ELASTICITIES OF OUTPUT SUPPLY AND INPUT DEMAND OF INDONESIAN FOODCROPS AND THEIR POLICY IMPLICATIONS: MULTI-INPUT MULTI-OUTPUT FRAMEWORK*)

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ABSTRAK

Ekonomi pertanian terbiasa melakukan analisisnya menggunakan pendekatan komoditas tunggal (output-tunggal, input-ganda). Masalahnya ialah pendekatan ini cenderung tidak sesuai dengan realitas di mana kebanyakan sistem produksi pertanian berkarakteristik output-ganda. Termotivasi oleh masalah ini, makalah ini ditulis dengan tujuan menjelaskan pendekatan input-ganda output-ganda (MI-MO) serta mengaplikasikannya pada subsektor tanaman pangan Indonesia. Berdasarkan pendekatan MI-MO selanjutnya dibangun sebuah model ekonometrika yang diestimasi dengan metode *seemingly unrelated regression* (SUR) terestriksi. Dugaan elastisitas harga silang yang diperoleh dari hasil estimasi model menunjukkan signifikannya efek silang harga input dan harga output terhadap permintaan input dan penawaran output. Hal ini menjustifikasi penggunaan pendekatan MI-MO pada subsektor tanaman pangan. Implikasi penting yang diperoleh dari studi ini ialah kebijakan harga, baik input maupun output, diperkirakan tidak efektif untuk diterapkan. Namun apabila secara politik kebijakan tersebut diperlukan, maka hendaklah diterapkan pada input karena besaran absolut elastisitas silang tersebut lebih besar pada permintaan input dibandingkan pada penawaran output.

Kata Kunci*: Multi-Input Multi-Output, Tanaman Pangan, Seemingly Unrelated Regression, Elastisitas.*

ABSTRACT

It is a commonly practiced that agricultural economists frame their analyses within the single commodity (multi-input single-output) framework. The problem with this framework is that this seems to be inappropriate because most agricultural production systems are characterized by multi-product farms. Motivated by this problem, this paper is aimed at providing a brief explanation on the multi-input multi-output (MI-MO) framework and applying the framework on the Indonesian food crops subsector. Based on this framework, an econometric model is specified and then estimated using the restricted seemingly unrelated regression method. Estimated cross-price elasticities obtained from the model suggest the significance of cross-effects of input or output prices on input demand or output supply, justifying the MI-MO nature of the crops. The most notable policy implication from this study is that a price policy on either outputs or inputs may not be effective. If, however, such a policy were politically desirable, it should be applied on inputs rather than on outputs because the magnitudes of the elasticities are in absolute term higher in input demands than in output supplies.

Key Words*: Multi-Input Multi-Output, Food Crops, Seemingly Unrelated Regression, Elasticities.*

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1. INTRODUCTION

1.1. Problem Formulation: Why Multi-Input Multi-Output?

Many agricultural economic commodity studies frame their analyses within the single commodity (multi-input, single-output) framework. Within this framework, it is implicitly or explicitly assumed that input allocation decisions are separable and independent of output allocation decisions. The problem is that this seems to be inappropriate because most agricultural production systems are characterized by multi-product farms.[1] Under this characteristic, production decisions about an output are very likely to be related to the production decisions about other outputs.

In addition, given agricultural land scarcity, especially in densely island of Java, where most food crops are produced, land competition or complementary amongst crops becomes an importance issue. Using a single-output approach to specify a multi-product environment may, therefore, lead to model misspecification (i.e. misrepresent the reality). Such misrepresentation may, in turns, lead to incorrect policy formulation derived from results of analyses that follow. An alternative to such approach is the multi-input multi-output (MI-MO) framework, which according to the literature can overcome the problem.

1.2. Objectives

The objectives of this paper are to provide a brief explanation on the MI-MO framework and to apply the framework on the Indonesian food crops subsector. Inclusive to the explanation are short discussion on its theoretical underpinnings and on an econometric model that follows. The econometric model is developed for the Indonesian food crops, from which elasticities of output supply and input demand are computed, and policy implications are formulated.

