DEMAND FOR INPUTS AND SUPPLY OF RICE UNDER RISK AND SELECTIVITY BIAS: A STUDY OF INDONESIAN FARMERS

by

Hermanto*)

Abstrak

Pengambilan keputusan dalam proses produksi pertanian pada umumnya dilakukan secara beruntut mengingat akan adanya senjang waktu antara saat input dialokasikan dengan saat realisasi produksi. Studi tentang bagaimana prilaku petani dalam membuat keputusan dalam memilih jenis varitas dan jumlah input yang digunakan dalam proses produksi yang penuh dengan resiko, dapat memberikan pengertian yang lebih baik tentang bagaimana petani bereaksi terhadap kebijakan pertanian yang berkaitan dengan harga dan investasi di Indonesia. Dari hasil analisis fungsi logit, dapat diidentifikasikan bahwa peluang petani untuk mandapatkan hasil panen padi yang tidak baik sangat ditentukan oleh besarnya frekuensi kekeringan dan serangan hama disuatu lokasi. Penelitian ini selanjutnya menggunakan peubah frekuensi serangan hama dan kekeringan sebagai peubah yang menggambarkan besarnya resiko berproduksi tanaman padi. Dari hasil analisis fungsi probit dapat ditunjukkan bahwa petani cenderung menjadi enggan resiko ketika mereka memilih varitas padi. Kenyataan ini dapat dipahami mengingat bahwa untuk menanam padi, khususnya dengan varitas unggul, petani harus mengeluarkan biaya yang lebih banyak untuk tenaga kerja dan pembelian pupuk jika dibanding dengan biaya yang harus dikeluarkan jika ia menanam varitas padi lokal. Analisis permintaan "ex-ante" menunjukkan bahwa tenaga kerja dapat dipandang sebagai input yang cenderung memperkecil resiko berproduksi padi varitas unggul. Hasil analisa juga menunjukkan bahwa pupuk adalah input yang cenderung meningkatkan resiko berproduksi baik untuk padi unggul maupun padi lokal. Sehubungan dengan analisis fungsi permintaan yang telah memperhitungkan efek bias dalam pemilihan varitas padi dapat ditunjukkan bahwa terjadi korelasi positif antara besarnya jumlah pupuk yang diminta dengan variabel yang menunjukkan efek bias dalam pemilihan varitas (VRSBT) tersebut. Hal ini menunjukkan bahwa dengan mengabaikan pengaruh efek bias pemilihan varitas dapat mempengaruhi keabsahan dalam pendugaan parameter fungsi permintaan pupuk.

INTRODUCTION

Background

When there are risks involved in the production process or in input and output prices, agents are typically assumed to behave as though they maximize the expected utility of profit. Depending on the agent's risk preference, the expected marginal value factor products may not equal to their respective factor prices. If the agent

*) Researcher of the Center for Agro-Socio Economic Research, Bogor.

is risk averse and the production is risky, the direction of inequality will rely on how the risk enters in the production function and whether the input is marginally risk increasing or risk decreasing.

The production process in agriculture is commonly characterized by sequential decisions due to time lags between the allocation of inputs and the realization of output. In the case of Indonesian rice production, an experienced farmer tends to decide what kind of crop to be planted given the information about prices and the likelihood of the forthcoming weather and insect infestations in the local area. In the early season, the farmer may select a technology from a set of alternatives. For example, the farmer may decide whether to plant a traditional (henceforth TV) or a high yielding variety (henceforth HYV) of crop. After the selection of varieties, the farmer will decide the level of variable inputs, such as labor and fertilizer. If an unconstrained rational farmer tends to modify his decisions at each step depending on any changes in information, the decision on the choice of technology can become more complicated with the presence of uncertainty in production. The farmer may trade the possibility of getting an increased in income from the application of a new technology with a lower income from a traditional technology, mainly because the increased in income from the application of new technology may be associated with the high variability of income.

When all inputs are implemented, there is not much a farmer can do to control the production process. Output levels are then largely determined by a number of exogenous factors, like rain fall, drought, insect and pests, crop deceases, and other factors that may affect farms' production. This lack of control makes it difficult to asses an ex-ante profit function, since one can only observe realized output.

For the purpose of an empirical study of farm behavior under production uncertainty, this research will use data from farm surveys in Indonesia. A better understanding about farmers behavior in rice production is important to the formulation of future agricultural policies. This study, hopefully can contribute in providing information on how the small farmers responded to government price policies in a risky crop production environment. This research should also provide insights into importance of the government's investment policies in rice production.

Objectives

The main objectives of this research can be summarized as follows:

1. to asses the nature of production uncertainty and its effects on rice production,
2. to asses farmers' response to output and input prices, risk related variables, and other exogenous variables on their choice of production technology, namely rice variety; and

3. to study the ex-ante demand for labor, and fertilizer under the production risk and variety selection biases.

THEORETICAL FRAMEWORK

Technological Change Under Risk

In general, literatures discussed choice theory under certainty assumption. If there are risks involve in the firm's decision process, the direct application of the choice theory is no longer appropriate. It is common in the application of theory of choice under uncertainty that agents are assumed to rank risky prospects according to the values of some function defined over the first two moment of the random pay-offs. This concept is usually referred to as the mean-standard deviation approach (Meyer, 1987).

When choice evolves risk over alternative technologies, Pope and Ziemer (1984) used the argument of mean-variance efficiency criteria. If the distribution of outcomes are normal, and if the agent is risk averse, then a rational agent will choose the highest expected outcome with the smallest variant. If there are two choice with the same expected outcomes, then the agent will choose one with the smallest variant of outcomes. If there are two outcomes with the same of variants, then the agent will choose one with the highest expected outcome.

The process of adoption of new technology under uncertainty can be viewed as a Bayesian learning process (Arrow, 1969). Initially a farmer becomes aware of a potential benefit from adopting a new technology, then he may begin to accumulate prior information about the new technology. Bayes theorem suggests that the decision makers have the capability to combine prior beliefs with current observation to form posterior beliefs. In the context of Bayesian learning process and technological adoption, Fuglie (1989) showed that the greater the difference between the actual mean yield and its initial beliefs, the more rapid the adjustment in the subjective beliefs. In the contrary, he stated also that the greater variance in the distribution of outcomes will slow the rate of adjustment in subjective beliefs about the true mean.

Maximization of The Expected Utility

In conjunction with the expected utility hypothesis, we can define a measure for agents' behavior toward the risky prospect. As in Arrow (1971) and Pratt (1964), if its assumed that the utility function of wealth, U(y), is concave or convex and twice differentiable, then the "absolute risk aversion" is defined as :

$$r(y) = -U''(y)/U'(y),$$

where $U'(y)$ is the first derivative of $U(y)$, and $U''(y)$ is the second derivative of $U(y)$.

