expansion island leads to increase output by 0.998 percent, respectively, holding wage labor rate and other inputs price constant.

4. Conclusions

The output supply and input demand elasticities were derived by applying the normalized translog profit function. The own-price elasticity of output is greater than unity or elastic, while the elasticities concerning variable inputs price: Seed, KNO3, NPK, TSP36, Pesticides are inelastic. The demand for variable inputs: Seed, KNO3, NPK, and TSP36 are inelastic, while the demand for Pesticides, Labor, and fuel is elastic. The elasticity of output supply concerning rainfall and land wide are positive. It means that since an increase in rainfall and land width will increase the effectiveness, efficiency, and managerial productivity of rainfed land, there is a need to increase their availability to affect the expansion of demand for variable inputs.

Based on the analysis result, it could be concluded that growers of rice are price-respective and assured the prevalence of their output and input prices would be essential to sustain farmer incentives for increasing production the greater the rainfall, the greater the yield of rice.

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