II. THEORETICAL FRAMEWORK

2.1. Production Transformation Set and the Profit Function

A production technology describes all feasible options for transforming inputs into outputs. In the MI-MO framework the technology may be described by way of a

[1] Most food crops in dry land or even in wet land areas are practically cultivated in the form of mixed cropping and/or inter-cropping. Applying this type of diversification reflects that farmers make decisions on planting several crops (and on allocating required inputs for the crops) simultaneously.

production transformation set. The boundary of a production transformation set can be represented as follows:[2]

$$F(Y, X; Z) = 0 \quad (1)$$

where:

$Y = Y_1, Y_2, \ldots, Y_m$ is a vector of m non-negative outputs,

$X = X_{m+1}, X_{m+2}, \ldots, X_n$ is a vector of n-m non-negative variable inputs, and

$Z = Z_{n+1}, Z_{n+2}, \ldots, Z_p$ is a vector of p-n non-negative quasi-fixed inputs.

Variable inputs are inputs that are fully adjustable to their profit maximizing levels within one sample period. Quasi-fixed inputs, on the other hand, are inputs which do not necessarily adjust fully within one sample period.

It is obvious that the production transformation set, F, is determined by the state of technological knowledge and physical laws such as climate. For instance, the production process of food crop outputs is limited by agronomical and other technical aspects. It is also affected by non-technical aspects such as government regulations, e.g. pollution control is the form of restrictions in the use of pesticide and government intervention in output price support.

It is worth noting that a production transformation set possesses certain regularity properties, namely: (i) domain, (ii) continuity, (iii) boundedness, (iv) smoothness and twice differentiability, (v) convexity, and (vi) monotonicity, details of which can be found in Siregar (1991). Amongst these, convexity and monotonicity are often assumed to hold for F. The reason is that the economic behavior implied by profit maximization would always be consistent with these properties being true for F.

Under profit maximization, using the *primal approach*, a set of output supply equations and a set of input demand equations can be obtained, i.e. by estimating (1). However, there are at least three major disadvantages to this approach. First, direct estimation of the production function using ordinary least square (OLS) leads to the simultaneity bias as input levels are endogenous. As well, OLS estimation of the output supply equations is inefficient as the error terms are most likely contemporaneously correlated. The same thing also applies to OLS estimation of the input demand equations. Second, if (1) is used to examine production decisions, the derivation of the output supply and input demand equations is much more complex as it involves solving a constrained maximization (Wall and Fisher, 1987, p.11). Third, unlike the production function, the

[2] Equation (1) is the implicit form of $Y = f(X; Z)$. That is, $Y - f(X; Z) \equiv F(Y, X; Z) = 0$.

profit function involves only prices of outputs and inputs and quantity of quasi-fixed inputs, which are not endogenous.

The *dual approach* does not subject to those disadvantages. Assuming that a producer aims to maximize variable profits and that a production technology set can be represented by (1), the profit maximization problem in the dual approach can be expressed as follows:

$$\prod(P, R; Z) = \max\{P'Y - R'X; F(Y, X; Z) \leq 0\} \quad (2)$$

where:

$P = P_1, P_2, \ldots, P_m$ is a vector of output prices,

$R = R_{m+1}, R_{m+2}, \ldots, R_n$ is a vector of variable input prices, and the inequality $\leq$ allows for a case of output inefficiency.