The definition of absolute risk aversion is not a unit free measure. To be a unit free measure, we can use "relative risk aversion" which is defined as (see also Hanoch, 1977; Deschamps, 1973; and Stiglitz, 1969):

$$R(y) = -y^*[U''(y)/U'(y)].$$

From the measure of r, we can classify agents' behavior toward risky prospects as the following : (1) an agent is risk averse if $r > 0$, (2) an agent is risk neutral if $r = 0$, and (3) an agent is risk lover (risk prone) if $r < 0$.

Pope, in numerous articles, has derived conditions to show when the dual to the maximization of expected utility under risk yields econometric restrictions not unlike those of profit maximization. In his 1980 paper, Pope argued that the derivatives of the profit function under price uncertainty no longer explicitly yield factor demands or output supply, because the first order conditions are not generally separable in factor inputs. He showed also that the presence of price uncertainty in general may cause a violation of the symmetry condition for input demand functions. However, he also introduced a class of utility functions of the form:

$$E[U(\pi)] = E[\pi] + Y(\theta, q),$$

where, θ is a vector of moments of the random variable price, and q is output. For this class of utility functions, factor demand and their symmetry conditions will be satisfied.

The above utility function form can be regarded as a Taylor's series approximation of the expected utility function. In addition, Levy (1973) showed that under "constant risk aversion" (CARA), if an agent maximizes a negative exponential form of utility function, i.e.:

$$U(\pi) = -e^{-\tau\pi},$$

and if π is normally distributed with mean $\mu\pi$ and variance $V(\pi)$, then:

$$E[U] = -\exp -\{E[\pi] - \tfrac{1}{2}\tau \quad V(\pi)\};$$

and maximizing E[U] is equivalent to:

$$\max E[\pi] - \tfrac{1}{2} \quad V(\pi),$$

where τ is coefficient of CARA.

An article by Roe and Antonovitz (1985) is one example of a method, using Pope's conceptual framework, to estimate input demand systems under uncertainty. They used a Taylor's series to approximate the indirect expected utility function. In this case they were able to derive the expected input demand function under uncertainty.

Demand Under Risk Situation

If agents are non risk neutral and production is risky, the form of th demand function is dependent on the form of the utility function. There a four important aspects which determine the input demand functions under uncertainty. They are : 1) the farmer's attitudes toward risk (wether the farmer is risk prone, neutral, or risk averse), 2) kind of uncertainties in agricultural production systems (i.e. input prices, output price, production uncertainties, or any combinations of these uncertainties), 3) how the risk enters in the expected utility function (risk enters in an additive or a multiplicative form), and 4) whether inputs are risk reducing or risk increasing.

Our objective here is to find conditions under which we can empirically test the expected utility of income hypothesis from the estimated input demand functions. First of all, we shall assume that farmers exhibit risk averse attitudes. This assumption is supported by the previous findings (see Binswanger, 1980; Dillon and Scandizzo, 1978). This assumption implies that the farmer's utility function is a strictly concave function of income, i.e.:

(1) $U'(\pi) > 0$, and $U''(\pi) < 0$,

where $U(\pi)$ is utility function with respect to the farm's income (profit) π.

Typically, Indonesian farmers are certain about the price of inputs because they purchase inputs on the spot market prior to their allocation. Farmers are also certain about the output price because, in Indonesia, the price of some strategic agricultural commodities including rice are announced by government prior to seed bed preparation. If this is the case, we may then assume that a farmer only faces output uncertainty. In this context we can express the stochastic production function as:

(2) $q = f(X, \epsilon)$,

where X is a set of production inputs, ϵ is normally distributed production error with zero mean.

Define the stochastic profit function in the following form:

(3) $\pi = P.f(X, \epsilon) - c.X$,

where P is output price, and c is a set of input prices. The farmer's objective is to maximize expected utility, or we can express it as follows:

(4) $\text{Max } E[U(\pi)] = \int_{-\infty}^{\infty} U(\pi)\, g(\pi)\, d\pi$,

where g(.) is the subjective density function of π. Sine there is only uncertainty in production, we can rewrite (4) as:

(5) $\text{Max } E[U(\pi)] = \int_{-\infty}^{\infty} U\{P.f(x, \epsilon) - c.X\}\, g(\epsilon)\, d\epsilon$.

The first order condition for a maximum is:

$$(6)\quad \delta\ E[U]/\delta X = \int_{-\infty}^{\infty} \delta U(.)/\delta\pi\,(P.f' - c)\, g(\epsilon)\, d(\epsilon) = 0$$

$$= E[U'(P.f' - c)]$$

or,

$$(7)\quad \delta\ E[U]/\delta X = P.E[U'].E[f'] + P.\mathrm{cov}(U', f') - c.E[U'] = 0.$$

Definition 1.

An input X is *marginally risk increasing* (decreasing) as

$$(8)\quad \mathrm{cov}(U', f') < (>)\ 0.$$

If the production function is strictly concave, i.e. $f' > 0$ and $f'' < 0$, then in principle, from (7) we can solve for the choice variable X; denote this result as:

$$(9)\quad X^* = X(P, c, \theta),$$

where θ are the moments of the random variable q other than the mean.

We can substitute (9) for X in the stochastic profit function (3), to obtain:

$$(10)\quad \pi^* = P.f(X^*, \epsilon) - c.X^*,$$

and the corresponding expected indirect utility function is

$$(11)\quad E[U^*] = \int_{-\infty}^{\infty} U(P.f(X^*, \epsilon) - c\,X^*)\, g(\epsilon)\, d\epsilon$$

$$= \int_{-\infty}^{\infty} U(P, c, \theta, \epsilon)\, g(\epsilon)\, d\epsilon$$

or in short we can write (11) as

$$(12)\quad E[U^*] = E[U(P, c, \theta, \epsilon)].$$

Our intention here is to find the condition under which we can determine the sign of the elasticities of derived input demand function under uncertainty. The literature commonly treats the risk factor as an additive term in the expected utility function. We can also regard this assumption as a Taylor series approximation of the expected utility function. In general, this class of the expected utility functions can be written in the following functional form:

(13) $E[U(\pi)] = \pi + \Sigma a_i \theta_i$,

where a_i are parameters. As previously discussed this calss of utility function will satisfy the factor demand and simetry conditions.

Assume that the stochastic production function takes a heteroskedastic form. If the risk factor enters as an additive linear form in the utility function (as in 13), then the expected utility function can be written in the following form:

(14) $E[U(\pi)] = P.f(X) - c.X - R\, P^2 h^2 \sigma_\epsilon{}^2$,

where $R = -\{\delta U/\delta V(\pi)\}:\{\delta U/\delta E[\pi]\}$, and $\sigma_\epsilon{}^2$ is variance of production.

Definition 2.

With regard to the values of R, we can define an agent to be *risk averse* (prone) if $R > (<) 0$, and *risk neutral* if $R = 0$ (Roe and Nygaard, 1980).

Proposition 1.

If the stochastic production function takes a heteroskedastic form, i.e. $q = f(X) + h(X)\epsilon$, then wether an input is risk reducing or risk increasing input, depends on the sign of h_X.

Proof:

Since the stochastic production function takes the heteroscedastic form, we can write the stochastic profit function in the following form:

(15) $\pi = P\{f(X) + h(X)\epsilon\} - c.X$.