Like (1), (2) also has certain regularity properties. It is shown by McFadden (1978, p.67) that if properties (i) and (iii) are adhered to in the production technology F, then $\prod$ is a convex, positively linearly homogenous, and closed and continuous function in both variable input and output prices for every positive fixed inputs (property vii). Furthermore, if F holds properties (i), (ii), and (iii), then, as shown by McFadden (1978, p.73), $\prod$ will be continuous jointly for all variables input and output prices and for all fixed inputs (property viii). Another property of $\prod$ is that it is monotonic in prices (property ix).[3]

2.2. Duality and the Derivation of Output Supply and Input Demand Functions

Duality means that if both F and $\prod$ fulfill certain regularity properties, the production function or the profit function can be applied to describe the production technology equally well. Duality proofs can be found for instance in Jorgensen and Lau (1974) and McFadden (1978). The latter shows the duality between production transformation sets and profit functions using the mathematical theory of convex conjugate functions as follows. As was mentioned, a production technology set satisfying properties (i) and (iii) will result in a profit function satisfying property (vii). McFadden shows that a profit function holding property (vii) will yield a production transformation set satisfying properties (i), (iii), (v), and (vi). It follows that the profit function as well as the output supply and input demand functions, which may be derived from the profit function, can be treated as if they come from a production technology which satisfies the

[3] Alternatives to (2) are revenue maximization and cost minimization. Since profit is revenue minus cost, it is obvious that revenue maximization and cost minimization are special cases of the profit maximization. Given its more general nature, profit maximization is more preferable than the other two.

properties of monotonicity and convexity even if these properties do not hold for the true production technology.

The output supply and input demand functions can be obtained by taking the first derivative of the profit function using the Hotelling's lemma as follows:

$$\frac{\delta \Pi(P,R;Z)}{\delta P_i} = Y_i(P,R;Z) \tag{3}$$

for i=1, 2, …, m, and

$$\frac{-\delta \Pi(P,R;Z)}{\delta R_j} = X_j(P,R;Z) \tag{4}$$

for j=m+1, m+2, …, n, where:

$Y_i(P, R; Z)$ is output supply equations and

$X_j(P, R; Z)$ is input demand equations.

Since, from (1), X, Y, and Z are positive, (3) and (4) indicate that profit is expected to monotonically increase with output prices and quasi-inputs, and to monotonically decrease with input prices, respectively.[4]

Assuming profit maximization, without assuming convexity and monotonicity of F, fundamental propositions of neo-classical profit maximization behavior can be elaborated as in the equations as follow.

$$\frac{\delta Y_i(P,R;Z)}{\delta P_i} = \frac{\delta}{\delta P_i}\left(\frac{\delta \Pi(P,R;Z)}{\delta P_i}\right) = \frac{\delta^2 \Pi(P,R;Z)}{\delta P_i^{\,2}} \tag{5}$$

Since $\prod$ is a convex function, then $\delta Y_i(P, R; Z) / \delta P_i$, which is the slope of supply functions, is positive. Furthermore:

$$\frac{\delta X_j(P,R;Z)}{\delta R_j} = \frac{\delta}{\delta R_j}\left(\frac{-\delta \Pi(P,R;Z)}{\delta R_j}\right) = \frac{-\delta^2 \Pi(P,R;Z)}{\delta R_j^{\,2}} \tag{6}$$

Since $\prod$ is a convex function, then $\delta X_j(P, R; Z) / \delta R_j$, which is the slope of variable input demand functions, is negative.

Another important proposition of the supply and demand functions is the symmetry in cross-price effects.

$$\frac{\delta Y_i(P,R;Z)}{\delta P_j} = \frac{\delta}{\delta P_j}\left(\frac{\delta \Pi(P,R;Z)}{\delta P_i}\right) = \frac{\delta}{\delta P_i}\left(\frac{\delta \Pi(P,R;Z)}{\delta P_j}\right) = \frac{\delta Y_j(P,R;Z)}{\delta P_i} \tag{7}$$

[4] Among others, Saez and Shumway (1985) provide more details on this.

$$\frac{\delta X_j(P,R;Z)}{\delta R_i} = \frac{\delta}{\delta R_i}\left(\frac{-\delta\Pi(P,R;Z)}{\delta R_j}\right) = \frac{\delta}{\delta R_j}\left(\frac{-\delta\Pi(P,R;Z)}{\delta R_i}\right) = \frac{\delta X_i(P,R;Z)}{\delta R_j} \quad (8)$$

Equations (7) and (8) show that the cross-price effects of output supply and variable input demand are symmetric. Another important proposition of neo-classical profit maximizing behavior is that the output supply and variable input demand equations are homogenous of degree zero in prices. This is because the profit function is linear homogenous, which means that its degree of homogeneity is one.[5] The implication of this proposition is that if prices of outputs and inputs increase proportionally then these will be offsetting each other, and hence output supplies and input demands remain unchanged.

2.3. Characteristics of a Production Technology Set and Estimation of Elasticities

There are several characteristics of a production technology which are useful for modeling a production technology. The characteristics are: (a) homogeneity, (b) homotheticity, (c) separability and homothetic separability, and (d) non-jointness. Hasenkamp (1976) and Weaver (1977) show that F is uniformly homogenous of degree c (where $c \neq 1$) in outputs if and only if $\prod$ is homogenous of degree 1/(1-c) in output prices and fixed factors. Similarly, F is homogenous of degree c in variable input if and only if $\prod$ is homogenous of degree 1/(1-c) in output prices and $\prod$ is homogenous of degree –c/(1-c) in variable input prices.

A production technology is almost homothetic if it can be expressed as follows:

$$F[H(Y, X; Z)], X; Z] = 0 \quad (9)$$

where F is monotonic in H, and H is homogenous of degree one in Y. It is apparent from (9) that every homogenous function is homothetic but a homothetic function is not necessarily homogenous.

Separability characteristic forms the basis of data aggregation. Partitioning outputs and inputs into three subsets: $N_1 = (Y_1, Y_2, \ldots, Y_m)$, $N_2 = (X_{m+1}, X_{m+2}, \ldots, X_n)$, and $N_3 = (Z_{n+1}, Z_{n+2}, \ldots, Z_p)$, a production technology is weakly separable if it can be written as follows:

$$F[a_1(N_1), a_2(N_2); a_3(N_3)] = 0 \quad (10)$$

where a_1, a_2, and a_3 are aggregator functions. Weak separability is a necessary condition but not a sufficient condition for consistent aggregation. Both conditions are satisfied by the characteristic of weak *homothetic* separability. However, if F is assumed to be

[5] If a continuously differentiable function is homogenous of degree c, then its first derivative is homogenous of degree c-1.

homogenous of degree one, as is usually done, the conditions for weak separability and weak homothetic separability are the same (Wall and Fisher, 1987, p.17). A function is weak homothetic separable in N_i if it is both homothetic and weakly separable in N_i. In terms of profit function, given that the duality properties hold, Weaver (1977) and Lau (1978) show that F is homothetically separable in a group of commodities (outputs or inputs) if and only if $\prod$ is homothetically separable in that commodity's prices.

Lau (1978) defines a production function to be non-joint in inputs and/or in outputs if there exist single production functions. Ball (1988) states that when an output is produced by a production technology which is joint in input quantities, decisions about its production depend on decisions about other outputs, e.g. the level of each output produced is dependent upon prices of competing outputs. So a production function can be represented by a set of independent functions as follows:

$$F_i(Y_i, X_{ij}; Z_{ik}) = 0 \tag{11}$$

where X_{ij} = amount of variable input X_j allocated to output Y_i, and Z_{ik} = amount of quasi-input Z_k allocated to output Y_i. Non-jointness is not of much interest in agriculture because the use of multiple inputs is virtually the rule (Wall and Fisher, 1987).

With regard to elasticities, Lau (1976) shows that elasticity of substitution is not sufficient as a description of a production technology. In addition, elasticity substitution does not have a straightforward interpretation in the case of MI-MO, whereas the price elasticity does. Following Weaver (1983) and Wall and Fisher (1987), the price elasticities of supply and demand, respectively, are:

$$E_{ih} = \frac{\delta Y_i}{\delta P_h} \cdot \frac{P_h}{Y_i} = \frac{\delta^2 \Pi}{\delta P_i \delta P_h} = G_{ih} \cdot \frac{P_h}{Y_i} \tag{12}$$