The variance of the stochastic profit function is:

(16) $\sigma_\pi{}^2 = P^2 h^2 \sigma_\epsilon{}^2$,

and the first order derivative of $\sigma_\pi{}^2$ with respect to i^{th} input is:

(17) $\delta\sigma_\pi{}^2/\delta X_i = P^2 h\, h_X \sigma_\epsilon{}^2$.

Provided that P^2, h, $\sigma_\epsilon{}^2 > 0$, then the sign of $\delta\sigma_\pi{}^2/\delta X_i$, depends on the sign of h_X. If $h_X > 0$, the input is called *marginally risk increasing*, and if $h_X < 0$, the input is called *marginally risk reducing* (q.e.d.).

Corollary 1.

If the stochastic production function takes a heteroscedastic form, then an input is said to be *marginally risk increasing* (reducing) if the risk averse farmer utilizes a *smaller* (larger) quantity of input than the corresponding risk neutral firm (Pope and Kramer, 1979).

METHODOLOGY

Risk Assessment

The SUSENAS 1980 survey was not explicitly designed to study the behavior of farmers toward risk. However, the farmers perception about the perceived production level, whether it was good, normal, or bad, was obtained. It was assumed that a farmer, based on his/hers past experience in farming, has the capability to formulate an expected production of his/hers farm plots. In this way, a farmer was able to distinguish two extreme values, one that would yield a high level of productions, the other a low level of rice production.

The purpose of the model developed here is to measure the probability of bad production from a binary variable; a value of one indicates that a farmer reported that their production is bad, a value of 0 (zero) if otherwise. We try to predict the probability of bad p roduction by relating the binary variable with other relevant experimental (exogenous) variables. Maddala (1983, p 22-26) described how to estimate probability that the ith observation takes value 1 by using the logit function.

The relation between the dummy of bad production and the exogenous variables can be presented in a logit form as follows:

$$(18)\quad F(-\beta'Z_i) = \frac{1}{1+\exp(\beta'Z_i)},$$

where

$$\beta'Z_i = \beta_0 + \beta_1 \text{FRISD} + \beta_2 \text{FRDRG} + \beta_3 \text{FRFLD} + \beta_4 \text{NRNMT}.$$

The following are the definition of variables used in the estimation of the logit function:

$F(-\beta'Z_i)$ = a dummy variable which takes value 1 if a farmer states that his/hers production is bad, and 0 otherwise,
FRISD = frequency of insect infestations in a region,
FRDRG = frequency of droughts in a region,

FRFLD = frequency of floods in a region,
NRNMT = number of rainy months in a region.

The probability of bad production for each farmer in a region then can be estimated from the following relation :

$$(19) \quad \hat{p}_i = \frac{\exp(\hat{\beta}' Z_i)}{1 + \exp(\hat{\beta}' Z_i)}$$

where,
$\hat{p}_i$ = is the estimated probability of bad production, and henceforth called PRBPD.

Variety Selection

Referring to the equation (12) we can express the indirect expected utility of profit function in the following form:

$$(20) \quad E[U(\pi^*)] = E[v^*(P,c,t,\theta,\epsilon)].$$

where, t represents the kind of technology.

If there are more than one type of technology t, then for the jth technology, the meta-profit function is defined as:

$$(21) \quad V(P,c,t,\theta,\epsilon) = \max \{E[v^*(P,c,t_j,\theta,\epsilon)]\}.$$

If there are only two choice of technology, i.e. rice vs. non-rice or HYV of rice vs. TV of rice, then the linearized technology decision rules are :

$$(22) \quad I^* = \alpha \{E[v^*(P,c,t_1,\theta,\epsilon)] - E[V^*(P,c,t_2,\theta,\epsilon)]\}$$

and,

$$(23) \quad I^* = 1,$$
$$\text{if } E[v^*(P,c,t_1,\theta,\epsilon)] - E[v^*(P,c,t_2,\theta,\epsilon)] > 0,$$
$$= 0, \text{ if otherwise,}$$

where α is a parameter.

Since the decision on inputs are made based on information available before the production processes are completed, it is also plausible to assume that the farmer makes decisions similar to a Bayesian rule (Feder *et al.*, 1985). In that case, the number of experience in farm production, the recent relevant information, and the capacity to interpret the relation between the experience in production and the recent information, should affect the farmer's forecast of farm production. In this study we will utilize the age of the head of house-hold as a proxy of farmer's number of experiments, the information about the frequency of insect infestations and droughts as proxies of risk in farm's production, and the education level of head of house-hold as a proxy of the capacity to interpret the information.

One way to analyze the relation between the explanatory variables and the farmer's choice of crop or a crop variety, is by using a probit model (Maddala, 1983 pp 26-27). The probability of a farm plot being planted to a certain crop or a variety of crop can be expressed in the following probit function :

$$(24) \quad F(-\beta'Z_i) = \int_{-\infty}^{-\beta'Z_i/\sigma} \frac{1}{(2\pi)^{1/2}} \exp\left(-\frac{t^2}{2}\right) dt,$$

and the corresponding log-likelihood function is

$$(25) \quad \log L = \sum_{i=1}^{n} I_i \log G(\beta'Z_i) + \sum_{i=1}^{n} (1 - I_i)\log[1 - G(\beta'Z_i)],$$

where,

I_i = 1, if $I_i^* > 0$,
0, if otherwise,

G = is the cumulative distribution function of $\beta'Z_i$, and

$$(26) \quad \beta'Z_i = \beta_0 + \beta_1 \mathrm{LPROPT} + \beta_2 \mathrm{LLWAGE} + \beta_3 \mathrm{LPRFER} + \beta_4 \mathrm{LLANDH} + \beta_5 \mathrm{LFRISD} + \beta_6 \mathrm{LFRDRG} + \beta_7 \mathrm{LIRRIX} + \beta_8 \mathrm{LEDUCN} + \beta_9 \mathrm{LAGEHH} + \beta_{10} \mathrm{LNCRIT} + \beta_{11} \mathrm{LNSTOR} + \beta_{12} \mathrm{LNPLOT} + \beta_{13} \mathrm{DYILN} + \beta_{14} \mathrm{DYSSN}.$$

The explanatory variables are defined as follows:

LPROPT = is the log of output price,
LLWAGE = is the log of labor wage,
LPRFER = is the log of fertilizer price,
LLANDH = is the log of house-hold's land holding,
LFRISD = is the log of frequency of insect infestations.
LFRDRG = is the log of frequency of droughts in a region,
LIRRIX = is the log of irrigation index

LEDUCN = is the log of education level of the head of house-hold,
LAGEHH = is the log of age of the head of house-hold,
LNCRIT = is the log of numbers of credit institutions
LNSTOR = is the log of number of storage,
LNPLOT = is the log of number of plots in a farm,
DYILN = is island effect,
DYSSN = is seasonal effect.