for all i, h = 1, 2, …, m, and

$$E_{jk} = \frac{\delta X_j}{\delta R_k} \cdot \frac{R_k}{X_j} = \frac{-\delta^2 \Pi}{\delta R_j \delta R_k} \cdot \frac{R_k}{X_j} = G_{jk} \frac{R_k}{X_j} \tag{13}$$

for j, k = m+1, m+2, …, n, where G_{jk} is the (j, k)-th element of the inverse of the Hessian of F. Equations (12) and (13) are termed Marshallian elasticities because they are not derived from an input or output constrained function (Hicksian function) but are from unconstrained profit function (Marshallian function). The sign of these elasticities are used to draw a conclusion whether outputs or inputs are gross substitutes ($E_{ih} > 0$, $E_{jk} < 0$) or gross complements ($E_{ih} < 0$, $E_{jk} > 0$).

III. METHOD OF ANALYSIS

3.1. Flexible Functional Forms

In order to choose a functional form, criteria as follows should be considered:[6]

(a) The specified functional form should be capable of satisfying the appropriate regularity properties, at least locally.

(b) Functional form specifications satisfying a structural property should be nested in the specified class of functions.

(c) In terms of the number of parameters, the functional form should contain as small a number of parameters as possible without losing its consistency with the maintained hypothesis.

(d) Computation and interpretation should be easy.

(e) The model should have interpolative and extrapolative robustness. The former means that within the range of observations, the properties of convexity and monotonicity should at least hold for the profit function, whereas the latter means that the model gives sufficient forecasting power.

Flexible functional forms follow most of the criteria above. A functional form is flexible if its parameters can be chosen to make the values of its first- and second-order derivatives equal to the first- and second-order derivatives of the function being approximated at any point in the domain. Among the commonly used flexible functional forms is the transcendental logarithm (translog). The profit function under this specification can be expressed as follows.

$$\ln \Pi^* = \beta_0 + \sum_{i=1}^{n} \beta_i \ln D_i + \sum_{i=1}^{p} \beta_i \ln Z_i + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln D_i \ln D_j$$

$$+ 0.5 \sum_{i=1}^{n} \sum_{j=n+1}^{p} \beta_{ij} \ln Z_i \ln Z_j + 0.5 \sum_{i=1}^{n} \sum_{j=n+1}^{p} \beta_{ij} \ln D_i \ln Z_j \qquad (18)$$

where $D_i = \begin{cases} P_i \ (output\ price)\ for\ i = 1,...,m \\ R_i \ (input\ price)\ for\ i = m+1,...,n \end{cases}$

Z_i is quantity of quasi-fixed input-i.

Using the Hotelling's lemma, the partial derivatives of (18) with respect to logs of output prices and logs of input prices are the output share equations and the negative input share equations, respectively, as follows:

$$\frac{\delta \ln \Pi^*}{\delta \ln D_i} = s_i = \beta_i + \sum_{j=1}^{n} \beta_{ij} \ln D_j + \sum_{j=n+1}^{p} \beta_{ij} \ln Z_j \qquad (19)$$

Similarly, the partial derivatives of (18) with respect to logs of quasi-inputs are the quasi-fixed inputs equations:

[6] Based on Blackorby, Primont, and Russell (1978) and Fuss, McFadden, and Mundlak (1978).

$$\frac{\delta \ln \Pi *}{\delta \ln Z_i} = z_i = \beta_i + \sum_{j=n+1}^{p} \beta_{ij} \ln Z_j \tag{20}$$

In order for the model to follow the theoretical considerations, there are four regularity conditions which are needed. These conditions can be manifested in terms of restrictions that are subject to test. The first is homogeneity in:

(a) prices:

$$\sum_{i=1}^{n} \beta_i = 1 \quad \text{and} \quad \sum_{j=1}^{n} \beta_{ij} = 0 \tag{21}$$

(b) quasi-fixed inputs:

$$\sum_{j=n+1}^{p} \beta_{ij} = 0 \tag{22}$$

Homogeneity in prices can be tested via normalizing prices of outputs and inputs with one of these prices. Similarly, homogeneity in quasi-fixed inputs can be obtained or tested by normalizing quantity of quasi-fixed inputs with quantity of one of these inputs.