Demand for Inputs

1. General Model

We have shown in the previous chapter that the derived demand for inputs is the first order derivative of the expected utility of indirect profit with respect to input price c, so we get the following general form of demand function:

$$(27) \quad X = X(P, c, \theta, \epsilon).$$

In this study we approximate the general functional form of demand function (6.27) by using Cobb-Douglas functional form. We can also view the Cobb-Douglas approximation of demand function as though we assume that the expected utility of indirect profit function takes translog functional form. If the expected utility of indirect profit is in translog form, then one can show that the derive demand function is in Cobb-Douglas form.

The complete form of the ex-ante demand function for an input is defined as follows:

$$(28) \quad \text{Ln } X_i = \beta_0 + \beta_1 \text{LPROPT} + \beta_2 \text{LLWAGE} + \beta_3 \text{LPRFER} + \beta_4 \text{LHAVAR} + \beta_5 \text{LFRISD} + \beta_6 \text{LFRDRG} + \beta_7 \text{LIRRIX} + \beta_8 \text{LEDUCN} + \beta_9 \text{LAGEHH} + \beta_{10} \text{LNCRIT} + \beta_{11} \text{LNSTOR} + \beta_{12} \text{LNPLOT} + \beta_{13} \text{DYILN} + \beta_{14} \text{DYSSN},$$

where,

X_i = is quantity of i^{th} input,
LHAVAR = is the log of area harvested,

the other variables are previously defined. In this study we are interested in estimating demand for labor and demand for fertilizer. These two inputs are the major inputs used in rice production in Indonesia.

2. Selectivity Bias

The problem faced here is that, the decision on variety of crop is made, the actual production is not observed by the farmer. In this way, the error term in the choice function may be correlated with the error terms of input demand functions. In the literature, this error is recognized as selectivity bias (Heckman, 1979). The problem can be regarded as a switching regression model (Maddala, 1983 pp.223-225).

We can then write the general form of conditional demand functions (see Maddala, 1983 and Lee, 1979) as follows:

$$(29) \quad E(X_{hi} \mid I_v = 1) = h S_i - \sigma_{hv} \frac{\phi(\tau Z_{vi})}{\Phi(\tau Z_{vi})},$$

and

$$(30) \quad E(X_{ti} \mid I_v = 0) = t S_i + \sigma_{tv} \frac{\phi(\tau Z_{vi})}{1 - \Phi(\tau Z_{vi})}.$$

where, $\phi(\tau Z)$ and $\Phi(\tau Z)$ are the normal and cumulative density functions respectively, the index h denotes HYV of rice, t denotes TV of rice, and v denotes selection of variety.

We can obtain an estimate for τ by using a probit model on equation (26). By applying 2SLS as mentioned in Lee (1979) and Maddala (1983), basically we can estimate τ., σ_h^2, σ_t^2, σ_{hv}, and σ_{tv}.

From the equations (29) and (30) we can define a complete form of conditional input demand functions for HYV and TV of rice. These model are:

$$(31) \quad \text{Ln } X_{ih} = \beta_0 + \beta_1 \text{LPROPT} + \beta_2 \text{LLWAGE} + \beta_3 \text{LPRFER} + \beta_4 \text{LHAVAR} + \beta_5 \text{LFRISD} + \beta_6 \text{LFRDRG} + \beta_7 \text{LIRRIX} + \beta_8 \text{LEDUCN} + \beta_9 \text{LAGEHH} + \beta_{10} \text{LNCRIT} + \beta_{11} \text{LNSTOR} + \beta_{12} \text{LNPLOT} + \beta_{13} \text{DYILN} + \beta_{14} \text{DYSSN} - \beta_{15} \text{VRSBH},$$

$$(32) \quad \text{Ln } X_{it} = \beta_0 + \beta_1 \text{LPROPT} + \beta_2 \text{LLWAGE} + \beta_3 \text{LPRFER} + \beta_4 \text{LHAVAR} + \beta_5 \text{LFRISD} + \beta_6 \text{LFRDRG} + \beta_7 \text{LIRRIX} + \beta_8 \text{LEDUCN} + \beta_9 \text{LAGEHH} + \beta_{10} \text{LNCRIT} + \beta_{11} \text{LNSTOR} + \beta_{12} \text{LNPLOT} + \beta_{13} \text{DYILN} + \beta_{14} \text{DYSSN} + \beta_{15} \text{VRSBT},$$

where,

$$\text{VRSBH} = \frac{\phi(\tau Z_{vi})}{\Phi(\tau Z_{vi})},$$

$$\text{VRSBT} = \frac{\phi(\tau Z_{vi})}{1 - \Phi(\tau Z_{vi})},$$

the other variables are previously defined.

3. Standard Error Correction Method

As mentioned above, we use a two-stage probit-OLS method to estimate the parameters of demand for inputs under selectivity bias. In this model, heteroscedasticity between the error terms of crop or variety choice and the error term of demand functions was taken into account. In addition, this two-stage method used predicted value of parameters from the probit crop or variety choice function. In this situation, the OLS standard errors are biased. A procedure for estimating the unbiased standard error was introduced by Lee *et al.* (1980). They showed how to derive the correct asymptotic covariance matrix for the two-stage model[1]. Based on Lee *et al.*, the following formula for the asymptotic covariance matrix of the first regime ,i.e. I = 1, (see the Appendix of Lee *et al.*, 1980, for the detailed derivation) is:

$$(33)\quad \text{var}\begin{bmatrix}\pi_{11}\\ \sigma_{1\epsilon}\end{bmatrix} = \sigma_1^2(W_1'W_1)^{-1} - \sigma_{1\epsilon}^2(W_1'W_1)^{-1} \times W_1'(A - AZ_1(Z'\Omega Z)^{-1}Z_1'A) \times W_1(W_1'W_1)^{-1},$$

and for the second regime (i.e. I = 0):

$$(34)\quad \text{var}\begin{bmatrix}\pi_{22}\\ \sigma_{2\epsilon}\end{bmatrix} = \sigma_2^2(W_2'W_2)^{-1} - \sigma_{2\epsilon}^2(W_2'W_2)^{-1} \times W_2'(B - BZ_2(Z'\Omega Z)^{-1}Z_2'B) \times W_2(W_2'W_2)^{-1},$$

where,

$\Omega = \text{diag.}\left[\frac{\phi_i^2}{\Phi_i(1 - \Phi_i)}\right]$ is an NxN matrix,

$A = \text{diag.}\left[z_i'\tau\frac{\phi_i}{\Phi_i} + \left(\frac{\phi_i}{\Phi_i}\right)^2\right]$ is an $N_1 x N_1$ matrix,

$B = \text{diag.}\left[\left(\frac{\phi_i}{\Phi_i(1 - \Phi_i)}\right)^2 - z_i'\tau\frac{\phi_i}{\Phi_i(1 - \Phi_i)}\right]$ is an $N_2 x N_2$ matrix,

$W_1 = [S_1, -\frac{\phi}{\Phi}]$ is an $N_1 x(m_1 + 1)$ matrix,

$W_2 = [S_2, \phi /(1-\Phi)]$ is an $N_2 x(m_2 + 1)$ matrix,

N_1 is the sample size for the first regime,

N_2 is the sample size for the second regime,

$N = N_1 + N_2$.

Furthermore, Lee *et al.* (1980) showed that the estimated variance from OLS estimation, taking into account hetero-scedasticity, will underestimate the true variance. This is not the case if heteroscedasticity has not been taken into account in the OLS estimation.

Source of Data

For empirical analysis, this study will utilize a data set from the 1980 National Socio-Economic Survey of Indonesia (SUSENAS 1980) conducted by the Central Bureau of Statistics of Indonesia (Biro Pusat Statistik, BPS). In conjunction with SUSENAS 1980, the BPS also conducted a village level survey, called the 1980 Village Potential Census (PODES 1980).

This study will cover all provinces on the islands of Sumatra, Java, Bali, Kalimantan, Sulawesi, and Nusateggara Islands, where rice is the dominant crop. Java island represents an area with better irrigation and infrastructure conditions.

Considering the budget and time available, this research will not use the information from all of sampled households. Instead, only about 11 percent of the total farm plots in these islands are included in the data actually analyzed. This percentage accounts to 5513 farm plots randomly selected from the merged SUSENAS 1980 and PODES 1980 data.

RISK ASSESSMENT

The logistic function of probability of bad production is estimated for the entire sample (i.e. 5513 observations). The results of the logistic functional estimation can be seen in Table 1. The results also show that the coefficient of frequency of insect infestations and the frequency of droughts are significantly greater than zero. These imply that production loss is mostly determined by the frequency of insect infestations and frequency of droughts in a certain region. These results are consistent with the fact that insect infestations is the major source of production loss, followed by losses due to drought.

Table 1. Logit function estimation of probability of bad production.

Variables	Coefficient	Std. error
Intercept	−2.670686***	0.213571
Frequency of insect infestation	0.039415***	0.002322
Frequency of drought	0.003708**	0.001685
Frequency of floods	0.001786	0.002306
No. of rainy months	0.069476	0.042433
Log Likelihood	− 2843.608330	
Est. Chi-Squared	481.407	
Chi-Squared (4, 0.005)	14.86	

*** is significant at α 0.01 = 2.576.
** is significant at α 0.05 = 2.960.

The direct relation between the probability of bad production and the corresponding explanatory variables can be seen in Table 2. Note that a one percent increase in the frequency of insect infestations in a region tends to increase 0.98 percent in the probability of bad production. It can be seen also, that a unitary increase in the frequency of droughts in a region tends to increase 0.09 percent in probability of bad production.

We have found that the probability of bad production was determined mainly by the frequency of insect infestations and the frequency of droughts. In the next analysis, we use these variables as proxies of production risk.

Table 2. The partial derivatives of PRBPD with respect to explanatory variables.

Variables	$\delta p / \delta Z_j$
Intercept	−0.666020***
Frequency of insect infestations	0.009829***
Frequency of drought	0.000924**
Frequency of floods	0.000445
No. of rainy months	0.017326

*** is significant at α 0.01 = 2.576.
** is significant at α 0.05 = 1.960.

VARIETY CHOICE UNDER RISK

The results of the estimated parameters of the variety selection probit model are presented in Table 3. One might expect that a farmer will select HYV if the HYV price is higher than the TV price. In contrast, we find that the coefficient of log of output price is significantly less than zero (-2.1186). This result is difficult to interpret. At this stage, the result suggests that the farmer who select HYV received a lower price than those choosing TV. One may suggest that farmers select HYV because of its high yield and hence its high profitability.

Table 3. Parameters estimation of the variety selection probit function.

Variables	Coefficients	Std. err.
Intercept	13.10170***	1.26300
Log of output price	−2.11864***	0.16590
Log of wages	−0.05915	0.07137
Log of fert. price	−0.63015***	0.18710
Log of land holding	0.00254	0.01665
Log of freq. of insect infestation	−0.05155	0.04381
Log of freq. of drought	−0.10668***	0.03937
Log. of irrig. index	1.32828***	0.09006
Log of education	0.06026	0.05976
Log of age	0.31913***	0.10040
Log of numb. of credit institutions	0.14592***	0.04872
Log of numb. of storage	0.05202	0.04858
Log of numb. of plots in farm	−0.03091	0.06912
Location effect	−0.09974	0.08707
Seasonal effect	0.07775	0.05774
Log-Likelihood	−1438.80	
Est. Chi-Squared	702.96	
Chi-Squared (14, 0.005)	31.32	

*** is significant at α 0.01 = 2.576.

As expected, the result shows that the coefficient of the log of fertilizer price is significantly less than zero (−0.6302). From previous results, the average fertilizer application per hectare on the HYV is higher than that is on the TV. Consequently, the higher price of fertilizer will reduce the profitability of planting HYV. In this way, the fertilizer price is negatively correlated with the probability of planting the HYV.

The fact that a farmer is risk averse in the choice of rice varieties is understandable; since to plant HYV, a farmer faces a considerable expenditure on labor and fertilizer. In this way, the greater production risk faced by a farmer tends to be associated with a lower probability of planting HYV.

We have already noted that HYV requires more fertilizer and water manageability to obtain a higher yield than TV. This statement is likely to be consistent with the fact that the coefficient of log of irrigation index is significantly greater than zero (1.3283). These figures suggest that irrigation services provide a suitable environmental condition for HYV by providing a greater potential output and reducing production risk.

If a farmer follows Bayes rule in the input decision process, his education level (as a proxy of cognitive ability) and age (as a proxy of number of experiments in farming) will play in important role in his input choice. The results obtained do not statistically show that farmer's education affects his choice of rice varieties. However, we can show that the coefficient of log of farmer's age is significantly greater than zero (0.3191). These findings suggest that farmer's experience in farming contributes more than does the farmer's formal education in the rice variety decision process.

We have discussed that planting HYV requires more purchased inputs (e.g. fertilizer and insecticides) than does the TV. To purchase inputs a farmer needs liquidity, which among other things, can be obtained from credit institutions, such as rural banks or village cooperatives (KUD). This will explain why the availability of credit institutions in a region induces the farmers to plant HYV.

EX-ANTE DEMAND FOR LABOR

HYV of Rice

Estimated elasticities of labor demand function for HYV of rice can be seen in the first column of Table 4. We observe from Table 4. that the elasticity of demand for labor allocated to the production of HYV with respect to output price is significantly greater than zero, i.e. 0.2280. This finding is consistent with our prior belief, it indicates that the farmer is responsive to the expected price of output in the ex-ante decision for labor input. If the expected price of output is considered high (low), the farmer tends to increase (decrease) demand for labor.

Evidently, here we find that the elasticity of demand for labor with respect to labor wage is significant and equals to −0.2614. This elasticity lies within the range of the estimated elasticities obtained from the previous studies, i.e. it lies within the range of −0.1576 (Sumodiningrat, 1982), and −0.6360 (Pitt and Sumodiningrat, 1988). The elasticity is also within the rage of −0.20 for dry season crops and −0.30 for rainy season (Hutabarat, 1986).