The second is symmetry which can be written as follows:

$$\beta_{ij} = \beta_{ji} \quad \text{for all i and j} \tag{23}$$

The third is monotonicity which holds if, at all observations, the estimated shares are positive for the output and negative for the variable input. The fourth is convexity which holds if the matrix of dual Hessian is positive semi-definite, i.e. if the matrix of the second partial derivatives of the profit function with respect to prices is positive. According to Saez and Shumway (1985), a sufficient but not necessary condition to examine the convexity is by checking the sign of own-price coefficients in (19). The fifth is homotheticity, which according to Wall and Fisher (1987) can be globally tested based on estimated coefficients of (19) by using the formula as follows:

$$\sum_{all\ k \in N} \beta_{ik} = 0 \quad \text{for all } i \in N \tag{24}$$

3.2. Issues in Estimating Output Supply and Input Demand Equations

In estimating (19), a stochastic structure must be assumed so that any deviations of the observed output supply and input demand quantities from their profit maximizing levels are caused by random errors in optimization. In addition, these errors are asserted to be additive with zero means and positive semi-definite variance-covariance matrix.

It is clear that the dependent (share) variables sum to unity if all equations in the system are estimated simultaneously. This leads to singular variance-covariance matrix because as the shares sum to one, the error term in one equation is forced to be a linear combination of error terms in other equations. This problem can be avoided by excluding one of the equations. Practically, the excluded equation is the one which is believed to be relatively least important.

In the MI-MO framework, production decisions on a crop are likely to be related to those on other crops. Thus the error terms of one equation in (19) are likely to be correlated contemporaneously to those of other equations. This makes OLS non-applicable to estimate the share equations. Furthermore, OLS is not appealing if one needs to impose cross-equation restrictions such as $\sum_{i=1}^{n} \beta_i = 1$ in (21). The contemporaneous correlation and this problem can be overcome by using the seemingly unrelated regression (SUR). The unrestricted model can be written as:

$$s = W\beta + e \qquad (25)$$

where, if there are 5 crops with 4 variable inputs in the system and T number of observations, s is the output and variable input shares vector of 8T by 1, W is the cross-product matrix of 8T by 104 containing logs of price of outputs and variable inputs, logs of quantity of quasi-fixed inputs (if there are three), and a constant, β is a parameter vector of 104 by 1, and e is an error term vector of 8T by 1. The restricted model is one where the homogeneity and symmetry conditions (21), (22) and (23) are imposed on (25). Thus the method of estimation utilized in this study is the unrestricted SUR.

The data required for estimating (24), in the case of Indonesia food crops, are the cost structure published by the Central Bureau of Statistics (CBS) and the relevant physical data from CBS and the Ministry of Agriculture. The data are of time series on quantity and price of outputs (dryland paddy, corn, cassava, groundnut, and soybean) and of inputs (labor, fertilizer, seeds, and pesticides), as well as on quantity of quasi-fixed inputs (area, precipitation, and an index of technological change), from which W and s were then calculated accordingly. Details of the data can be found in Siregar (2001).

IV. RESULTS AND DISCUSSION

4.1. Testing of Properties of the Production Technology

The first step to test for the properties of the production technology is to estimate the share equation (19).[7] Using the SUR method, it is found that 70% of the estimated parameters of (19) were significant under the 0.05 significance level (two-tailed tests), or 81% if the 0.10 significance level was used. Among these estimated parameters, all of the own-price coefficients had the correct sign and mostly were significant under the 0.05 significance level. The cross-price coefficients were mostly significant too, whereas the coefficients on the quasi-fixed inputs were generally insignificant.[8]

Monotonicity property holds in the model as all estimated shares of output supply were positive and those of variable input demand were negative. Convexity also holds in the model as all own-price coefficients of outputs were positive and those of inputs were negative. Using the F-tests, the null-hypothesis of homogeneity or symmetry cannot be rejected, indicating that these properties are supported by the data. Using the F-tests, it was also found that the homotheticity was supported by the data.