Table 4. Elasticities of demand for labor allocated to the production of HYV.

Variables	OLS	OLS with sel. bias
Intercept	0.89012	1.21680
	(0.84050)	(2.14849)[1]
Log of output price	0.22795*	0.16752
	(0.12000)	(0.37697)
Log of wages	−0.26136***	−0.26302***
	(0.04949)	(0.05024)
Log of fert. price	0.01484	−0.00334
	(0.11910)	(0.16420)
Log of area harv.	0.79793***	0.79767***
	(0.01967)	(0.01971)
Log of freq. of insect infestation	0.04311	0.04154
	(0.02918)	(0.03077)
Log of freq. of drought	0.11171***	0.10948***
	(0.02617)	(0.02939)
Log. of irrig. index	0.26608***	0.30492
	(0.06207)	(0.23540)
Log of education	0.03895	0.04088
	(0.03667)	(0.03828)
Log of age	−0.05249	−0.04388
	(0.06479)	(0.08025)
Log of numb. of credit institutions	0.09191***	0.09621**
	(0.02900)	(0.03860)
Log of numb. of storage	−0.07856***	−0.07800***
	(0.02912)	(0.02926)[1]
Log of numb. of plots in farm	−0.02518	−0.02613
	(0.04419)	(0.04449)
Location effect	0.33124***	0.32965***
	(0.04942)	(0.05044)
Seasonal effect	0.03804	0.04050
	(0.03642)	(0.03932)
VRSBH		−0.05690
		(0.33301)
R-Squared	0.52263	0.52264
F-Statistic	125.51351	117.07805

Notes:

Numbers in parenthesis are standard errors.

[1] is the corrected standard errors using formula (33).

*** is significant at α 0.01 = 2.576.

** is significant at α 0.05 = 1.960.

* is significant at α 0.10 = 1.645.

We are also interested in the relation between demand for labor and selected fixed inputs. From the fist column of Table 4, the elasticities of demand for labor allocated to the HYV with respect to area harvested, irrigation index, number of credit institutions, and the location effect are significantly greater than zero. The elasticity of demand for labor with respect to number of storage is negative.

The elasticity of demand for labor with respect to area harvested (as a proxy of land availability) is 0.7980. This indicates that labor demand responds less than the increase in farm land.

As expected, we find that the elasticity of demand for labor with respect to irrigation index is 0.2661. This implies that rice production is more labor intensive in areas where irrigation service is good. Labor demand also responds positively to the number of credit institutions (0.0919). This positive response suggests that credit accessibility to farmers tends to decrease their liquidity constraints.

In general, we can see the effect of the development of infrastructures to demand for labor from the elasticity of demand for labor with respect to location effect (dummy variable which takes value 1 for Java and 0 for others). We find out that the elasticity of demand for labor with respect to island effect is 0.3312.

Contrary to expectation, estimated elasticity of demand for labor with respect to number of storage is negative (−0.0786). There seems to be no direct explanation why this elasticity is negative. However, we may explain this phenomena indirectly. One may argue that the storage facilities are developed in sub-urban areas, in where rice is not intensively planted by farmers. If this is the case, the more storage facilities in a region will correlate to the less labors allocated in production of HYV.

Proposition 1 states that if the stochastic production function takes a heteroscedastic form, then an input is said to be marginally risk increasing (reducing) if the risk averse farmer utilizes a smaller (larger) quantity of input than the corresponding risk neutral firm. Evidently, we can see that the elasticity of demand for labor with respect to frequency of droughts (as a proxy of production risk) is significantly greater than zero, i.e. equal to 0.1117. Since we assumed that farmers are risk averse, we deduce that labor is a marginally risk reducing input in the production of HYV.

From this finding, we can infer, that a farmer who plants HYV tends to increase the use of labor if he predicts that there is a high chance of observing drought in the area. In this case, the additional labor may be employed to irrigate the farm land, to maintain and improve the existing irrigation channels. More over, in the predominantly dry areas, farmers may employ more labor in the land preparation stage.

The elasticities of demand for labor in the production of HYV under variety selectivity bias appear in second column of Table 4. The listed standard errors of this model were corrected by using the formula (33).

The results reported in the second column of Table 4 indicate that the correlation coefficient between labor demand and variety selectivity bias (VRSBH) is not significantly different from zero. This implies that statistically we cannot conclude that the demand for labor allocated to the HYV is significantly influenced by the errors in variety choice functions. Consequently, the parameters estimated in the first column of Table 4 are likely to be unbiased estimators of the parameters of the labor demand function.

TV of Rice

The estimated elasticities of demand for labor in the production of the TV are listed in the first column of Table 5. Apparently we find here, that the elasticity of demand for labor allocated to the production of TV with respect to labor wage is significant and equals to −0.3095. This elasticity lies within the range of the elasticity values obtained from previous studies, i.e. within the range of −0.1185 (Sumodiningrat, 1982) and −0.7850 (Pitt and Sumodiningrat, 1988). This elasticity is also close to −0.3031, which is computed by Gunawan (1988).

As expected, we find that the elasticity of demand for labor with respect to area harvested is positive and equal to 0.6166. For the same reasons as in HYV, we find also that the elasticity of demand for labor with respect to number of credit institutions is positive (0.0690), and with respect to number of storage is negative (−0.0984).

Different from who plant HYV, farmers who plant TV tend to decrease the labor use, when they expect to observe insect infestations and drought season. In this case, we may view labor as a marginally risk increasing input for the farmers who plant TV of rice.

The elasticities of demand for labor allocated to the production of TV estimated with regard to variety selectivity bias are listed in the second column of Table 5. The results suggest that the coefficient of correlation between demand for labor and variety selectivity bias (VRSBT) is not significantly different from zero. Therefore, we infer that the unconditional estimated coefficients listed in the first column of Table 5 are unbiased estimators for the elasticities of labor demand function allocated to the production of TV.

Table 5. Elasticities of demand for labor allocated to the production of TV.

Variables	OLS	OLS with sel. bias
Intercept	3.33722***	4.31226***
	(0.97370)	(1.58738)[1]
Log of output price	0.15389	0.01074
	(0.11560)	(0.22415)
Log of wages	−0.30953***	−0.31514***
	(0.04992)	(0.04986)
Log of fert. price	−0.11374	−0.16187
	(0.14910)	(0.15455)
Log of area harv.	0.61323***	0.61437***
	(0.02342)	(0.02264)
Log of freq. of insect infestation	−0.04968*	−0.05216*
	(0.03002)	(0.02967)
Log of freq. of drought	−0.05492*	−0.06440**
	(0.02908)	(0.03130)
Log. of irrig. index	−0.08238	0.02564
	(0.07098)	(0.16114)
Log of education	0.01701	0.01885
	(0.04555)	(0.04466)
Log of age	0.01423	0.03415
	(0.07397)	(0.07725)
Log of numb. of credit institutions	0.06900*	0.07699**
	(0.03738)	(0.03805)
Log of numb. of storage	−0.09842***	−0.09176**
	(0.03614)	(0.03655)[1]
Log of numb. of plots in farm	0.00528	0.00188
	(0.05001)	(0.04927)
Location effect	0.02555	0.02074
	(0.07216)	(0.07054)
Seasonal effect	0.01830	0.02317
	(0.04209)	(0.04182)
VRSBT		0.22215
		(0.29810)
R-Squared	0.46550	0.46577
F-Statistic	64.44644	60.15667

Notes:
Numbers in parenthesis are standard errors.
[1] is the corrected standard errors using formula (33).
*** is significant at α 0.01 = 2.576.
** is significant at α 0.05 = 1.960.
* is significant at α 0.10 = 1.645.