4.2. Estimated Elasticities

Consistent estimators of the own-price and cross-price elasticities (Weaver, 1983), respectively are:

$$\hat{E}_{iit} = \left(\hat{\beta}_{ii} / \hat{s}_{it}\right) + \hat{s}_{it} - 1 \qquad (25)$$

$$\hat{E}_{ijt} = \left(\beta_{ij} / \hat{s}_{it}\right) + \hat{s}_{jt} \qquad (26).$$

The estimated elasticities are presented in Tables 1 and 2. Own-price supply elasticities have positive sign as expected (Table 1). All of these are inelastic, indicating that supply of any of the crops is not responsive to a change in its own-price. In terms of cross-price elasticities, 60 percent of them are negative, suggesting the existence of competition between output supplies. Elasticities of output supply with respect to input prices are not high (i.e., less than 0.25 in absolute terms) as expected.

[7] Ideally (20) should also be estimated. Since the focus of this study is on output supply and input demand functions, (20) is not estimated.

[8] The reported figures were from the restricted model; restriction tests will be reported shortly. Each estimated equation in the system (19) was subject to usual econometric tests. In general, it was found that non-normality of the residuals, serial correlation, and multicollinearity were not serious. Contemporaneous correlation between residuals across equations was tested using the Breusch-Pagan Lagrange Multiplier test, and found to be significant, justifying the use of SUR instead of the OLS. The functional form was also tested against a non-flexible functional form (the Cobb-Douglas). The test provides evidence in favour of the translog model.

As for the estimated cross-price elasticities, 53 percent of them are significant, suggesting the existence of cross-effects of input or output prices on input demand or output supply. This significant relationship may justify the MI-MO nature of the crops.[9]

As for the estimated input demand equations, all own-price elasticities of input demand have negative sign as expected, and are inelastic (Table 2). The own-price elasticity of fertilizer demand was the highest (in absolute term), i.e. almost unity. Compared to the own-price elasticities of output supply, the own-price elasticities of input demand in absolute terms are generally higher, but they are all inelastic. This indicates that a price policy on either outputs or inputs may not be effective, and hence should not be directly implemented. If such a policy were politically desirable, however, it should be applied on inputs rather than on outputs because the magnitudes are higher in input demand than in output supply. And the sequence of priority is fertilizer, pesticide, and seeds.

Table 1: Estimated Own- and Cross-Price Elasticities of Output Supply of Indonesian Food Crops

Price	Output Supply Equation				
	Paddy	Corn	Cassava	Groundnut	Soybean
Paddy	0.452	-0.028	-0.129	0.031	0.018
Corn	-0.019	0.435	-0.146	0.062	-0.081
Cassava	-0.196	-0.326	0.261	0.063	-0.058
Groundnut	0.057	0.164	0.053	0.088	-0.040
Soybean	0.022	-0.149	-0.048	-0.028	0.186
Labor	-0.010	-0.068	-0.057	0.050	-0.087
Fertilizer	-0.045	-0.172	0.073	-0.100	0.052
Seeds	-0.067	0.040	-0.028	0.006	-0.114
Pesticide	-0.197	0.102	0.009	-0.126	0.124

Notes: The figures were calculated at the mean value of shares. Significance test for each estimated elasticity can be conducted by making use of the estimated standard error as follows: $S\hat{E}(\hat{E}_{ij}) = (1/\hat{s}_i)S\hat{E}(\hat{\beta}_{ij})$. Most own-price elasticities of output supply and input demand are statistically significant under the usual significance level.

In terms of cross-price elasticities, 67 percent of them are negative, suggesting gross-complementarity among the inputs. Effects of changes in output prices on input demands are generally positive and inelastic, except for the pesticide demand whereby most of such effects are elastic. This is understandable because the amount of pesticide uses in the industry is relatively low (averaged around 0.55 kg per ha).

[9] Bias of technical change can be computed by using the following formula: $\hat{B}_{hk,t} = \hat{\beta}_{hT}/\hat{s}_{h,t} - \hat{\beta}_{kT}/\hat{s}_{k,t}$, and returns to scale by using the formula as follows: $R\hat{T}S = \sum_{j=1}^{n}\hat{s}_{j,t} / \sum_{i=1}^{m}\hat{s}_{i,t}$. These are, however, not reported in this paper.

The own- and cross-price elasticities of input demand and of output supply, in general, are less than those obtained by Altemeir et al. (1988). This is probably because of differing approach, i.e. they only took first derivative of the profit function with respect to input prices whereas in this study it was done with respect to both output and input prices. This could also be due to different type of data used in the two studies, i.e. cross-section in Altemeir et al. and time-series in this study.[10]

Table 2: Estimated Own- and Cross-Price Elasticities of Input Demand of Indonesian Food Crops

Price	Input Demand Equation			
	Labor	Fertilizer	Seed	Pesticide
Paddy	0.014	0.451	0.251	7.419
Corn	0.069	1.165	-0.100	-2.669
Cassava	0.129	-1.104	0.157	-0.508
Groundnut	-0.134	1.795	-0.038	8.747
Soybean	0.162	-0.639	0.529	-5.960
Labor	-0.260	0.181	0.295	-3.328
Fertilizer	0.027	-0.968	-0.193	-1.419
Seeds	0.119	-0.517	-0.743	-1.651
Pesticide	-0.130	-0.373	-0.162	-0.805

V. CONCLUDING REMARKS

5.1. Conclusion

The profit function specified in form of the translog model was satisfactory with regard to theoretical properties and to statistical significance and a priori plausibility of regression coefficients. Within the MI-MO framework, the profit function was found useful in studying comprehensive economic relationships amongst outputs, inputs, and between outputs and inputs. It was also useful in providing some characteristics of the production technology of the Indonesian food crops.

Despite this usefulness, it would perhaps be better to include a large number of inputs and outputs in the profit function. However, data availability constrains that

[10] This was also mentioned by Mears et al. (1981).

inclusion. Capital, for instance, was not included simply because this data is absent from the CBS and Ministry of Agriculture publications. For the future research, it is suggested that the panel data approach is employed. This, however, depends on the availability of cross-sectional (provincial) agricultural cost structure and other relevant data.

5.2. Policy Implications

The inelastic characteristic of own-price supply elasticities of Indonesian food crops imply that the farmers' revenue would decrease if productions or supplies of the crops are increased, unless followed by efforts to enhance the demand for the crops primarily through developing relevant agro-industries. Considering the high population of Indonesia and the importance of food crop products in their diet, it seems likely that the agro-industrial development would benefit the farmers as well as the industrialists.

Compared to the own-price elasticities of output supply, the own-price elasticities of input demand in absolute terms are generally higher, suggesting that a price policy on either outputs or inputs may not be effective. If such a policy were politically desirable, however, it should be applied on inputs rather than on outputs because the magnitudes are higher in input demand than in output supply. The priority is still on fertilizer.

The inelastic nature of own-price input demand elasticities suggest that attempts to increase non-subsidized input prices, such as of pesticide and seeds, in order for instance to increase quality, would not significantly reduce usages of the inputs, but increase revenues of the inputs producers. As for subsidized inputs, especially particular kind of fertilizers, the inelastic elasticities imply that lowering the input subsidies would lead to more efficient usages of the fertilizers. In addition, the increasing tendency of the fertilizer prices after the subsidy reduction would create incentives (higher prices) to the fertilizer companies and traders.[11] Considering the vulnerable nature of Indonesian food crops farmers, such a reduction must be undertaken gradually.

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[11] It is important to note that such subsidy reduction must be followed by more effective government monitoring on the fertilizer market ensuring that no counterfeit fertilizer is around.

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