EX-ANTE DEMAND FOR FERTILIZER

HYV of Rice

The results of OLS regression estimations for unconditional elasticities of demand for fertilizer applied to the HYV production are depicted in the first column of Table 6. Contrary to the expectation, we find that the elasticity of demand for fertilizer applied to the HYV production with respect to expected price of output is significantly less than zero (– 1.0418). This result can be explained that the price of HYV of rice is endogenously determined by local supply and demand for rice. If this is the case, farmers who plant HYV in a more productive area tend to received less output price.

Not surprisingly, we find most of the elasticities of demand for fertilizer applied to the HYV production with respect to some fixed inputs are significantly different from zero. As expected, we observe that elasticities of demand for fertilizer with respect to area harvested is positive (0.8990). This result suggests that the demand for fertilizer expands in less proportion than the increase in area harvested. This is to be expected if the increase in area planted, hence harvested, occurs on the more marginally productive land. The elasticity of demand for fertilizer with respect to irrigation index is positive (0.6923). Reasoning similar to the above also applies here.

Apparently, we examine that the elasticities of demand for fertilizer with respect to education level and age of the farmer are positive. These facts are consistent with the hypothesis that farmers "learn" not unlike the application of Bayes' rule, in the inputs decision process. Obviously, the age of the farmer (as a proxy of farmer's experience in farming) and farmer's education level (as a proxy of farmer's cognitive ability) play in important role in the decision process.

Table 6 on the first column show that the elasticity of demand for fertilizer with respect to number of credit institutions (as a proxy of credit availability) is positive (0.1857). This fact suggests that if we can provide farmers with more liquidity, the demand for fertilizer can be expected to increase. The impact of the development of infrastructures on the demand for fertilizer is given by the elasticity of demand for fertilizer with respect to the location effect (dummy variable). The elasticity is positive (0.5301), which implies that on average, the development for infrastructure will induce an increase in demand fertilizer in a certain area.

Referring to the Proposition 1 (if a stochastic production function takes a hetero-scedastic form), an input is said to be marginally risk increasing (reducing) if the risk averse farmer utilizes a smaller (larger) quantity of input than the corresponding risk neutral firm. Since we assume that a farmer is risk averse, the fact that the elasticity of demand for fertilizer with respect to frequency of insect

Table 6. Elasticities of demand for fertilizer allocated to the production of HYV.

Variables	OLS	OLS with sel. bias
Intercept	5.19904***	9.58443**
	(1.58900)	(3.93504)[1]
Log of output price	−1.04181***	−1.85315***
	(0.22680)	(0.68886)
Log of wages	0.06639	0.04408
	(0.09356)	(0.09109)
Log of fert. price	−0.33097+	−0.57499*
	(0.22520)	(0.29985)
Log of area harv.	0.89895***	0.89545***
	(0.03719)	(0.03430)
Log of freq. of insect infestation	−0.15225***	−0.17343***
	(0.05517)	(0.05583)
Log of freq. of drought	0.06485	0.03495
	(0.04948)	(0.05338)
Log. of irrig. index	0.69231***	1.21370***
	(0.11730)	(0.42744)
Log of education	0.21897***	0.24496***
	(0.06933)	(0.06980)
Log of age	0.29708**	0.41254***
	(0.12250)	(0.14598)
Log of numb. of credit institutions	0.18565***	0.24339***
	(0.05483)	(0.07027)
Log of numb. of storage	−0.07976	−0.07227
	(0.05505)	(0.05345)[1]
Log of numb. of plots in farm	−0.18712**	−0.19979**
	(0.08354)	(0.08088)
Location effect	0.53005***	0.50861***
	(0.09342)	(0.09255)
Seasonal effect	−0.06085	−0.02786
	(0.06884)	(0.07160)
VRSBH		−0.76382
		(0.60324)
R-Squared	0.32811	0.32888
F-Statistic	55.98522	52.40306

Notes:

Numbers in parenthesis are standard errors.

[1] is the corrected standard errors using formula (33).

*** is significant at α 0.01 = 2.576.

** is significant at α 0.05 = 1.960.

* is significant at α 0.10 = 1.645.

\+ is significant at α 0.20 = 1.282.

infestations is less than zero (−0.1523) implies that fertilizer is a marginally risk increasing input.

If a farmer is risk averse and if he/she has more than one portfolio choices, the portfolio choice theory suggests that the farmer will allocate the resources to the available portfolios in such a way that risk is minimized. In this research we are able to show that the elasticity of demand for fertilizer applied to the production of HYV rice with respect to the number of plots operated by a farmer is negative (−0.1871). We have found also that fertilizer is a risk increasing input. Accordingly, the farmer with more than one plot, has more flexibility in minimizing the production risk, and hence, tends to reduce the quantity of fertilizer used in each plot.

The conditional estimated elasticities of demand for fertilizer applied to the production of HYV appear in the second column of Table 6. The coefficient of correlation between demand for fertilizer and variety selectivity bias (VRSBH) is not significantly different from zero. In this case, the unconditional elasticities of demand for labor listed in the first column of Table 6 are unbiased estimators.

TV of Rice

The estimated elasticities of demand for fertilizer allocated in the production of TV are listed in the first column of Table 7. We find that the R-Squared is 0.2803, and the $F(14, 1036) = 28.8186$ is significantly greater than $F(14, \infty) = 2.13$. We find nine parameters are significantly different from zero.

We expect that the elasticities of demand for fertilizer applied to TV production with respect to output and fertilizer price are significantly different from zero. In contrast, the analysis show that these two elasticities are not significantly different from zero. The likely for this results, is that farmers who plant TV may apply different intensification practices, which range from the most intensive to the least intensive. In other word, some farmers who plant TV may apply fertilizer at the recommend levels, but others may apply no fertilizer. The heterogeneity in fertilizer application levels can be seen from the high coefficient of variation (CV) of fertilizer application per hectare. We found that CV of fertilizer used per hectare for TV is 155.72%, while CV of fertilizer used per hectare for HYV is 67.46%. Consequently, the variation of either output or fertilizer price does not significantly explain the variation of fertilizer used in TV production.

The elasticities of demand for fertilizer applied to the production of TV with respect to area harvested, irrigation index, farmer's education level, farmer's age, number of credit institutions, location effect, and seasonal effect are significantly greater than zero. The elasticity of demand for fertilizer with respect to area harvested is 0.7260. We find also that elasticity of demand for fertilizer with respect to

Table 7. Elasticities of demand for fertilizer allocated to the production of TV.

Variables	OLS	OLS with sel. bias
Intercept	−3.93781*	1.37398
	(2.22400)	(3.04175)[1]
Log of putput price	0.29903	−0.48081
	(0.26410)	(0.42451)
Log of wages	−0.09218	−0.12274
	(0.11400)	(0.10337)
Log of fert. price	0.01352	−0.24867
	(0.34050)	(0.31391)
Log of harv. area	0.72600***	0.73219***
	(0.05349)	(0.04123)
Log of freq. of insect infestation	−0.26446***	−0.27798***
	(0.06856)	(0.06174)
Log of freq. of drought	0.19978***	0.14813**
	(0.06643)	(0.06284)
Log. of irrig. index	1.39371***	1.98214***
	(0.16210)	(0.29757)
Log of education	0.26007**	0.27010***
	(0.10400)	(0.09083)
Log of age	0.72372***	0.83226***
	(0.16890)	(0.15724)
Log of numb. of credit institutions	0.25018***	0.29370***
	(0.08537)	(0.07696)
Log of numb. of storage	−0.00404	0.03228
	(0.08253)	(0.07410)[1]
Log of numb. of plots in farm	−0.01184	−0.03039
	(0.11420)	(0.10122)
Location effect	1.04045***	1.01427***
	(0.16480)	(0.14109)
Seasonal effect	0.16945*	0.19601**
	(0.09613)	(0.08562)
VRSBT		1.21025**
		(0.52895)
R-Squared	0.28029	0.28234
F-Statistic	28.81859	27.14552

Notes:

Numbers in parenthesis are standard errors.

[1] is the corrected standard errors using formula (33).

*** is significant at α 0.01 = 2.576.

** is significant at α 0.05 = 1.960.

* is significant at α 0.10 = 1.645.

irrigation index is 1.3937. Contrast to the former case, this implies that fertilizer demand grows in greater proportion to the increase in the irrigation index.

We find that elasticity of demand for fertilizer with respect to farmer's education is 0.2601, and with respect to farmer's age is 0.7237. As mentioned, if a farmer follow Bayes' rule in the decision process, then farmer's education level (as proxy of cognitive ability) and farmer's age (as a proxy of farming experience) will determine the farm's demand for inputs. Therefore, we may infer that farmers who plant TV behave as though they learn and update their prior beliefs in determining input levels.

From Table 7 we observe that the elasticity of demand for fertilizer with respect to number of credit institutions in an area is 0.2502. Again, liquidity seems to have an important effect on input use. The presence of infrastructures also have a positive effect on input levels (1.0405), as does the seasonal effects (0.1695).

With regard to the hetero-scedastic form of the stochastic production function, the elasticity of demand for fertilizer with respect to frequency of insect infestations (as a proxy of production risk) is negative (−0.2645). As in the previous case we may conclude that fertilizer is a marginally risk increasing input. However, we find also that fertilizer tends to be risk reducing inputs in the predominantly dry areas, i.e. the elasticity of demand for fertilizer with respect to frequency of droughts is positive (0.1998).

The elasticity of demand for fertilizer with regard to variety selectivity bias (VRSBT) is significantly different from zero (second column of Table 7). In this situation, ignoring the impact of the error in the variety selection will significantly bias the estimation of parameters in fertilizer demand function. In this case, it is advisable that we estimate the demand for fertilizer conditional on the fact that the farmer has chosen to plant TV. In fact, parameters listed in the second column of Table 7 empirically represent the parameters of demand for fertilizer conditional on the event that the farmer has chosen to plant TV of rice.

In general there are no major changes if we compare the elasticities listed in the first and second column of Table 7. However, we find that generally the conditional demand elasticities listed in the second column are slightly more elastic than the ones listed in the first column. This suggests that the change of an explanatory variable does not only directly induce the change in demand for fertilizer, but it may also alter the farmer's decision on variety to be planted. In this way, demand elasticities conditional on variety selection are generally more elastic than demand elasticities un-conditioned on variety selection.

CONCLUSIONS

The logit function analysis showed that the probability of bad production was determined mainly by the frequency of insect infestations and drought. These variables were then used as a proxy of production risk.

The result showed that the probability of selecting HYV increases if the price of fertilizer decreases. This finding is consistent with the argument that the farmer tends to minimize cost in the rice production, in the sense that if the fertilizer price is increasing, then the farmer tends to choose the TV which requires less fertilization than does the HYV.

We found that an increase in the frequency of drought to be associated with a decreasing probability of planting HYV. This implies that farmers tend to be risk averse in the variety decision stage.

Consistent with the previous results, we found that the probability to plant HYV was positively determined by the irrigation index and number of credit institutions. This implies that the government's investment policies in agriculture have a positive impact on the technology adoption.

Observing the ex-ante demand for labor allocated to the HYV, we obtained the expected result that the elasticity of demand for labor with respect to output price was positive, and the elasticity with respect to labor wage was negative. We examined also that the elasticities of demand for labor allocated to HYV with respect to area harvested, irrigation index, number of credit institutions, and location effect were significantly greater than zero.

Evidently, the results showed that the elasticity of demand for labor with respect to frequency of droughts was significantly greater than zero. This result suggests that labor is a marginally risk reducing input in HYV production.

From the estimated elasticities of demand for labor allocated to the production of the TV, we also obtained the expected result that the elasticity of demand for labor with respect to labor wage was significantly negative. In addition, we find also that labor tended to be risk increasing input on the production of TV.

As expected, we found that the elasticity of demand for fertilizer allocated to the HYV with respect to fertilizer price to be significantly negative. In this case, we may infer that farmers maximize the expected utility of profit.

Not surprisingly, we found that the elasticities of demand for fertilizer applied to the production of HYV with respect to the area harvested, irrigation index, number of credit institutions, and location effect were significantly positive. The main implication is that the government's investment policies in irrigation and rural infrastructure significantly increase the demand for fertilizer allocated to the HYV.

In this study we showed that the elasticity of demand for fertilizer with respect to frequency of insect infestations was less than zero. Since we assume that the farmers are risk averse, this finding implies that fertilizer is a marginally risk increasing input.

We also showed that the elasticity of demand for fertilizer allocated to the HYV with respect to the number of plots in a farm was negative. Accordingly, we may conclude that farmers who have more than one plots, tend to minimize the production risk by reducing the quantity of fertilizer used in each plot.

The demand for fertilizer allocated to TV was also affected by the area harvested, irrigation index, education level, age, number of credit institutions, location effect, and seasonal effect. These findings are consistent with the previous findings. Fertilizer demand was also negatively correlated with the frequency of insect infestations, and positively correlated with the frequency of droughts.

In relation with the demand model conditioned to selectivity bias, we found that the coefficient of correlation between demand for fertilizer and variety selectivity bias (VRSBT) was significantly different from zero. In this situation, ignoring errors in the variety selection will significantly mislead the estimation of parameters in fertilizer demand function.

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